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Breeding of F_1 hybrids in muskmelon: Accomplishment and Prospects

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Abstract

Heterosis breeding has been extensively explored and utilized in muskmelon. Being cross pollinated crop and its ability to produce plenty of seeds per fruit facilitates heterosis breeding and make it economically viable. Presence of different pollination mechanisms *like* monoecy, gynoecy and genetic male sterility could be effectively explored for economic production of F_1 hybrids. A large number of varieties have been developed through continuous inbreeding and selection without losing vigour, which is unexpected in cross pollinated crops. Now there is need to give the attention to develop high quality (TSS) and disease resistant hybrids utilizing economic tools.

Key Words: Muskmelon, heterosis, F_1 hybrid

Introduction

Heterosis breeding is one of the most efficient tools of plant breeders to exploit the genetic diversity. Munger (1942) was the first to observe hybrid vigour in muskmelon. Since then, sporadic attempts have been made to observe the performance of heterotic effect in this crop. In India, Punjab Hybrid-1 was the first commercial muskmelon hybrid, which has been developed by utilizing ms-1 gene (Nandpuri *et al.*, 1982). Later on, Pusa Rasraj (Kesavan *et al.,* 1987) and MH-10 (Lal and Dhaliwal, 1993) were developed by exploiting monoecy and gynoecy, respectively. Muskmelon is enriched with great variability and therefore, heterosis breeding can be efficiently utilized to produce hybrids providing high yield and quality fruits (Pandey *et al.*, 2005). Robinson *et al.* (1976) observed variability in vine length (1-10 m), fruit weight (10 g-10 kg), flesh TSS (3-18 per cent) and flesh acidity (pH 3-7). High yield and uniform fruit shape and size, as well as consistently excellent quality, are prerequisites for the release of superior melon varieties/hybrids (Feyzian *et al.*, 2009). Moreover, there is a need to develop suitable hybrids, which may be utilized on commercial scale. Because of cross-compatibility and evident heterosis for agronomic traits, muskmelon is well suited for heterosis breeding (Dhaliwal, 1997). The present review emphasized on need to exploit hybrid vigour in muskmelon.

Sex forms and pollination behaviour

Muskmelon (*Cucumis melo* L.) is predominantly an andromonoecious (hermaphrodite and staminate flowers) but gynoecious (only pistillate flowers) or monoecious (pistillate and staminate flowers) sex forms have also been reported (Dhaliwal, 1997). Anthesis takes place at around 5.30 am and stigma is receptive 12 hours before to the day of anthesis. Duration of pollen fertility is between 5.00 am to 2.00 pm and dehiscence of anther takes place between 5.00 to 6.00 am. Early morning pollination is desirable for maximum fruit setting. It is a strictly cross pollinated crop and honey bees are the chief insect pollinators. However, their andromonoecious sex form of most commercial varieties provides the probability of selfing. Cucurbits are highly cross pollinated but do not suffer from inbreeding depression (Allard, 1960). Hybrid vigour is not depressed is muskmelon due to continuous inbreeding and most of the cultivars have been developed through inbreeding and selection (Scott, 1933). Varying amount of out-crossing has been reported in muskmelon and it depends on the genotypic behaviour, sex form, isolation distance, wind direction, bee activity, seasonal influences, etc. Whitaker and Bohn (1952) reported that average range of cross pollination vary from 20 to 30 per cent. Foster (1968) using 'g-1' and 'ms-2' genes in a hybrid seed production study, found the extent of out-crossing among male fertile andromonoecious plants (24.6 per cent), male fertile monoecious plants (58.4 per cent), male sterile andromonoecious plants (99.0 per cent) and male sterile monoecious plants (99.6 per cent).

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Targeted traits for hybrid development

More and Seshadri (1998), Peter and Swamy (2006) and Pitrat (2009) advocated the following breeding goals for muskmelon breeding programme. High yield and uniform fruit shape and size, are prerequisites for superior melon hybrids. An early and tough netted skin fruit having small seed cavity are the important traits. Being dessert fruit, quality parameters, especially TSS, flesh thickness, texture and colour should be taken into account. The sugar content should vary from 11-13 per cent but not less than 10 per cent. The hybrid should be resistance to biotic stresses *viz.*, powdery mildew, downy mildew, cucumber mosaic virus and fruit fly.

Manifestation of heterosis

Muskmelon has the advantage of producing a large number of seeds in a single cross coupled with lesser requirement of seed for planting per unit area. Munger (1942) was first to report heterosis in muskmelon and observed 30% higher yield and uniform fruits. The hybrids generally showed heterosis for earliness (Gaurav *et al*., 2000 and Choudhary *et al*., 2003). Significant and desirable heterosis for flesh thickness has been observed by Chadha and Nandpuri (1980), Dhaliwal and Lal (1996) and Choudhary *et al*. (2003).

Munshi and Verma (1999) found promising combinations (Pusa Madhuras x Hara Madhu, Pusa Sharbati x Pusa Madhuras, Pusa Madhuras x Ravi and Pusa Madhuras x T-96) for earliness and fruit yield per plant. Significant heterobeltiosis has also been recorded by Gurav *et al.* (2000) in Kavit x Bhang, Hara Madhu x Pusa Madhuras and Jam B x Jam D for fruit yield and yield contributing traits and emphasized the need to exploit the same crosses in muskmelon breeding. Lal and Kaur (2002) observed desirable heterosis in MS-1 x NDM-15 for TSS, WI-998 x NDM-15 for yield per vine and WI-998 x DMDR-3 for resistance to downy mildew. Heterobeltiosis upto the extent of 44.44 per cent (*ms*-1 x Hara Madhu) for fruit yield per plant have been reported by Choudhary *et al.* (2003). Subramanian (2008) recorded heterobeltiosis for fruit yield and number of fruits per vine in melon cross involving ARY x AJ (C5). Heterosis for total soluble solids was reported by Chadha and Nandpuri (1980), Dhaliwal and Lal (1996), Munshi and Verma (1999), Lal and Kaur (2002), Choudhary *et al.* (2003) and Moon *et al.* (2006). More and Seshadri (1980) observed 50 hybrids and found that M_1 x Mix Top Mark, M_1 x Golden Perfection, M_2 x Yauco Treat, M_2 x PMR-6 and M_2 x Top Mark superior over better parents for earliness, yield and quality attributes.

Heterobeltiosis for days to female flower, fruit maturity, fruits per plant, fruit weight, flesh thickness, fruit yield and sugar content was observed by Chadha and Nandpuri (1980), Dixit and Kalloo (1983), Mishra and Seshadri (1985), Randhawa and Singh (1990), Singh and Randhawa (1990), Dhaliwal and Lal (1996), Munshi and Verma (1997), Lal and Kaur (2002), Choudhary *et al.* (2003) and Subramanian (2008). Mishra and Seshadri (1985) crossed 2 genetic male sterile lines with 32 andromonoecious varieties and reported heterosis over better parent for cross combinations ms-1 x Harela (31.3%) for yield, ms-2 x Pusa Madhuras (13.5%) for TSS and ms-1 x Persiiski-5 for earliness (19.0%) and early yield (43.47%). It is possible that heterosis has contributed to a yield increase for specific cultivars. The overall quality and percentage of marketable yield over total has also increased as a result of breeding efforts (Gusmini and Wehner, 2008). Quality character (especially TSS) is highly influenced by environmental factors; hence, it is not possible to fix it within architectural limits even in pure varieties. Since its inheritance and expression is very complex, it is necessary to find out whether F_1 hybrids can prove superior to the pure bred varieties and heterozygosity *per se* can bring about the genetic balance necessary in the manifestation of this quality attributes. Besides, growing season in some parts of north India is limited and hence earliness is much sought after here to avoid pre-monsoon showers which deteriorates the fruit quality and invites many diseases (More and Seshadri, 1998).

Resistance against certain specific diseases can also be transmitted to the hybrids. Foster (1960) transmitted crown blight resistance to F_1 hybrids. Resistance had been reported to be dominant (Dhillon and Wehner, 1991), which might be utilized in the breeding programme. Kesavan and More (1987 & 1991) utilized three monoecious lines (M_1, M_2 and M_3) in hybrid programme and identified four promising hybrids resistance to powdery mildew along with desirable horticultural characters.

Exploitation of monoecy

Generally muskmelon is andromonoecious but some genotypes have monoecious sex form. Monoecism has been assessed for its use in heterosis breeding and excludes emasculation (More *et al*., 1980 and Kesavan and More, 1991). They also advocated the use of monoecious lines in hybrid seed production which reduces the time required by 50 per cent and enhance fruit set 40-70 per cent as compared to 5-10 per cent in andromonoecious parent. Monoecious character was controlled by a single pair of recessive genes. Considering the problems associated with use of male sterile gene(s) for production of muskmelon hybrids (maintenance of single recessive gene due to heterozygous condition and problem of identifying and rouging of 50 per cent male fertile plants from the female row at the time of flowering) and also to overcome the problems of andromonecious sex form. More *et al*. (1980) developed four monoecious lines (M_1, M_2, M_3 and M_4) for commercial utilization in heterosis breeding. Main problem in using monoecious lines in heterosis breeding is undesirable linkage between genes controlling sex expression and fruit shape (Risser, 1984). Due to this limitation, F_1 hybrids with round fruits cannot be obtained. This problem is also found in Pusa Rasraj, hence this hybrid is not accepted commercially, due to its undesirable fruit shape and poor external appearance (Sandha and Lal, 1999).

Exploitation of gynoecy

Gynoecious lines produce only female flowers and ensure 100 % pure hybrid seed production. Peterson *et al.* (1983) was first to develop gynoecious line in muskmelon from the progeny of gynomonoecious lines *i.e.*, monoecious x hermaphrodite cross. Such lines can be maintained through the stimulation of male flowers by chemicals. The use of silver compounds like silver nitrate at 100-200 ppm (More and Seshadri, 1987) has been used successfully to induce perfect flowers in gynoecious lines for their maintenance. The chief advantage of using gynoecious lines over *ms* lines in heterosis breeding is the tedious job of identification and rouging of 50 per cent male fertile plants from the mixed population can be avoided. Therefore, Loy *et al.* (1979) advocated the use of gynoecious lines in hybrid seed production. Lal and Dhaliwal (1993) used WI-998, a gynoecious line in hybrid production and reported that it has good combining ability for yield and earliness but was average combiner for TSS per cent. A cross between WI-998 x Hara Madhu *i.e.*, MH-10 was found promising and was released for commercial cultivation in Punjab during 1995. It is not only early and high yielding but also has good transport quality.

Dhaliwal and Lal (1996) evaluated a large number of crosses involving monoecism, gynoecism and male sterility in the female parent. The cross W-321 x N-233 was out yielded in comparison to Punjab Hybrid-1 (check) by more than 50 per cent and was also significantly earlier. Thus, the hybrid W-321 x N-233 has good potential for commercial exploitation. This cross should be commercially viable as it involves gynoecious female parent, which can be conventionally maintained by inducing maleness with the help of growth regulators (More and Seshadri, 1987). It has been observed that gynoecious lines are poor in TSS, so it is essential to improve the TSS level of available gynoecious lines through selection for the production of better quality hybrids. The instability of gynoecious lines at high temperature also poses a problem in their utilization.

Exploitation of male sterility

Male sterility has also been utilized in heterosis breeding of muskmelon (Nandpuri *et al.*, 1974 and Mishra and Seshadri, 1988) and exploited commercially by Nandpuri *et al.* (1982) in the form of Punjab Hybrid-1. The cost of muskmelon F_1 seed is 15-30 times high than the open pollinated varieties. Thus male sterile genes offer the potential of lower the cost of hybrid seeds. Male fertile plants are rogued out and mature fruits are harvested from male sterile plants only to obtain seeds. This seed will provide male fertile and male sterile plants in 1:1 ratio, serves as a stock seed to repeat the cycle. The same seed is used for hybrid seed production by altering the parental lines in the ratio of 3:1 (female: male). However, 50 % male fertile plants have to be removed at the appearance of first male flower from the female rows. Fruits develop on male sterile plants will produce hybrid seed (Kumar and Dhaliwal, 1991). The efficiency of male sterility can be considerably increased if the plants are identified only in the seedling stage using marker genes. Male sterility in muskmelon has been reported by several researches (Bohn and Whitaker, 1949; Bohn and Principe, 1964 and Foster, 1968). Sterility is governed by a single recessive nuclear gene. Presently five recessive nuclear male sterile genes (*ms*-1, *ms*-2, *ms*-3, *ms*-4 and *ms*-5) are known. The genetic male sterile line *ms*-1 was identified (Bohn and Whitaker, 1949) and is the only line commercially utilized in India (Nandpuri *et al.,* 1982). The development of Punjab Hybrid-1 (*ms*-1 x Hara Madhu) has been developed by PAU, Ludhiana (Nandpuri *et al.*, 1982).

Prospects

Good characteristics of a muskmelon variety are thick skin, thick flesh with good consistency and mild musky flavour, attractive outer colour, small or negligible hollowness of fruit, and resistant to powdery mildew, downy mildew, cucumber mosaic virus and fruit fly. Presence of considerable variability in the crop, if explored and collected, can be made use to develop such line (s) with the above good characteristics. Prospect of exploiting heterosis in muskmelon is very high. There is need to identify specific combinations which exhibit heterosis for economic characters. The use of growth regulators can also go a long way to increase productivity. As India is a secondary centre of muskmelon wide genetic variability exists which need to be maintained and exploited by the breeders.

Priority should be given to develop multiple disease resistant hybrids. Stable monoecious and gynoecious lines should be developed so that hybrid seed can be produced economically. The future research on heterosis breeding in muskmelon should concentrate on the development of suitable male sterile lines with suitable genetic markers *viz.*, green glabrous and yellow green leaves at early stage, which may be utilized on commercial scale.

Conclusion

Muskmelon is ideally suited for heterosis breeding because of its cross pollination behaviour and heterosis for economic traits. In hybrids, it is possible to combine large number of desirable genes. Such types of combinations are very difficult to achieve with the help of inbreeding and selection. When the resistance is controlled by dominant genes, the insect pest, disease and stress resistant hybrids can be developed more steadily than open pollinated varieties. With the availability of perfect out-crossing systems like male sterility and gynoecy the production of hybrid seed either manually or by use of monoecy can be discarded. It is not possible to produce 100 per cent pure seed utilizing male sterility but contamination by self or sib seed can be minimized by taking strict care at the time of identification and by incorporating tightly linked marker genes to rogue out 50 per cent fertile plants. The later would also help in reducing the cost of hybrid seed. Availability of gynoecious line in muskmelon has brightened the scope of heterosis breeding in this crop. The cost of hybrid seed produced by exploiting gynoecy is certainly be much less than any other method. But TSS content of such lines needs to be improved so as to develop hybrids superior to existing varieties or hybrids. Recently the sources of resistance have now been identified against diseases like powdery mildew and can be exploited in the form of disease resistant hybrids.

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