Attempts to increase the productivity of *cucurbits* are going on in all the *cucurbits* growing countries of the world and several researchers have contributed to enrich the literature on these crops. In foregoing pages, the available literature on various aspects namely determination of diversity, sex expression and its physiology, sex modification, use of different sex forms in breeding programmes and use of gynoecy in hybrid seed production has been reviewed for cucurbits in general and ridge gourd in particular.

### 2.1 DETERMINATION OF MOLECULAR DIVERSITY

AFLP (amplified fragment length polymorphism) markers (*Vos et al.*, 1995) have been used successfully in diversity analyses. AFLP is a molecular technique which analyzes natural genetic diversity of a germplasm collection. *Wang et al.*, (1997) published a genetic map of melon (*Cucumis melo* L.) based on AFLP markers about the genetic diversity available in the germplasm. *Garcia-Mas et al.*, (2000) proposed the use of AFLP markers for measuring genetic diversity in melons from the studies conducted on comparison of AFLP, RAPD and RFLP markers.

AFLP markers have also been used successfully by *Ferriol et al.*
(2003b) in diversity analyses of the germplasm collection of *Cucurbita pepo*. Ferriol *et al.*, (2004) reported that AFLP marker system is useful for analyzing the genetic diversity of some *Cucurbita moschata* landraces.

### 2.2 GENETICAL MECHANISM OF SEX EXPRESSION

Flowering habit (sex expression) in plants is hereditary and controlled by some genetic factors on chromosomes. Also, it is largely influenced by environmental factors. Hermaphroditism in angiosperms is the basic form. It is presumed that through the process of spontaneous mutations, other sex forms were originated in nature. The abortion of stamen and pistil in the perfect flower resulted in pistillate and staminate flowers respectively, and the appearance of these flowers on the same plant or on different plants decided the various flowering habits (Kalloo, 1988). Extensive genetical studies on sex mechanism have been conducted in different cucurbits and have considerable importance from a theoretical standpoint as well as in practical breeding.

**A. CUCUMBER**

Gynoecism is conditioned by a single dominant gene, subject to considerable influence from modifying genes and environment factors. These have been variously designated as *F* (Trachenko, 1935), *Acr* (Shifriss, 1961),
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$acr^F$ (Kubicki, 1965), st (Galun, 1961), $gy$ (Kubicki, 1980) and M (Iezzoni et al., 1980). Kubicki (1969 a, b, c and d) suggested multiple alleles at this locus and established that different gynoecious lines (inbreds) were different in degree of female expression and their response to GA$_3$ application and postulated another major gene that interacts with the previous gene, to increase the degree of sex expression. $Acr$ accelerates female tendency and decreases male tendency in the plant during flower development. It also brings about a change in growth habit of the plant at flowering time. Shifriss et al. (1964) synthesized gynodioecious race (female and hermaphrodite flowers in equal proportions) by incorporating $Acr$ in “Marketer” and “Tokyo” varieties of cucumber. George (1970) proposed a method of development of the dioecious race by combining $Acr$ with the gene controlling the determinate growth habit of plant.

Frankel and Galun (1977) propounded that gene M controls a trigger mechanism that permits only stamen or pistil development. Flowers of M/-plants are, therefore, unisexual and flowers of m/m plants may be hermaphrodite. The second type of gene controls the flowering pattern in monoecious cucumber. This comprises an initial strong male tendency which gradually changes into a female tendency. One gene of this type ‘st’ brings femaleness closer to the base and another ‘a’ has the opposite effect. The
different genotypes in this scheme are androecious (M/-st+/st+a/a), monoecious (M/-st+/st+, A/-), gynoecious (M/-st/st, A/-), andromonoecious (m/m st+, A/-) and hermaphrodite (m/m st/st, A/-). M is completely dominant but there is no complete dominance in st gene; st+/st heterozygote shows an intermediate phenotype and its expression is strongly affected by environment. The gene ‘a’ is fully expressed only in M/-st+/st+ genotypes. Galun (1980) reported that, st+/st shifts the overall flowering pattern basipetally or acropetally.

Inheritance of sex expression from crosses involving dioecious cucumber was studied by Scott and Baker (1975). They found two main loci, a and acr, with epistasis to control sex expression and proposed that a locus permitted maleness (aa), whereas acr locus controlled the intensity of femaleness. The inheritance and breeding of the stability of gynoecious sex expression in cucumbers was studied by Hsiao, (1981). He observed the higher degree of female stability in F₁ hybrids derived from crosses between a stable and a less stable parents than the crosses between two less stable parents. Nandgaonkar and Baker (1981) determined that multiple pistillate flowering habit is recessive to single pistillate flowering habit in gynoecious pickling cucumber. Genetic analysis of F₁, F₂ and BC₁ progenies showed that one major gene with several modifying factors control this trait.
Zuradzka (1988) proposed that the trait of multiple pistillate flowers shows partial dominant or intermediate inheritance. The multiple pistillate flower traits appeared to be controlled by 1-4 pairs of genes and estimates of its heritability ranged from 0.38 to 0.77. The flower number was inherited independently of sex expression. Pyzhenkov (1986) found two interacting types of genetic systems controlling sex expression, one monogenic (the major gene being F) conditioning differences between sexual types and one polygenic conditioning different degrees of sex expression. As a result, a broad range of sex expression, from dominance to recessiveness of gynoecy, with many intermediate types, was obtained in the progeny of the crosses. The results of a study on inheritance of sex expression in cucumber (Chen HuiMing et al., 1999) indicated that the sex of cucumber is determined by two major loci F and M and another gene which is recessive to monoecious lines. The recessive gene is closely linked with the dominant gene which determines the female sex expression.

B. MUSKMELON

The original hypothesis of Poole and Grimball (1939) is based on digenic inheritance of sex. Hermaphrodite is designated as double recessive with monoecious having the two dominant genes. The andromonoecious (+a) and gynomonoecious (g+) were heterozygotes, confirming the 9:3:3:1
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segregating pattern. They considered that environmental factors can modify gynomonoecious into gynoecious or trimonoecious. Kubicki (1966) thought that four pairs of independently segregating genes were responsible for various forms of sex expression. Rowe (1969) concluded that gynoecious sex expression was controlled by multiple modifying genes in addition to the major genotype A-gg. Studies made at the Indian Agricultural Research Institute, New Delhi have confirmed the high instability of gynoecism in muskmelon, and also of the gynomonoecious condition. Lazanov (1979) reported that the gynoecism in muskmelon is governed by MMgg, in the presence of Tr gene. The possibility of modifier at ‘g’ locus has been proposed to explain the varying degrees of segregation among gynoecious, gynomonoecious and hermaphrodite crosses (Shinde and Seshadri, 1983 ; Magdum and Seshadri, 1983).

Kenigsbuch and Cohen (1990) studied the inheritance of gynoecy in muskmelon. The segregation ratio of F2 progeny of a cross between gynoecious and monoecious parents indicated two recessive gene differences between the gynoecy and monoecy while the segregation ratio from a cross between gynoecious and andromonoecious parents indicated three recessive gene differences between the parents. They also indicated that the monoecious, andromonoecious and gynoecious parents carried the genes
AAGGMM, aaGGMM and AAggmm, respectively for sex expression. They proposed that monoecious muskmelons have the genotype AG, andromonoecious have aaG, trimonoecious or gynomonoecious have AAggM, hermaphrodite have aagg and gynoecious muskmelons have Aggmm.

C. WATERMELON

The mechanism is fairly simple in that a single pair of genes determines monoecious versus andromonoecious expression (Rosa, 1928; Poole and Grimball, 1945).

D. RIDGE GOURD

Extensive investigations have been conducted on ridge gourd in India. Singh et al. (1948) came to the conclusion that two gene loci are involved, each associated with multiple allelomorphic series (A-aa’ and G-gg’). The genotypes were monoecious (AG), andromonoecious (a’G), androecious (aG), gynomonoecious (Ag’), gynoecious (Ag) and perfect or hermaphroditic (ag, a’g, a’g’,ag’). Richharia (1948) assumed two independent genes one of which determines the inheritance of both sexes, whereas the other controls the female sex only. The first has been found to be epistatic in action and in the absence of both, the individual has perfect flowers. He obtained a F₂ segregation comprising 12 monoecious: 3 gynoecious: 1 hermaphroditic. Scientific reports of the IARI (1963) indicated the action of two pairs of genes
in *Luffa acutangula* towards the expression of sex. Chaudhury and Thakur (1965) studied intervarietal and interspecific crosses in *Luffa*. They postulated that sex expression was controlled by two independent suppressor genes ‘A’ and ‘G’, the former suppressing male organs in solitary flower and the later suppressing the femaleness in the recemes. Roy *et al.* (1975) thought that A, a’a and G, g’g controlled the appearance of male and female sexes allowing for weak suppression of androecium / gynoecium in different phenotypes. The monoecious sex form has been assigned for more than one genotypic expression as AAGG, Aa’GG, Aa’Gg, a’a’GG and a’a’Gg’, gynoecious as AAgg, Aa’gg, Aa’g’g and androecious as aaGG, aa’GG and aa’Gg’.

E. *MOMORDICA*

The appearance of various intermediate sex forms like andromonoecious, gynoecious and trimonoecious in colchicine treated plants of *Momordica charantia*, but remaining as diploids, is an interesting phenomenon reported in the literature. Probably the hidden genetic mechanism has been exposed, but more information could not be gathered, since all these plants of intermediate sex forms were found to be sterile.

Ram *et al.* (2002) examined the possible involvement of genetic and/or
environmental factors in the expression of gynoecious flowering habit in bitter gourd.

F. *PUMPKIN*

Kubichi (1970) found that the androecious form was controlled by *aa* and monoecious form by *AA* in *Cucurbita pepo*. Robinson *et al.* (1976, 1978) observed gynoecious sex expression in the crosses between two monoecious varieties of *Cucurbita maxima* and two monoecious varieties of *Cucurbita moschata*. Shifriss (1985) developed a gynoecious line of *Cucurbita pepo* with phenotypically sensitive sex expression, by crossing three monoecious inbreds and selecting for increased number of pistillate flowers in plants of several filial generations.

G. *BUFFALO GOURD*

A population segregating into gynoecious and monoecious plants was termed as gynomonodioecious. In this population Fulks *et al.* (1979) reported that gynoecism was controlled by a dominant gene in heterozygous state while the monoecism was controlled by a homozygous recessive state. Dossey *et al.* (1981) observed the genetic control of gynoecy in this crop and indicated that monoecy is controlled by a homozygous recessive condition (*mm*) and gynoecy by a dominant gene in the heterozygous condition (*Mm*).
2.3 SEX MODIFICATION

The principle in sex modification in cucurbits lies in alternating the sequence of flowering and sex ratio. Besides the environmental factors, endogenous levels of auxins, gibberellins, ethylene and abscisic acid, at the time and seat of ontogeny determine the sex ratio and sequence of flowering. Exogenous application of plant regulators can alter the sex ratio and sequence, if applied at the critical stages (2 to 4 leaf stage) at which the suppression or promotion of either sex is possible. Hence, modification of sex to desired direction has to be manipulated by exogenous application of plant regulators once, twice or even thrice, at different intervals. High ethylene level is favourable to female sex expression and it is suggested that it promotes the formation of ovary in cucumber, muskmelon and summer squash but it affects the male flower production in watermelon. Kalloo (1974) suggested the foliar spray of Etherel (50 to 100 ppm) at two to three true leaf stages on *Cucumis melo* to change the behavior of female lines at an early stage.

The role of auxin is recognized in the early evolution of ethylene. Etherel has no effect on *Luffia acutangula* (Bose and Nitsch, 1970). Sreeramulu (1983) found increase in number of female flowers with the spray of NAA (100 ppm) at the 2 and 4 true leaf stage on sponge gourd. Gibberellins play a key role in promoting male sex expression and are
antagonistic to that of ethylene and abscisic acid (Rudich, 1983). In fact, gynoecious lines of cucumber are maintained by induction of male flowers through sprays of GA$_3$ / GA$_7$ at 1500 to 2000 ppm. Now-a-days silver nitrate (AgNO$_3$) at 300-400 ppm has been found to bring about the same modification. Lower et al., (1978) found that 50 ppm AgNO$_3$ + 50 ppm GA produced the greatest increase in number of staminate flowers in gynoecious cucumber. Tolla and Peterson (1979) reported the silver nitrate to be more effective than gibberellic acid for induction of staminate flowers in a gynoecious cucumber line. Byers et al., (1972) reported the induction of perfect flowers on a gynoecious line of muskmelon with foliar applications of MCEB at the 4 leaf stage. This method permitted maintenance of gynoecious lines for the production of F$_1$ hybrid muskmelon seed.

Gibberellic acid promotes maleness in several cucurbits. Presently, its application is confined mainly to induce staminate flowers in gynoecious lines of cucumber. Similar effects were noticed by Kalloo and Franken (1978) and Aleksandrova and Krusleva (1981). Owens et al., (1980) studied the abilities of silver nitrate and aminoethoxyvinylglycine and recommended multiple applications of silver nitrate at 100 ppm and aminoethoxyvinylglycine at 50 ppm for induction of perfect flowers in gynoecious muskmelon. Risser and Rode (1985) reported that the hermaphrodite flowers were induced in
the monoecious plants of muskmelon by spraying with 500 ppm of silver nitrate. Comparison of the effects of GA$_3$ and AgNO$_3$ applications to gynoecious lines of pickling cucumbers on induction of male flowers was studied by Prochazkova and Tronickova (1981). They observed that the lines strongly responding to one treatment, tended to be among those which were least responsive to the other. Milotay (1983) found silver thiosulphate more efficient than silver nitrate, as it showed greater stability and less sensitivity to pollution and water quality of the treatment solution. More and Munger (1986) reported that, two applications of 250 ppm AgNO$_3$ at 2-true-leaf stage produced maximum number of male flowers, when exposed to 15 or 20 hours of light.

Rajput et al., (1994) reported that, the foliar sprays with 400 ppm AgNO$_3$ at pre-flowering stage induced hermaphrodite flowers on strictly gynoecious vines of *Momordica dioica*. Chaudhary et al., (2001) found that silver nitrate was superior over silver thiosulphate and gibberellic acid in terms of male flower induction in gynoecious cucumber, although the effect was dependent on the genotype and environment.

According to the observations reported by Mulkey and Pike (1972), the gynoecious character, as expressed in inbreds, gynoecious X hermaphrodite hybrids and back cross derivatives could be stabilized by hybridization with
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the hermaphrodite line. Globerson and Dagan (1973) reported that the plants developing from the seed treatment with dichloromethane and gibberellin for 2 – 4 hours produced staminate flowers on the first 6 – 8 nodes, whereas plants developing from seeds soaked in GA + water or in water produced only pistillate flowers. Tronickova and Cucova (1973) reported the use of hermaphrodite cucumbers for the propagation of gynoecious lines.

Conversely to promote greater number of female flowers and alter the sex ratio in desired direction, several chemicals have been tried and found useful. In cucumber, maleic hydrazide (MH) at 50-100 ppm, GA$_3$ at 5-10 ppm and 2-chloro-ethyl phosphonic acid (commercially called etherel, ethephon or CEPA) at 150-250 ppm; in watermelon, tri-iodo benzoic acid (TIBA) 25-50 ppm and boron 3 ppm; in bottle gourd, boron 3 ppm and calcium 5 ppm (Choudhary, 1966, 1979) and in sponge gourd, etherel 250 ppm have been found to be useful. These chemicals increased the yield in terms of number of fruits per plant, but the individual fruit size was slightly reduced, especially in watermelon. Wehner and Ellington (1995) studied the effect of growth regulators on sex expression of sponge gourd and reported that ethephon (100 mg per liter) did not increase the percentage of pistillate flowers. This kind of sex modification is more useful and practicable in crops like cucumber and bottle gourd where continuous and simultaneous flowering,
fruit set and fruit picking take place. Fujii (1974) suggested that some transmissible alteration of sex expression may be induced by gamma ray (40 kR) treatment.

The response of different cucurbit species and different sex forms within a taxon, to various kinds of exogenous sprays of plant regulators is explained by ‘optimum curve hypothesis’ by Freidlander et al. (1977). This hypothesis is based on a scheme where sex expression (node number) may be considered as a function of abscisic acid and ethylene concentration and described by an optimum curve. The location of each sex type of a crop plant is determined according to the growth substance content of its shoot tips and its response to exogenous treatment. Low gibberellin content in the gynoecious cucumber under short day condition seems to be correlated with a marked response to external addition of gibberellin. On the other hand, in plants having a high gibberellin concentration, addition of this growth substance caused only a small change in sex expression. It is propounded that the node number is a function of endogenous gibberellin concentrations and it may be suggested as a saturation curve.

2.4 PHYSIOLOGY OF SEX EXPRESSION

Determination of sex occurs early in the growth of the primordium and
is susceptible to control through environmental and chemical treatments. The environmental control functions through the agency of growth metabolism of the plant which affects determination by establishing various auxin levels in the neighbourhood of differentiating primordia.

Heslop-Harrison (1963) proposed a kind of ‘gene-operon’ system to explain the numerous processes concerning the sequential initiation of the organs of the flower, like the one in monoecious cucumber. It is a kind of system which reflects the function of a relay system of gene activation operating through the agency of specific ‘inducers’ with short intercellular ranges. From several studies it has been possible to speculate on the functions and characteristics of ‘organ forming’ substances and the function y be supposed to function specifically by the release of blocks of genetic information or perhaps more accurately to set in trend, the processes leading to the step by step release of such information in defined cell lineages. Superimposed on the above mentioned short range systems governing differentiation in the flowering apex, there may be a generalized form of control, mediated through auxin metabolism of the whole plant. This auxin mediated control may operate in two ways; in conjunction with the determination of individual floral members in the early life of primordium and later in determining the balance of growth between gynoecium and
Rudich and Halevy (1974) examined the involvement of abscisic acid in the regulation of sex expression in cucumber. They observed that ABA promoted femaleness in gynoecious plants but did not change the sex expression of monoecious ones. When ABA was applied together with GA, the promoting activity of the GA on male flower formation in the gynoecious line was reduced. ABA also inhibited tendril formation and reduced internodal length. A combined ABA and ethephon treatment resulted in a synergistic activity inhibiting growth and increasing the period of female flower appearance in the monoecious line.

Makus et al., (1975) suggested that ethylene may play a role in the regulation of cucumber seedling morphology. Fuchs et al., (1977) observed that the single gibberellin treatment induced the appearance of staminate floral buds in several consecutive nodes on the main stem of genetically female cucumber plants. Similarly, the repeated GA treatments induced the appearance of staminate flowers in otherwise strictly hermaphrodite plants, next to bisexual flowers. From these results, they inferred that the hormonally induced staminate buds did not develop by sexual reversion of would-be pistillate or bisexual buds, but represented adventitious bud which, in normally grown female or hermaphrodite plants, never developed.
Galun (1983) concluded that genetic, environmental and chemical factors influence cucumber floral bud. Three to four major genes coupled with modifiers, environmental factors like day length, temperature and almost all major groups of growth regulators, all in conjunction determine the sex differentiation in cucumber plant. Wehner and Ellington (1995) studied the effect of ethephon on sex expression of sponge gourd. He found that ethephon (100 mg/l) could not increase the percentage of pistillate flowers.

2.5 METHODS OF BREEDING

In the context of modern concept of breeding of superior populations rather than individual plants, methods of breeding undergo suitable modifications. From pure line and mass selection methods, several techniques have been developed, combining the virtues of both the methods. In a mass pedigree method of selection, Andrus and Bohn (1967) obtained several advantages in cantaloupe breeding. They advocated that inbreeding be withheld until after some period of mass selection with or perhaps without conscious selection. The principle here is to allow natural simulated selection with a resultant opportunity to allow for more genetic recombination. Emphasis in melon breeding, being desert fruits, should be on getting a cultivar that has dependable quality of a standard grade rather than
outstandingly sweet or extraordinary flavour. Abusaleha and Dutta (1990) reported the variability, heritability and scope for improvement in ridge gourd.

By inbreeding and pure line selection one can select a cultivar with uniformity in one character, but only by sacrificing some other indispensable quality characteristic. Invariably, more homozygous inbreds lack earliness, productivity or one or the other quality trait. It implies that the lack of genetic balance of quality traits can overcome environmental sensitivity. Thus far, in no case, a wholly satisfactory combination of horticultural characteristics in an apparently homozygous line has been obtained. The behavioural characteristics which may result in good overall performance are based on polygenic systems and it is not uncommon to harvest two fruits of muskmelon or watermelon from the same vine on different days with varying quality of sweetness.

Miller (1976) observed the effect of blending gynoecious and monoecious cucumber seeds. He found increasing harvest returns with higher proportions of gynoecious seeds. Pyzhenkov and Nikulenkova (1981) bred a gynoecious form of the Klinskii type cucumber by means of hybridization and subsequent selection. More and Seshadri (1988) developed tropical gynoecious lines from the crosses between the temperate gynoecious (G) lines and the tropical monoecious lines. Similarly, Om et al., (1992) developed
gynoecious cucumber inbreds from a backcross breeding programme. Lower (1996) reported the release of three gynoecious pickling cucumber inbreds; Gy 7, Gy 8 and Gy 9 selected from crosses between gynoecious and monoecious lines.


Shifriss (1986) developed a gynoecious line of B+B+ genotype producing green fruit from a gynoecious line NJ20, homozygous for gene B, conditioning precocious yellow fruit pigmentation in *Cucurbita pepo* and concluded that the presence of gene B is not essential to the expression of gynoecy.

### 2.6 HETEROSIS BREEDING

In the recent past, the gynoecious form has generated special interest among breeders because of its utility in the production of hybrids. This has been extensively studied and identified in cucumber and is now being used for the production of hybrids. However, it has been rarely reported in
muskmelon and ridge gourd.

The phenomenal success in heterosis breeding in cucumber and to a lesser extent in summer squash is entirely due to manipulation of sex expression to the desired direction. The genetic control of sex mechanism in cucumber, especially of the gynoecious sex form, has made it possible to exploit heterosis. Pike and Mulkey (1971) studied the use of hermaphrodite cucumber lines in the development of gynoecious hybrids. They observed that the fruits produced on the hybrids were similar in size and shape to those of the gynoecious parent. Yang et al., (1980) studied the characteristics of hermaphrodite cucumber and its use in breeding. They observed gynoecious and subgynoecious plants which flowered a few days earlier than the gynoecious parent. Hybrid cucumber and squash are not that important for mature fruit yield, as for earliness, number of fruits and external attributes of uniformity of size and shape, especially in cucumber slices, attractive colour, flesh texture and other quality traits. Most of the hybrids carry multiple disease resistance due to the fact that dominant genes control resistance to some diseases.

Heterosis for higher number of fruits, bearing at each flowering node, would mean maintenance of plant vigour to a very high degree which has been accomplished in glasshouse culture of protected environment. Not only
high yield but sustaining one which is spread over nearly four months, would make the glasshouse culture competitive to produce superior quality fruits of uniformity and of attractive colour and shape. Earliness is another character which is manifested in the hybrids, besides lesser percentage of unmarketable culls. The latter character is important in pickling hybrids because mis-shapen fruits are rejected at the time of grading for processing. In pickling hybrids, machine harvesting has come into vogue requiring development of cultivars with a concentrated fruit set. Multiple pistillate lines producing more than one fruit at each flowering node are being attempted in pickling types to suit once-over harvest.

In the crosses between gynoecious and hermaphrodite lines, El. Shawaf and Baker (1981) observed greater additive genetic variance than non additive for yield and associated components, except for gynoecious expression, where non additive variance was more important. Staub et al., (1986) reported that the hybrids involving the genetically similar gynoecious (induced pollens by silver nitrate) and bisexual as male parents, did not differ in yield, fruit shape, defects, keeping quality and sex expression.

Hormuzdi and More (1989) generated information on heterosis in cucumber using gynoecious and monoecious females and suggested the use of gynoecious lines for heterosis breeding in cucumber. Vijayakumari et al.,
(1991) evaluated gynoecious hybrids for horticultural characteristics in cucumber. They found that the yield of tropical gynoecious hybrids was superior in comparison with those of the temperate gynoecious hybrids. Kalloo (1993) discussed critically the problems in the exploitation of hybrid varieties in India and suggested the use of gynoecious lines for low cost hybrid seed production in vegetable crops. Khristova (1995) developed new hybrids of small fruited cucumber, based on newly bred gynoecious lines, superior over standard variety in total and marketable yield by 20-40%. Kadam and Desai (1995) suggested the possibility of the exploitation of heterosis in ridge gourd.

Scurtu and Scurtu (1995) indicated the utilization of sex expression in cucumber for the production of hybrids. Dogra et al., (1997) reported highest heterobeltiosis for yield in a cross between gynoecious and monoecious lines. Dhillon and Ishiki (1998) in a study of gynoecious cucumber hybrids for yield stability in subtropical field conditions concluded that the rank of top performing hybrids was consistent through the years. Sharma and Vidyasagar (2001) reported new cucumber hybrids using monoecious and gynoecious inbred lines for cultivation in Himachal Pradesh.

In muskmelon, heterosis breeding has different requirements. Being desert fruits, quality characteristics of the hybrids should be superior in
respect of uniformity and stability over pure bred cultivars. Earlier maturity is another major advantage in the acceptance of melon hybrids. It has been reported in cantaloupe hybrids that the additive factors are more responsible than the non-additive ones for the heterosis of most of the characteristics. The andromonoecious condition of muskmelon necessitates emasculation. Foster (1968) in a series of experiments highlighted the importance of monoecious parents in producing hybrids by cheaper method of hybrid seed production. By using a marker gene glabrous, he showed that the field crossing could produce 30-35% F₁ hybrid seed using andromonoecious lines, 60% using monoecious lines and 75% when male sterility and monoecism were combined with marker gene in seed parents. Marker character would facilitate rouging of self / sib-pollinated seedlings occurring as mixture in hybrid population. Male sterility has not been much advantage in melon hybrids as indicated earlier in hybrid seed production.

Tarsem Lal et al., (1993) recommended muskmelon hybrid MLH10 bred with the gynoecious line W321 for commercial use due to its superiority over standard check. Ivanov (1995) described the procedures for the different uses of the sexual types in breeding melon. Ivanov (1997) developed two new muskmelon hybrids using a gynoecious line. In a review on heterosis breeding in muskmelon, Dhariwal (1997) suggested the use of gynoecious
lines to make qualitatively superior hybrids at cheaper cost of seed production. Sandha et al., (1999) suggested that muskmelon is well suited for heterosis breeding due to its cross compatibility, evident heterosis for agronomic traits and the availability of pollination mechanisms like genetic male sterility, monoecy and gynoecy which had been exploited successfully for commercial seed production.

In summer squash (*Cucurbita pepo*), earliness and high number of fruits per plant were the advantages in hybrid. Application of ethephon or ethrel to young plants at 2-3 leaf stage would suppress male flower formation for 2-3 weeks and complete suppression can be achieved at higher concentration of 600 ppm applied twice at 2 and 4 leaf stage. This method has made hybrid squash seed production comparatively easier and nearly 56% of the total squash seed produced in the U.S.A. is of F$_1$ hybrids.

Likewise, heterosis breeding has potentialities in Asiatic cucurbits (bottle gourd, bitter gourd, pumpkin, Indian squash melon and ridge gourd) as well. Earliness and uniformity in quality characteristics have comprised the of advantages in watermelon hybrids, extensively produced in Japan. Zhou WeiBo et al., (1997) developed an early maturing and high yielding bitter gourd hybrid ‘Cuilu No. 1’ by crossing early gynoecious line.
In most of the heterosis studies in different cucurbits, additive gene action quality traits, which implies the possibility of development of synthetics through the developing several inbred lines. Even though inbreeding depression would be negligible or nearly absent in early synthetic population, interference of natural self and sib-population are major retardants in these crops for producing synthetics. Kanthaswamy et al., (1999) suggested the use of different kinds of male sterility systems, gynoecious lines and self incompatibility in heterosis breeding to overcome the low productivity in vegetable crops.

### 2.7 HYBRID SEED PRODUCTION

In cucurbits, hybrid seed production has been simplified by genetic manipulation of sex mechanism and sex expression. In cucumber, the important step comprises the manipulation of gynoecious seed parent. Homozygous gynoecious lines are developed in the nursery using GA$_3$ 1500 ppm or silver nitrate 200-300 ppm to induce male flowers. The gynoecious lines are crossed with the monoecious male parents to produce $F_1$ hybrids. Kubicki (1966) reported that the genetic basis for obtaining gynoecious muskmelon lines and possibility of their use for hybrid seed production. Similarly, Meshcherov and Techanovich (1974) suggested that the breeding
of female and hermaphrodite forms in melon. Peterson and Weigle (1958) suggested that the utilization of gynoecious lines which are crossed with monoecious inbreds for the production of hybrid seed. Peterson (1960) reported a gynoecious inbred line of cucumber for hybrid seed production. Wehner and Miller (1985) studied the effect of gynoecious expression on yield and earliness of fresh marketable cucumber hybrid. Meshcherov et al. (1982) suggested the use of gynoecious lines for exploitation of heterosis in cucumber.

Kubicki (1970) proposed a method of production of gynoecious seed parents by crossing gynoecious line $MMFF$ with an andromonoecious line $mmff$. After several generations of back-crossing, stable hermaphrodite type $mmFF$ is produced. This is further backcrossed using the gynoecious line as a recurrent parent; as a result, gynoecious and hermaphrodite isogenic lines are produced. When these are crossed, all gynoecious plants are produced. Thus, hermaphrodite plants act as complementary maintainers. Pike and Peterson (1969) suggested that the use of two gynoecious lines for hybrid seed production, in which one line is treated with GA or silver nitrate to produce male flowers for pollination.

An experiment was conducted at the Agriculture College Farm, Dharwad, using gynoecious female and monoecious male parents to study the
effect of growth regulators on seed production and quality in hybrid cucumber (Sitaram et al., 1989). They found that sowing two female to one male line side by side to be effective. Soto et al., (1995) studied economic efficiency on seed production intensification of pickling cucumber hybrid cultivars and their parents and observed 5 - 6: 1 ratio as the best for economic results. Tarsem Lal and Lal (1995) presented the information on muskmelon hybrid ‘MH-10’ seed production using gynoecious female parent.

There is yet another method of hybrid seed production advocated in bottle gourd by Choudhary and Singh (1971). In this case male buds of female parents are pinched off when both male and female parents are grown in adjacent rows. Hence, all the fruits set in female parent would be necessarily through cross-pollination by insects. In muskmelon, cucumber and Luffa, where male flowers are produced in clusters or in recemes, the pinching of male buds will not be complete and effective and hence, this technique will not work satisfactorily.

In summer squash, F₁ hybrid seeds can be produced between two monoecious parents. The female parent is sprayed with etherel at 200-250 ppm concentration, at 2 and 4 true leaf stage which would later produce pistillate flowers successively in the first five or six flowering nodes. The first few fruits set in female parents, would be by crossing with pollen of male
parents through the agency of insects. Four fruits per plant containing hybrid seeds would be a sufficient seed yield (Taylor, 1983).

There is another method of hybrid seed production, viz., the use of male sterile stocks. In cucurbits, genetic male sterility has been reported in muskmelon (Bohn and Whitaker, 1949; Bohn and Principe, 1964; Foster, 1968), summer and winter squash (Shifriss, 1945; Eisa and Munger, 1968) and watermelon (Watts, 1962). Being a single recessive in genetic mechanism, the stocks have to be maintained under heterozygous condition in isolation, by sibbing male fertile and male sterile plants.