HETEROSIS AND COMBINING ABILITY STUDIES IN MUSKMELON (*Cucumis melo* L.)

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
in
HORTICULTURE (VEGETABLE SCIENCE)
(Minor Subject: Plant Breeding and Genetics)

By

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CERTIFICATE - I

This is to certify that the thesis entitled, **"Heterosis and combining ability studies in muskmelon (*Cucumis melo* L.)"** submitted for the degree of **Master of Science** in the subject of **Horticulture (Vegetable Science)** (Minor subject: **Plant Breeding and Genetics**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ms. Simranpreet Kaur (L-2018-A-165-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE – II

This is to certify that the thesis entitled, "**Heterosis and combining ability studies in muskmelon (*Cucumis melo* L.)**" submitted by **Ms. Simranpreet Kaur** (Admn. No. **L-2018-A-165-M**) to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.** in the subject of **Vegetable Science** (Minor subject: **Plant Breeding and Genetics**) has been approved by the Student's Advisory Committee along with External Examiner after an oral examination on the same.

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ABSTRACT

In the present investigation, ten diverse inbred lines were crossed in a half diallel fashion to generate forty-five F_1 hybrids. The analysis of variance exhibited a significant difference among all the genotypes for the target traits. Among the parental lines, MM-625 and MM 916/NS-1 were identified as the best general combiners for fruit yield ha^{-1} and TSS content, respectively. The cross-combination MS-1×MM-610 exhibited the highest specific combining ability for fruit yield ha^{-1}, while Kajri×MM-904 was identified as the best combination for TSS content. Further, the F_1 hybrids KP_4HM-15×MM Sel-103, MM Sel-103×MM-904, MM 916/NS-1×Riogold exhibited the positively significant heterobeltiosis for fruit yield ha^{-1} and TSS content. The cross combinations, KP_4HM-15×MM Sel-103, KP_4HM-15×MM-1831, and MM-610×MM 916/NS-1 recorded the highest standard heterosis for fruit yield and TSS content over the popular hybrids, MH-27, MH-51, and Farmer Glory. The genetic inheritance inferences revealed the predominance of non-additive gene action (dominance) for most of the characters indicating their exploitation through hybrid breeding. In relationship analysis, fruit yield per ha^{-1} exhibited positive and significant correlation with average fruit weight, number of fruits per vine, flesh thickness, vine length and number of branches. The direct and indirect effect of different characters on fruit yield per hectare were also studied. The path analysis indicated the effectiveness of selection through direct and indirect effect of variables. Kajri × MM-904, MM Sel-103 × MM 916/NS-1 and KP_4HM-15 × MM Sel-103 F_1 hybrids were found to be resistant to Fusarium wilt, root knot nematode and virus infestation, respectively. In molecular divergence analysis, among 121 SSRs, 70 primers exhibited the parental polymorphism. Certain SSR markers *viz.*, DM0561, CMAAAGN14, TJ147, CMMS35_3, CMAGN45 and DE1337 identified specific/unique alleles, which could further be utilized to identify the respective genotypes. DNA finger printing of F_1 hybrids was also carried out using these SSR markers. Overall, the finding of this study revealed that the novel inbred lines can effectively be combined to generate heterotic F_1 hybrids for yield and other traits, such as total soluble solids, β-carotene content, netting intensity, both rind and flesh thickness. Further, SSR markers can potentially be utilized for confirming the genetic diversity among parental lines and DNA finger printing of F_1 hybrids.

Keywords: β-carotene, cantaloupe, diallel analysis, GCA, genetic diversity, SCA, SSR markers, Vitamin C

_____ _____

Signature of Major Advisor **Signature of the Student**

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ਮੁੱਖ ਸ਼ਬਦ: ਬੀਟਾ-ਕੈਰੋਟੀਨ, ਕੈਨਟਾਲੁਪ, ਡਾਈਐਲੀਲ ਮੁਲਾਂਕਣ, GCA ਅਨੁਵਾਂਸ਼ਿਕੀ ਵਿਭਿੰਨਤਾ, SCA, SSR ਮਾਰਕਰ, ਵਿਟਾਮਿਨ ਸੀ

ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿੱਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER I

INTRODUCTION

Muskmelon (*Cucumis melo* L.) is an important cucurbitaceous crop, known for its sweetness, unique flavor, and aroma. In 2019, muskmelon was cultivated on 1.22 million ha area with 31.9 million tons of production around the world. China, Iran, Turkey, India, Afghanistan, Kazakhstan, and the USA are the leading muskmelon producing countries (FAO 2021). In India, muskmelon is grown on 57 thousand ha area, with 1.3 million tons of production (NHB 2019). Uttar Pradesh, Andhra Pradesh, Punjab, Madhya Pradesh and Karnataka are the major muskmelon producing states in the country. Punjab ranks third in muskmelon production, at the national level with area 5.6 thousand ha and 99.1 thousand tons of annual production (Kumar *et al* 2018).

Muskmelon is a good source of health promoting compounds, such as, β-carotene and ascorbic acid. β-carotene helps in reducing the risk of chronic heart disease and in prevention of night blindness. On an average, muskmelon fruit pulp contains 5.6 to 36 µg/g of β-carotene in fresh fruit pulp (Lester and Eischen 1995). It also contains 42.2 mg of ascorbic acid per 100 g of an edible portion which helps in maintaining a healthy immune system, reducing bacterial infection and prevention of cardiovascular diseases (Lester and Lester 2015). Besides, melon fruit also possesses carbohydrates (8.36 g), proteins (0.88 g), water (89.7 g), dietary fibre (0.8 g), sugar and essential mineral salts. Its seeds are edible and greatly nutritious contain crude protein (34.4%) and oil (40-44%) which is valuable for painful discharge and suppression of urine (Shashikumar *et al* 2016).

Most of the researchers believed that melon was domesticated in Tropical Africa because several related wild species had been observed in that region (Kerje and Grum 2000), but later data suggested that this species might have originated in Asia. It is a diploid species with 2n = 24 chromosomes. It is a cross pollinated crop but, it does not suffer from inbreeding depression (Dhaliwal *et al* 1996). Thus, inbred development and maintenance is comparatively easier in muskmelon as compared with other cross-pollinated crops.

Muskmelon exhibits great polymorphism for fruit traits, such as fruit size, shape, TSS, β-carotene and flesh color. Owing to this diversity *Cucumis melo* L has been classified into 16 intraspecific groups (Pitrat *et al* 2000). Melon also exhibits varied pollination control mechanisms such as, male sterility, gynoecism and monoecism which could be utilized for breeding programs. Male sterile line MS-1 and MS-5 have already been utilized at PAU through development of hybrids, Punjab hybrid, MH-27 and MH-51 (Singh *et al* 2019).

Heterosis breeding has been extensively explored and utilized in muskmelon. Conventional breeding methods in melon have improved melon genetics significantly. Melon improvement through conventional hybridization is relatively slow and narrow to a restricted

gene pool. Through heterosis breeding, it is possible to obtain viable intraspecific melon hybrids between wild-type genotypes and commercial melon varieties, to facilitate the transfer of the genetic traits of certain melon groups (Kamer *et al* 2015). Sweetness, level of phytonutrients, flesh thickness, texture, color, and aroma are the important quality determinants of muskmelon (Lal and Dhaliwal 1993). Round netted fruits with thick orange flesh and tough rind suitable for long transportation are preferred by the growers and salesmen. Early harvest in muskmelon is of great importance, as market prices for such a crop ensure great returns to the farmers. Thus, heterosis breeding can be an effective strategy for combining all possible desirable characters in melon cultivars.

The development of F_1 hybrids is the quickest way for improving important economic traits of muskmelon and an easy way of introducing disease resistance governed by dominant genes. Hybrids are developed by crossing superior inbred lines in possible combination. Therefore, for developing hybrids, information about combining ability and *per se* performance of inbred lines are necessary (Sandha and Lal 1999). Combining ability analysis is one of the powerful tools available, which offers an estimate of combining ability effects and help in selecting desirable parents and crosses for further course of action (Chadha and Nandpuri 1980).

Among the mating designs, the diallel analysis (half diallel design) proposed by Griffing (1956) provides the information about the performance of parents and their F_1 hybrids. The general combining ability allows the identification of parents with the higher frequency of favourable alleles, while the specific combining ability indicates the most promising hybrid combinations (Valerio *et al* 2009). In the half diallel design each parent is crossed with each other in all possible combinations (apart from the reciprocals). It involves half matings and requires a less experimental area for estimation of material (Varinder and Vashisht 2018).

Munger (1942) was first to report hybrid vigour in muskmelon, hence many international public and private institutes/ companies have developed excellent commercial F_1 hybrids possessing good fruit quality and resistance to various diseases for local as well as distant markets, however a limited success has been achieved in this direction in India. A few hybrids, such as Punjab Hybrid, MH-27, MH-51, Pusa Rasraj and MH-10 (Lal and Dhaliwal 1993, Singh *et al* 2020) had been developed due to narrow genetic base of available male-sterile/ gynoecious/ monoecious parental lines. In muskmelon, the ability to produce the abundant seeds per fruit holds the potential to use andromonoecious inbred lines in hybrid breeding. Thus, there is an urgent need to explore the possibility of utilization of new inbred lines to develop F_1 hybrids with round netted firm fruits with superior horticultural characters combined with inbuilt resistance to diseases.

In addition to generating information on combining ability of inbred lines and gene

action to plan an appropriate breeding program, it is also critical to characterize the genetic polymorphism among breeding lines/ hybrids at the molecular level. DNA-based molecular markers provide a powerful technique for genetic diversity evaluation, selection of diverse parental lines for hybrid development and cultivar DNA finger printing (Luan *et al* 2010). Microsatellite markers (SSRs) offer several advantages as compared with other DNA markers. These markers are highly polymorphic, reproducible, multi-allelic and co-dominant in nature. Therefore, SSRs can be effectively used to assess the genetic divergence among breeding lines/ hybrids.

Thus, keeping in view the above background knowledge the current study was planned and executed with the overall aim to identify breeding lines having the good combining ability for yield and other fruit characters, particularly TSS, netting, firmness, rind thickness, small seed cavity and flesh thickness, to generate promising F_1 hybrids and to characterize these breeding lines/ hybrids at the molecular level.

Objectives

1. Estimation of heterosis and combining ability for yield and fruit quality traits.
2. Assessment of the genetic components of variation for suggesting an appropriate breeding strategy for target traits.
3. Characterization of genetic divergence among muskmelon inbred lines/ hybrids at a molecular level.

CHAPTER II

REVIEW OF LITERATURE

The exploitation of heterosis breeding in muskmelon is advantageous as it is a cross pollinated crop. Muskmelon offers a great scope for exploitation of hybrid vigour on commercial scale to increase the productivity and production. Muskmelon possess the genetic variability for most of the yield attributing traits viz, earliness, number of fruits per plant, fruit weight, etc. The present investigation entitled "HETEROSIS AND COMBINING ABILITY STUDIES IN MUSKMELON (*Cucumis melo* L.)" has been reviewed under the following subheadings:

2.1. Heterosis breeding

2.2. Combining ability analysis

2.3. Gene action

2.4. Correlation analysis

2.5. Path coefficient analysis

2.6. Reaction to disease incidence

2.7. Genetic diversity

2.1 Heterosis breeding

Heterosis breeding is one of the most efficient tools for exploiting the genetic capability in crop plants. Improved yield, uniform shape, size, and consistently high quality are the pre-requisites of commercial hybrids/cultivars in muskmelon. Muskmelon possesses great variability for fruit traits, thus heterosis breeding can be effectively utilized to produce hybrids with high yield and quality (Sandha and Lal 1999).

Since the first report of hybrid vigour in muskmelon (Munger 1942) some efforts have been made to develop commercial F_1 hybrids in muskmelon. In India, Punjab Agricultural University, Ludhiana was the first to release muskmelon hybrid, Punjab hybrid (Nandpuri *et al* 1982) using the GMS inbred, MS-1 possessing a recessive male sterility gene (*ms-1)*. Subsequently, three more F_1 hybrids, Punjab Anmol, MH-27, and MH-51 have been developed at PAU, Ludhiana using male sterility mechanism (Sandha and Lal 1999, Anonymous 2019). Development of Pusa Rasraj and MH-10 utilizing monoecism and gynoecism are other two examples of successful utilization of heterosis in muskmelon in India.

In general, netting intensity, absence of sutures, blossom end thickness, flesh thickness, flesh firmness, rind thickness, small cavity, and disease resistance are the characters which determine the superiority of hybrids over varieties. Such combinations are easy to come up through hybrid breeding (Sandha and Lal 1999). Heterosis for netting intensity, flesh firmness, flesh thickness and TSS has been reported (Singh and Vashisht

2018). Kamer *et al* (2015) reported heterosis for rind colour, fruit flesh thickness, moisture content, soluble solids, and ascorbic acid content by involving five parental lines, Kooz Assal, Matrouh, Orange, Green and Ideal. Sedera *et al* (2016) evaluated thirty-six F_1 hybrids and nine parental lines in a half diallel mating design. They found that there was a significant distinction among hybrids for mid and better-parent heterosis.

2.1.1 Growth attributes

Kumar *et al* (2005) observed significant relative heterosis and heterobeltiosis for number of primary branches, number of the node where first female flower appeared and days to first fruit harvesting in the hybrids AMM-01-18 × AMM-02-26, AMM-00-25 × AMM-00-11 & AMM-01-18 × DM-1. Cross Pusa Madhuras × IIHR-615-5-2 for days to first pistillate flower opening and Kajri × IIHR-615-5-2 for days to first fruit harvest cross shown maximum desirable heterosis.

Kamer *et al* (2015) observed significant heterosis for vine length, flowering time, rind colour, number of branches per vine and harvesting date. Lakshmi *et al* (2016) made twelve F_1 crosses of pickling melon from which maximum standard heterosis for number of nodes per vine was observed in cross CMC GKVK-1 × CMC GKVK-13 (2.65) and for number of primary branches per vine in CMC GKVK-8 × CMC GKVK-11 (33.60). Hybrids, DCM-31 × Kashi Madhu and DMM-159 × DCM-31 showed heterosis over better parents for characters such as days to first female flower anthesis, days to first fruit harvest and total fruit yield, respectively (Saha 2017).

Duradundi *et al* (2017) found maximum and significant heterosis for number of branches per vine at 60 DAS, number of leaves per vine at 60 DAS, vine length at 90 DAS, days to first flowering, days to first female flowering, days to first fruit harvest, number of fruiting branches per vine in crosses KM-2 × PS (39.77%), KM-2 x PS (49.60 %), KM-1 × HM (-18.56 %), KM-1 × DK (26.37 %), KM-2 × PS (-24.94 %), KM-2 × PS (-18.95 %), KM-2 × PS (38.60 %), KM-2 × PS and KM-3 x PS (-35.94 %) respectively over the commercial check.

Hassan *et al* (2018) reported significant positive heterosis for fruit number per vine in 8 crosses over mid parent and 6 crosses over better parent ranged from 100 % to 69.44% respectively. Costa *et al* (2019) evaluated 41 treatments of melon genotypes of *Momordica* group, out of 26 hybrids 15 of them showed significant positive heterosis for mean fruit mass.

2.1.2 Earliness

In muskmelon, early maturity, along with high productivity and enhanced quality is of utmost importance to catch early market profits (Dhaliwal and Lal 1996, Sandha and Lal 1999). Dhaliwal and Lal (l996) identified a hybrid W 321 × N 233, which was early and exhibited 50% heterosis over the commercial hybrid. Munshi and Verma (1999) reported Pusa Madhuras × Hara Madhu, Pusa Sharbati × Pusa Madhuras, Pusa Madhuras × Ravi as the

promising combinations for earliness and fruit yield.

Lakshmi *et al* 2016 made twelve F_1 crosses of pickling melon from which maximum standard heterosis for earliness was observed in hybrid CMC GKVK 8 × CMC GKVK 15 (- 21.40%).

2.1.3 Fruit characters

2.1.3.1 Fruit length and width

Kumar *et al* (2005) observed significant relative heterosis and heterobeltiosis for fruit length and fruit girth in the hybrids AMM-01-18 × AMM-02-26, AMM-00-25 × AMM-00-11 & AMM-01-18 × DM-1. Jose *et al* (2005) studied fruit quality traits in twelve exotic accessions and their hybrids with a "Piel de Sapo" inodorus melon cultivar which indicated general positive heterosis for fruit length and fruit shape and from negative to positive heterosis for fruit weight and fruit diameter.

Pornsuriya *et al* (2014) recorded the cross combinations viz., Cylindrical fruit × Honda (W × H), Round fruit × Honda (R × H), Cylindrical fruit × Argo (W × A), Cylindrical fruit × Argo (S × A) and Round fruit x Argo (R × A) exhibited significantly positive heterosis for fruit cavity width, fruit cavity length, fruit width and fruit length.

Hassan *et al* (2018) reported significant positive heterosis of F_1 hybrids for fruit width ranged from -32.05 to 26.79% for mid-parent and from -34.25 to 15.46% over better parents, respectively. The heterotic expression for fruit length varied with values ranging from -41.13 to 53.62% for MP and BP heterosis, respectively.

Costa *et al* (2019) evaluated 41 treatments of melon genotypes of *Momordica* group, out of 26 hybrids 15 of them showed significant positive heterosis for mean fruit length and mean fruit diameter.

2.1.3.2 Flesh and rind thickness

Choudary *et al* (2003) observed that cross MS-1 x Punjab Sunehri showed high heterobeltiosis (23.53 %) for rind thickness. Significant relative heterosis and heterobeltiosis for flesh thickness were seen in the hybrid Hara Madhu × RM-50 & AMM-00-25 × AMM-00-11 (Tomar R.S and Bhalala M.K 2006). Lakshmi *et al* (2016) found among twelve F_1 crosses of pickling melon maximum standard heterosis for fruit flesh thickness was shown by cross CMC GKVK 8 × CMC GKVK 15 (21.46 cm).

Hassan *et al* (2018) reported significant positive heterosis for flesh thickness which was up to 62.06% over mid parent and 20.8% over the better parent. For cavity diameter, desirable negative mid parent, and better parent heterosis values varied from -41.59% to -58.81% was observed.

Costa *et al* (2019) evaluated significant positive heterosis for mean pulp thickness in fifteen hybrids of melon genotypes of *Momordica* group.

2.1.3.3 Flesh color and rind color

Sedera *et al* (2016) recorded highly significant positive heterosis over mid and better-parent for seven hybrids among them cross Ananas El Dokki × Aswan showed the highest value of heterosis for flesh color.

2.1.4 Yield and yield attributing traits

Gurav *et al* (2000) studied heterosis and recorded the highest heterosis in a cross of Kavit × Bhang with high per se performance for the number of fruits and average fruit weight. Lal and Kaur (2002) observed maximum heterosis for fruit yield per vine in cross WI-998 × NDM-15 among 40 cross combinations. Moon *et al* (2003) evaluated hybrids in half diallel mating design and observed that average fruit yield was highest in parents M-3, DMDR-1, and Hara Madhu. While, among hybrids M-3 × DMDR-1, Pusa Madhuras × DMDR-1 and Pusa Madhuras × Hara Madhu were the best F_1 hybrids for average fruit weight.

Choudary *et al* (2003) observed that three hybrids namely MS-1 × Hara Madhu (44.44 %), Jobner Local × Durgapura Madhu (38.65 %) and Hara Madhu × Durgapura Madhu (35.90 %) exhibited significant heterosis for yield over the better parent. Higher heterosis among the crosses were shown by cross Hara Madhu × Tonk Local over better parent and standard check for number of fruits per plant (15.96 %) and cross MS-1 × Tonk Local exhibited a significant increase in fruit weight (30.16 %) over the better parent.

Moon *et al* (2006) observed F_1 hybrid, Pusa Madhuras × Ham Madhu showed 44.54% and 15.89 % higher heterosis for higher yield over the better parent and commercial check, respectively. Out of five hybrids, four hybrids Hara Madhu × RM-50, AMM-01-18 × AMM-02-26, AMM-00-25 × AMM-00-11 and AMM-01-18 × DM-1 showed significant heterosis for number of fruits per plant and fruit weight over the mid-parent and the better parent (Tomar and Bhalala 2006). Subramanian (2008) prepared five crosses concerning Vellari melon (C. *melo*. var. *utilissimus*) and muskmelon lines and found that cross ARY × Mica Jeet recorded maximum heterosis over better parent for fruit yield and number of fruits per vine. Heterosis for yield and components traits has been reported by several authors.

Feyzian *et al* (2009) reported significant heterosis (56.9%) which was revealed by cross KM-2 × PS over the commercial check for fruit yield. Nerson H (2010) observed average heterosis for fruit yield of three Galia type hybrids was 63% higher than the average fruit yield of five parental accessions. Pornsuriya *et al* (2013) concluded that crosses between thai melon and cantaloupe revealed that the cross R × H was highly significant for fruit weight (71.37%) and yield (68.39%) over the mid parent.

Jagtap and Musmade (2014) investigated the extent of heterosis of 21 hybrids derived from seven parental lines in half diallel mating design. They observed IVMM-3 x MHY-5, IVMM-3 x Punjab Sunehri and Hara Madhu × IVMM-3 were best performing hybrids for the weight of fruit per vine. Pornsuriya *et al* (2014) studied the heterosis for fruit characters and yield of crosses between Thai melon (oriental pickling melon) lines and cantaloupe cultivars.

The cross combinations Cylindrical fruit × Honda, Round fruit × Honda and Cylindrical fruit × Argo (56.33, 68.39 and 24.80%, respectively) exhibited significantly positive heterosis for total fruit yield and crosses Cylindrical fruit × Honda and Round fruit x Honda (54.03 and 71.37%, respectively) for fruit weight.

Lakshmi *et al* (2016) studied twelve F_1 hybrid of pickling melon and observed highest standard heterosis for fruit yield per vine in cross CMC GKVK 9 × CMC GKVK 12 (59.51 kg) followed by CMC GKVK 9 × CMC GKVK 11(54.63 kg) and maximum standard heterosis for number of fruits per vine in cross CMC GKVK 9 × CMC GKVK 15 (94.35) and for fruit weight in cross CMC GKVK 8 × CMC GKVK 15 (24.65 g).

Duradundi *et al* (2017) observed maximum standard heterosis for number of fruits per vine in cross KM-2 × PS (53.13 %) and for average fruit weight in cross KM-1 × HM (52.79 %). For fruit yield per hectare, maximum heterosis over commercial check was observed in the cross KM-2 × PS (56.96 %) followed by KM-1 × DK (52.17 %) and KM-3 × PS (46.52 %). Hassan *et al* (2018) reported that out of 15 studied crosses, eight over mid parent and five over better parent showed significant positive heterosis for fruit weight. Similarly, significant heterosis for total yield per vine was observed in nine crosses over the mid parent and seven crosses over the better parent.

2.1.5 Quality traits

Lal and Kaur (2002) observed maximum heterosis for TSS content in cross MS-1 × NDM-15 among 40 cross combinations. Burger *et al* (2004) observed few accessions of melon were showing 50-times higher ascorbic acid fluctuating from 0.7 mg to 35.3 mg/100g. While Sharma and Lal (2004) found vitamin C variation ranged from 8.3 to 23.1 mg/100 g of fresh weight in ten varieties of melon.

Moon *et al* (2006) evaluated twenty-eight F_1 hybrids developed from eight genetically diverse inbred lines of muskmelon. Among all the parents, Ravi had the highest TSS content, total sugars and reducing sugars. DVRM-1 and Hara Madhu showed the highest values for carotenoid and ascorbic acid contents, respectively. While Tomar and Bhalala (2006) observed F_1 hybrids Hara Madhu × RM-50, AMM-01-18 × AMM-02-26, AMM-00-25 × AMM-00-11 and AMM-01-18 × DM-1exhibited significant heterosis for total soluble solids, acidity, moisture content and total soluble sugars over the mid-parent and the better parent. Crosby *et al* (2007) observed the carotenoid content in white fleshed and dark orange-flesh melon genotype. It ranged from 0 to 40 µg/g in white to dark orange-flesh. Two genotypes 'TAM Uvalde' and 'Mission' acquired more than 36 µg/g carotenoids.

Pornsuriya *et al* (2014) observed higher heterosis for fruit sweetness (TSS-7.9° Brix) in cross Round fruit × Honda than all other crosses between Thai melon and cantaloupe cultivars. Sedera *et al* (2016) recorded highly significant positive heterosis over mid parent for number of hybrids. Cross Aswan × Fayoum showed the highest heterosis for TSS and

total sugars. Similarly, for better-parent crosses Beni Swif 1 × El Behaira 1, Aswan × El Behaira and Aswan × El Behaira 1and Aswan × Fayoum 1 showed the highest heterosis value for TSS and total sugars. Further, in a line × tester study, Duradundi *et al* (2017) generated 30 F_1 hybrid combinations. All the combinations confirmed significant heterosis over the better parent, best parent, and the commercial check for the different quality parameters.

Shashikumar *et al* (2017) observed hybrids, Arka Jeet × IIHR 121, Arka Jeet × IIHR 122, Punjab Sunehri × IIHR 190, Punjab Sunehri × IIHR 718, IIHR 681 × IIHR 121, IIHR 681 × IIHR 122 and IIHR 352 × IIHR 616 were expressing higher heterosis over the mid-parent for downy mildew resistance. Hassan *et al* (2018) reported the largest number of crosses having a desirable positive mid parent and better parent heterosis. 15, 14 and 11 crosses exhibited up to 39.09%, 112.36% and 65.31% desirable mid parent heterosis for carotenoids, ascorbic acid and TSS, respectively and 14, 13 and 9 crosses showed up to 35.93%, 107.98% and 58.82% better parent for the three traits, respectively.

2.2 Combining ability analysis

The concept of combining ability is becoming important in plant breeding. It is particularly useful to study and compare the characters of lines in hybrids combination. It provides an estimate of the combining ability effect and facilitates the selection of desirable parents and crosses for further exploitation (Nandpuri *et al* 1983). It also provides a means to understand the nature and magnitude of gene action involved in heterosis. Sprague and Tatum (1942) initially identified the terms general and specific combining ability. The general combining ability is associated with additive gene effects representing the average behaviour of parents in hybrid combination. The specific combining ability associated with non-additive genetic effects represents certain hybrid combinations which show relatively better performance than average parental lines (Mendes *et al* 2018).

2.2.1 Growth attributes

In a line × tester study, Aravindakumar *et al* (2005) found Arka Jeet among the lines and IIHR-615-5-2 among the testers were good general combiners for most of the growth parameter. Kumar *et al* (2005) observed that variance due to GCA and SCA effects represented the role of additive gene action for all the studied traits except for days to first pistillate flower opening. Line (Arka Jeet) and tester (IIHR-615-5-2) were found to be good general combiner for most of the studied traits. While cross Pusa Madhuras × IIHR-615-5-2 for days to first pistillate flower opening and Kajri × IIHR-615-5-2 for days to first fruit harvest, were identified as good specific combinations.

Tomar and Bhalala (2006) observed that three parents showing positive and significant GCA effects and found to be good general combiner for growth parameters. Parent AMM-01-18 was good general combiner for number of primary branches, parent Hara Madhu for number of nodes to first female flower, days to first fruit harvest, number of fruits per

plant and parent AMM-00-11 for days to first open female flower, number of primary branches.

Choudary *et al* (2006) revealed that most of the parents exhibited significant positive gca effect and found to be good general combiner for ancillary traits. Parent Hara Madhu and Jobner Local observed to be good general combiner for vine length, parent Ms-1 for days to first female flower, days to first fruit harvest and size of seed cavity, parent Punjab Sunehri for number of vines per plant and average weight of first three harvested fruits. Hybrids showing significant positive sca effect for growth parameters were Ms-1 × Tonk Local, Ms-1 × MHY-3, Ms-1 × Hara Madhu, Punjab Sunehri × Jobner Local, Ms-1 × Hara Madhu and Tonk Local × Durgapura Madhu. They were found to be good specific combiners.

Vashisht *et al* (2010) reported Hara Madhu was the best general combiner for TSS content and fruit shape index and Punjab Rasila was the best combiner for seed cavity ratio and flesh thickness. Among the crosses, MM-28 × IVMM-3 recorded highest SCA value for first pistillate flower opening trait.

Shahsikumar *et al* (2016) have reported that significant GCA effects of parental lines RM43 and IIHR 122 and significant SCA effects of hybrids, MS-1 × IIHR 616, RM43 × IIHR 718 and RH43 × IIHR 121 for large size of fruits. Among parental lines, IIHR 352, IIHR 190 and IIHR 122 demonstrated consistently high and negative GCA effects for the disease resistance. Among the 30 Hybrids, Arka Jeet × IIHR 121, Arka Jeet × IIHR 122, Punjab Sunehri × IIHR 190, Punjab Sunehri × IIHR 718, IIHR 681 × IIHR 121, IIHR 681 × IIHR 122 and IIHR 352 × IIHR 616 significant SCA effects for downy mildew resistance (Shashikumar *et al* 2017).

Hassan *et al* (2018) found that GCA effects of all the parental genotypes were found to be highly significant for most of the studied traits. Three crosses (P2 × P4), (P3 × P6) and (P5 × P6) exhibited significant desirable positive or negative SCA effects for cavity diameter.

Rolania and Fageria (2018) observed that parents GP-210, GP-211, GP-211, GP-141, EC-5, EC-3, EC-2, and Kesar showed greater combining ability in terms of vine length, days to first fruit harvest, small size seed cavity, and resistance to the fruit fly. The crosses Kesar × EC-2 and EC- 3 × GP-211 were superior in size of the seed cavity and resistance to the fruit fly.

2.2.2 Earliness

In a line × tester study, Dhaliwal and Lal (1996) identified W-321 among the lines and H-172 among the testers exhibiting significant GCA effect for earliness.

Shahsikumar *et al* (2016) have reported significant GCA effects of parental lines RM-43 and IIHR-122 and significant SCA effects of hybrids, MS-1 × IIHR-616, RM43 × IIHR-718 and RH43 × IIHR-121 for earliness.

Saha (2017) identified DHM-163 line showing significant GCA effect for earliness.

2.2.2 Fruit characters

2.2.2.1 Fruit length and width

Costa *et al* (2019) evaluated 41 melon genotypes of *Momordica* group, the significant positive GCA effect was shown by G-03, G-11, G-14, G-16, and G-18 for mean fruit mass, mean fruit length and mean fruit diameter. The SCA effect also play role in 30.7% of the hybrid combinations for controlling most of the characters.

2.2.2.2 Flesh and rind thickness

(Choudary *et al* 2006) observed that among all the other parents Tonk Local showed maximum gca effect for rind thickness and hybrids Jobner Local × Durgapura Madhu and Hara Madhu × Tonk Local depicted significant positive sca effect for rind thickness. The cross MHY-3 × Hara Madhu exhibited a significant positive sca effect for flesh thickness.

Sedera *et al* (2016) recorded highly significant general and specific combining ability effects which indicated the presence of both additive and non-additive types of gene action. The highly significant positive GCA effect was shown by parent Fayoum and SCA effect by cross Ananas × El Behaira 4 in controlling flesh color.

Rolania and Fageria (2018) observed that parents GP-210, GP-211, GP-211, GP-141, EC-5, EC-3, EC-2, Kesar and crosses Kesar × EC-2 and EC- 3 × GP-211 showed greater general and specific combining ability respectively, in terms of high flesh thickness and rind thickness.

Costa *et al* (2019) found significant positive GCA effect was shown by G-03, G-11, G-14, G-16, and G-18 for mean pulp thickness. The SCA effect also play role in 30.7% of the hybrid combinations for controlling most of the characters.

2.2.3 Yield and yield attributing traits

The best and significant GCA effect was recorded for parent Jam-E-Shahada and the highest significant SCA effect of cross Kavit × Bhang over better parent for the number of fruits and weight of fruit vine (Gurav *et al* 2000). Lal and Kaur (2002) observed that MS-1 and NDM-15 are good combiners among females and males for fruit yield.

Tomar and Bhalala (2006) revealed that the Parent AMM-01-18 and AMM-02-26 exhibited positive and significant GCA effects for fruit yield, number of fruits per plant, and fruit weight. The hybrids like AMM-01-18 × AMM-02-26, Hara Madhu × RM-50 and AMM-01-18 × DM-1 showed significant SCA effects for fruit yield over the environments.

Durgapuri Madhu and Tonk Local depicted high GCA effect for number of fruits and fruit yield. Among the crosses maximum sca effect were shown by Ms-1 × Punjab Sunehri and Ms-1 x Hara madhu for fruit yield and for number of fruits, Hara Madhu × Tonk Local and Ms-1 × Punjab Sunehri were best cross combinations (Choudary *et al* 2006).

Vashisht *et al* (2010) reported among parental line, Hara Madhu was the best combiner for fruit yield per vine, fruit weight and number of fruits per vine. Whereas among

crosses, MM-28 × IVMM-3 recorded highest SCA value for number of fruits per vine and fruit weight while MM-28 × NDM-21 exhibited best SCA effects for total fruit yield per vine.

Saha (2017) identified DCM-31 line showing significant GCA effect for fruit yield. Rolania and Fageria (2018) observed that parents GP-210, GP-211, GP-211, GP-141, EC-5, EC-3, EC-2, Kesar showed greater general combining ability in terms of number of fruits and fruit weight. The crosses Kesar × EC-2 and EC- 3 × GP-211 were superior in fruit weight and yield showing high sca effect.

2.2.4 Quality traits

Tomar and Bhalala (2006) found that the parents AMM-01-18 and AMM-00-11 exhibited positive and significant gca effects for moisture content, total soluble solids, acidity and total soluble sugars and parent Hara Madhu was a good combiner for acidity and total soluble sugars only. Choudary *et al* (2006) discovered that Durgapuri madhu and Tonk Local showed maximum gca effect for TSS and shelf life, respectively. Maximum sca effect was exhibited by Hara Madhu × Tonk Local and MHY-3 × Tonk Local for shelf life and Punjab Sunehri × Tank Local and Jobner Local × Tonk Local were the best cross combinations for TSS.

Sedera *et al* (2016) recorded highly significant general and specific combining ability effects which indicated the presence of both additive and non-additive types of gene action. For TSS highly significant positive GCA effect was shown by parents Sohag, Ananas El Dokki, Fayoum and Ananas. Maximum SCA effect was shown by cross Aswan × Fayoum. Similarly, for total sugars highly significant positive GCA effect was shown by parents Beni Swif, El Behaira 4, Ananas, Ananas El Dokki and Sohag1and SCA effect was shown by cross hybrid Aswan × El Behaira 1.

Shahsikumar *et al* (2016) have reported significant GCA effects of parental lines RM-43 and IIHR-122 and significant SCA effects of hybrids, MS-1 × IIHR-616, RM43 × IIHR-718 and RH43 × IIHR-121 for TSS content. Saha (2017) identified that the Hybrids, DMM-159 × Kashi Madhu, DHM-163 × DCM-31, DMM-159 × Pusa Madhuras, Pusa Madhuras × Kashi Madhu exhibited significant SCA effects for mineral and fruit quality traits.

Hassan *et al* (2018) found that GCA effect of all the parental genotypes were found to be highly significant for most of the studied traits. Five crosses (P1 × P2, P2 × P4 × P3 × P6 and (P5 × P6) exhibited significant desirable positive SCA effect for ascorbic acid content, three crosses (P2 × P4), (P3 × P6) and (P5 × P6) for carotenoids and two crosses (P2 × P4) and (P5 × P6) for TSS.

Rolania and Fageria (2018) observed that parents GP-210, GP-211, GP-211, GP-141, EC-5, EC-3, EC-2, Kesar and crosses Kesar × EC-2 and EC- 3 × GP-211 showed greater general and specific combining ability respectively, for shelf life and TSS.

2.3 Gene action

Earlier in 1900s, Hayman (1953), Jinks (1954), Dickson & Jinks (1956) showed that non-allelic interactions, as well as additive and dominance effects, play an important role in the inheritance of characters. Jinks and Jones (1958) showed that the additive genetic[d] and the additive x additive [i] and additive x dominance [j] interaction components of means estimated from the means of two parental lines (P1 and P2) and of their F_1 hybrid are functions of the degree of association (r) of alleles of like effect in the parents. Their real magnitudes and signs are therefore revealed only when the alleles of like effect are completely associated (r= 1) in the parents. Swamy *et al* (1985) observed that quality characters exhibiting high heritability and high genetic advance as percent of mean for sutures, netting, shape index, flesh thickness, average weight per fruit, total fruit yield and titrable acidity in muskmelon. High heritability along with high genetic advance as percent of mean indicates the presence of additive gene action.

In the diallel set, eight parents and twenty-eight F_1 hybrids of muskmelon, Moon *et al* (2002) notified the presence of overdominance for biochemical traits like TSS, total sugars, reducing sugars, non-reducing sugars, carotenoid, and ascorbic acid contents in fruits. Tomar and Bhalala (2006) found that the hybrid Hara Madhu × RM-50 involved parents with good × poor combiners and hybrid AMM-01- 18 × AMM-02-26 involved both parents with good combiners for fruit yield indicating the role of additive × additive type of gene action. Munshi *et al* (2006) reported predominance of non-additive genetic variance (over-dominance) and low narrow-sense heritability for characters like days to first fruit harvest, number of fruits per plant and fruit yield.

Zalapa *et al* (2006) crossed two lines USDA 846-1 and Top-Mark at two locations Arlington (AR) and Hancock (HCK) to estimate genotype × environment interactions (G × E) of melon cultivars. Both the parental lines differed significantly for average weight per fruit, fruit number and primary branch number. Additive gene effects were governing primary branch number and fruit number per plant, while dominance and epistatic genetic effects mainly controlled days to anthesis, fruit weight per plant and average weight per fruit. The environmental component of the variance was lower than genetic variance component for all traits in each location. Broad sense heritabilities were relatively high for all traits and ranged from 0.64 to 1.00. Narrow-sense heritabilities were varied from 0.62 to 0.79 for all the traits. Predominating non-additive genetic variance was observed in fifty genotypes of melon (Tomar *et al* 2008).

Barros *et al* (2011) evaluated six parents and their fifteen respective hybrids out of which four hybrids Gold Mine × Hy Mark, AF-646 x AF-1749, Meloa x Rochedo and AF-646 × Rochedo were found to be best combination. They observed that total fruit number, fruit yield, flesh firmness and TSS content were directed by additive and non-additive gene

effects, while average fruit weight, Polar diameter of fruit (cm), flesh thickness, seed cavity was governed by additive gene effects. Shamloul *et al* (2011) estimated the genetic behaviour of sweet melon (*Cucumis melo* L. var. *aegyptiacus*). Eight inbred lines were developed and crossed according to factorial mating design to generated sixteen F_1 hybrids. The additive genetic variance played an important role in the inheritance of yield and yield-related traits. The magnitudes of additive genetic variance were lower than their non-additive including dominance for all studied yield traits, except for number of male flowers per plant and fruit length. The MAGD105, MAGD106 and MAGD107 are promising lines that could be used in improvement programs.

Mohammadi *et al* (2014) reported genotype × environment interaction effects for quantitative traits of cantaloupe for 2 years. The parents Dastjerdi, Tiltorogh and Rishbaba had the highest significant positive additive effect for fruit weight. For total fruit yield the highest and significant additive effect was recorded by Rishbaba in the first year and Samsori in the second year and for TSS significant additive effect was shown by parent Savei. For late maturity Magasi had the highest additive positive effect while Dastjerdi had highest negative additive effect. Among the crosses Rishbaba × Tiltorogh, Magasi × Savei and Tiltorogh×Savei had the positive significant dominance effect for total yield, Rishbaba × Shahabadi and Tiltorogh × Savei for flesh thickness and Rishbaba × Shahabadi and Magasi × Savei crosses for TSS in both the years.

Singh and Vashisht (2015) reported that cross MM-28 × NDM-21 indicated variance due to additive gene effect was highly non-significant and variance due to dominance gene effect was significant for number of fruits per vine, fruit weight and TSS content. In cross Hara Madhu × NDM-21, variances due to additive and dominance gene effect were highly significant for number of fruits per vine, fruit weight and TSS content. It showed that contribution towards genetic variance was made by both additive genetic variance and dominance variance. In most of the crosses, Patil *et al* (2016) reported that the relative contribution of dominance gene action was higher than additive gene action identified by crossing five inbreds of muskmelon for characters, such as fruit length, fruit diameter, pulp thickness and fruit weight.

Sedera *et al* (2016) estimated that additive and dominant components of variance were highly significant, suggesting the importance of both additive and non-additive effects in the determination of flesh color, TSS% and total sugars. High broad-sense heritability and intermediate narrow sense heritability indicates the great influences of the genetic variance on the expression of flesh color, TSS and total sugar. Moreover, the non-additive genetic variance component is relatively large comparing to the additive genetic variance. Dominance genetic variation was higher than additive genetic variation identified in 46 genotypes for various yield attributing traits (Saha 2017).

Saha *et al* (2018) they found that in the diallel analysis all the characters were displaying over-dominance gene effect excluding traits (node no of first female flower, average fruit weight, first fruit harvest and total fruit yield). In all the characters dominance component of genetic variance (H_1) was higher than the additive component of genetic variance (D) indicating predominance of dominant gene action over additive gene action. The values of narrow-sense heritability were also found to be less than 50% for all the characters, the positive sign of 'F' value in most of the characters, the proportion of genes with positive and negative effects ($H_2/4H_1$) in parents was found to be less than 0.25 for all these characters, and the mean degree of dominance $(H_1/D)^{½}$ also found to be more than 1 for all the characters (except some characters) confirmed the presence of over-dominance.

Costa *et al* (2019) evaluated forty-one treatments of melon genotypes of *Momordica* group, the significant positive GCA and SCA effects showed the importance of the additive and non-additive genes effects. The additive gene action contributes the larger role in the control of most characters like mean fruit mass, mean fruit length, mean fruit diameter, fruit length/diameter ratio, fruit internal cavity and mean pulp thickness.

2.4 Correlation analysis

The concept of correlation was first presented by Galton (1889) and later this theory was expanded by Fisher (1918). Correlation analysis stipulates the nature and extent of the relationship between yield and its components. The relationship between these traits were determined by phenotypic and genotypic correlations. The phenotypic correlation tells the degree of association between two variables which are determine by genetic and environment factors. The genotypic correlation is of inheritable nature that characterizes the genetic segment of phenotypic correlation (Phuke *et al* 2017). Several researchers have previously explored the correlation between the various characters of melon like yield and yield contributing components.

Abd El-Salam *et al* (2002) showed that positive correlations between number of fruits per plant and each of average fruit weight, TSS, fruit length, total yield, and fruit flesh thickness. Yadav and Ram (2002) found positive and significant correlation among the melon genotypes. They found stem scar size, fruit equatorial diameter, flesh thickness, seed cavity size, fruit weight and seed weight all these characters were positively correlated among themselves.

Taha *et al* (2003) found a significant positive correlation of fruit weight with plant length, earliness, number of fruits per vine with number of primary branches, netting development with primary branch number, flesh thickness and TSS. They also observed negative correlation of earliness with netting development, TSS with earliness and primary branch number with stem length.

Choudhary *et al* (2004) observed that total fruit yield had a significant positive

correlation with vine length, number of vines per plant, fruit weight, fruits per plant, harvest duration, rind thickness and shelf-life. Rawhia (2004) found that flesh thickness was positively correlated with fruit diameter. Fruit weight had positive correlation with each of fruit length, fruit diameter, seed cavity diameter. They also observed negative correlation between flesh thickness and fruit seed cavity diameter.

Pandey *et al* (2005) studied genetic variability among 35 melon genotypes and reported correlation among various characters. They found that fruit yield had positive and significant correlation with fruit weight, fruit diameter, fruit length, flesh thickness and rind thickness at both genotypic and phenotypic level.

Chamnan and Kasem (2006) cited that fruit number had a highly positive correlation with fruit yield and marketable width of fruit had negative correlation with fruit length and fruit shape. Zalapa *et al* (2006) observed positive and significant phenotypic correlations between fruit number and weight per plant at both locations Arlington and Hancock. Reddy *et al* (2007) found that fruit traits of snapmelon like fruit weight, vine length, flesh thickness, fruit length, fruit diameter, first female flower node, length of fruit cavity, ascorbic acid, and maturity period was positively and significantly correlated with total fruit yield.

Tomar *et al* (2008) found that fruit weight showed positive and significant genotypic and phenotypic correlation with total fruit yield, fruit length, fruit width, flesh thickness and moisture percentage, while the negative and significant correlation was seen with TSS in muskmelon genotypes. Zalapa *et al* (2008) reported negative correlations of primary branch number and fruit weight with average fresh weight per plant and days to anthesis with early pistillate flowering and maturity.

Mehta *et al* (2009) observed that fruit yield was positively and significantly correlated with fruit weight, flesh thickness, fruit width, fruits per plant and moisture percentage while for TSS it showed significant and negative correlation, at both genotypic and phenotypic levels.

Feyzian *et al* (2009) investigated the relationship among yield components and their direct and indirect effects on the total yield of melon. They involved the Iranian melon landraces under two conditions of cultivation, pruning and non-pruning. All characteristics except for fruit number, fruit shape index and total weight of all fruits showed significant correlation under the pruning condition but traits for total weight of all fruits, fruit shape index and rind thickness showed non-significant correlation under non-pruning conditions.

Rad *et al* (2010) revealed that fruit yield had a positive and significant correlation with fruit weight and flesh diameter. Abou Kamer (2011) reported that total fruit yield was correlated with each of plant length, fruit number, and average fruit weight and found a positive correlation between total sugars and each of TSS and reducing sugars. Reddy *et al* (2013) studied that vine length, the number of primary branches per vine, fruit length, fruit

diameter, average fruit weight, number of fruits per vine, fruit cavity length, fruit cavity width, rind thickness, and seed yield had a positive correlation with fruit yield, while it had a negative correlation with the node numbers of the first pistillate flower, days to last fruit harvest, and pulp thickness

Bhimappa *et al* (2017) reported that the correlation coefficients (phenotypic and genotypic) among different quantitative traits along with fruit yield exhibited a highly significant and positive relationship with average fruit weight, fruit length, fruit width, flesh thickness and cavity length. TSS showed a highly significant and positive relationship with days to first staminate and pistillate flower opening, days to first fruit harvest after pollination, total crop duration, days from pollination to harvest, vine length, flesh thickness and negative association with node to first male flower, cavity width.

Pasha *et al* (2019) investigated the correlation between the different characters of snap melon. Traits such as node at first female flower appearance, days to first female flower opening, vine length, number of fruits per plant, fruit length, fruit diameter, seed cavity breadth, fruit flesh thickness, and fruit weight at average, had shown a significant positive correlation with total yield at both phenotypic and genotypic levels representing that any improvement in these traits will increase the yield in snap melon.

2.5 Path coefficient analysis

Path analysis was firstly suggested by Wright (1921) but was applied for the first time in plant breeding by Dewey and Lu (1959). The path coefficient analysis used to determine the direct and indirect effects of traits on fruit yield. The estimates of the correlation coefficients revealed only the relationship between yield and yield associated traits, but did not show the direct and indirect effects of different traits on fruit yield *per se*. This is because the attributes which are in association do not exist by themselves but are linked to other components (Phuke *et al* 2017).

Choudhary *et al* (2004) in the path coefficient analysis revealed that total fruit yield had positive correlation with of the studied traits and these traits exerted positive and direct effects on total fruit yield at the genotypic level. Those traits were rind thickness, TSS, the severity of downy mildew, the severity of powdery mildew and incidence of the fruit fly. In contrast, the characters like vine length, number of vines per plant, days to first female flower, harvest duration and size of seed cavity had a negative indirect effect on total fruit yield.

Reddy *et al* (2007) conducted a path analysis of snap melon in which they showed that vine length, non-reducing sugars, and total carotenoids had a high direct effect on total fruit yield. Thus, for yield advancement in snap melon direct selection for vine length, non-reducing sugars, and total carotenoids will be recommended.

Tomar *et al* (2008) found that fruit weight had a positive direct effect on fruit yield as it showed negative indirect effect through total soluble sugars and acidity percentage and

positive indirect effects through moisture percentage, total soluble solids, fruit width and flesh thickness.

Mehta *et al* (2009) showed in path analysis that the fruits per plant and moisture percentage showed highly positive direct effect and positive correlation with fruit yield.

Reddy *et al* (2013) in path analysis, at the phenotypic level average fruit weight and number of fruits per vine, had positively high direct effects on fruit yield in melon. At the genotypic level, node numbers of the first pistillate flower had a highly significant positive direct effect on fruit yield, while its relationship with fruit yield was significantly negative.

Bhimappa *et al* (2017) analysed path coefficient at genotypic level revealed that TSS had a direct positive effect and indirect effects through total crop duration, average fruit weight and negative indirect effects through days to first fruit harvest, cavity length, and days to first male flower.

Pasha *et al* (2019) revealed that the characters i.e., the node at first female flower appearance, number of fruits per plant, fruit length, fruit diameter, fruit flesh thickness, and fruit weight at average, showed a positive direct effect on grain yield at both phenotypic and genotypic levels indicating the effectiveness of direct selection, so these traits can be selected for the crop improvement program.

2.6 Screening for disease resistance

Screening of genotypes is a very essential step in detecting a resistant cultivar against the fungal infection, pathogen infestation and viral diseases. Various screening methods have been reported by many scientists and researchers to study the diseases. Muskmelon is prone to several diseases caused by fungi, bacteria, nematodes, and viruses. Diseases caused by these sources produce considerable losses in yield and fruit quality. Some of these diseases are soil-borne, seed-borne, and some are surviving on collateral hosts. The viral disease is very devastative except these all-other diseases can be managed by different chemicals like fungicides, antibiotics and nematicides. Major diseases wilt caused by (*fusarium oxysporum),* Root-knot nematodes caused by (*Meloidogyne spps)* and viral disease caused by (*Aphis spp*) are the major destructive diseases of melon. To control these losses various scientists discovered resistant sources through different breeding methods are reviewed below.

2.6.1 Fusarium wilt incidence

Burger *et al* (2003) screened genotypes for resistance to wilt caused by *Fusarium oxysporum* f sp. *melonis*. The variability of 17 susceptible genotypes to race 1 was examined at the seedling stage in growth-chamber experiments. Using four combinations of light (60 and 90 RE ma s^{-1}) and temperatures of (27 and 31°C), only light intensity showed a statistically significant effect. Disease incidence varied from 0 to 100 % in a genotype-dependent manner. Marker-assisted selection for fusarium wilt resistance breeding using CAPS and SCAR markers was compared consuming a single set of genotypes that included

24 melon accessions and breeding lines, whose genotypes regarding the Fom-2 gene were well characterized.

Perchepied and Pitrat (2004) studied the partial resistance to *F. oxysporum* f. sp. *melonis* race 1.2 by using a recombinant inbred line (RIL) population. The population is developed by single seed descent method from F_1 progeny of cross 'Isabelle' (partially resistant) x 'Vedrantis' (susceptible line). Artificial inoculation method was done with a yellowing strain (TST) and a wilting strain (D'Oleon 8) at six locations. Phenotypic correlations were greatly significant between the distinct locations and trials. The heritability of the resistance was high, varied from 0.72 to 0.96, and 4 to 14 genetic factors were assessed to confer resistance to *F. oxysporum* f. sp. *melonis* race 1.2. through this study they provide a better knowledge of the polygenic inheritance.

Herman and Perl-Treves (2007) found new source of resistance to *Fusarium oxysporum* f. sp. *melonis* race1, 2 in melon. 'line BIZ' developed at Zeraitn Gedera Ltd, Israel. The 'BIZ line' seedlings were contrasted with two susceptible genotypes, 'Line 33' and 'PI-414723' and one partially resistant genotype 'Isabelle' to observe the disease reaction at higher intensity of inoculum. BIZ line displayed almost complete resistance to race 1, 2 even at high inoculum levels of 10^6 spores $m1^{-1}$ and root wounding, suggested that such resistance is stronger than that in 'Isabelle'.

Otunouloud *et al* (2009) evaluated 32 accessions for Fom race 1, 2 resistances. They found three Japanese accessions (Kogane Nashi Makuwa, C-211 and C160), one Russian line (C-160) and two Spanish line, (C-300 and Mollerusa-7) showed high resistance level. These lines have been morphologically and molecularly characterized to prove the resistant against Fom races 0, 1 and 2. Based on the analysis, these accessions were grouped accordingly to botanical subspecies as these accessions belongs to high levels of resistance to race 1, 2.

Chikh-Rouhou *et al* (2011) found four resistance accessions to *Fusarium oxysporum* f.sp. *melonis* (*Fom*) race 1.2 namely, Portuguese accession 'BG-5384', Japanese 'Shiro Uri Okayama', 'Kogane Nashi Makuwa', and 'C-211'. These lines show high level of resistance to races 0, 1, and 2 of *Fom*, showing partial resistance to the race 1.2. The inheritance of resistance was depended on polygenes with a complex genetic control because many epistatic interactions were detected. The three epistatic effects; additivity × additivity, dominance × dominance, and dominance × additivity was present and exhibiting significant difference among each accession.

Oumouloud *et al* (2013) studied that 2 genes (Fom-1 & Fom-2) was originally discoerved in cultivar 'Doublon' and 'CM-17187'. They both had high level of resistance against Race 0 &2 and race 0 & 1, respectively.

Vashist *et al* (2015) identified a promising inbred line, namely KP_4HM-15 which was was developed through a backcross breeding method using KP-4 (locally called *Kariam Phut*)

as a donor parent and 'Hara Madhu' as a recurrent parent. The resistance genes were transfered from snapmelon (KP-4) to 'Hara Madhu'. From BC_4 generations onward, it was exposed to inbreeding and selection for desirable horticultural traits coupled with *Fusarium* wilt resistance.

Patel *et al* (2018) discovered four races of *Fusarium oxysporum* f.sp. *melonis (Fom)*, which provide resistance to *fusarium* wilt in melon accessions. *Fom*-1 and 2 governed by race (0 & 2) and race (0 & 1) respectively. *Fom*-3 and 4 also built resistance along with *fom*-1 to melon species. Resistance to these races were found in sub sp a*grestis* and sub sp *melo* cultivars.

2.6.2 Viral Disease incidence

Studies on inheritance of resistance to Cucumber green mottle mosaic virus (CGMMV) showed that resistance was governed by polygenes with recessive nature. Out of 15 crosses studied, Rajamony *et al* (1990) reported 10 crosses found to be interacting (except one Phoot × Harela) showed duplicate type of epistasis. Kachri × Phoot (R × R type) cross exhibited heterosis in F_1 and transgressive segregation in F_2 for resistance.

Several QTLs that are responsible for resistance against CMV were mapped in melon by using different CMV isolates and observed that resistance to CMV exhibited recessive and oligogenic in nature (Dogimont *et al* 2000).

Daryono *et al* (2003) screened forty melon cultivars collected from 17 Asian countries for studying resistance to Cucumber mosaic virus (CMV-B2). Artificial inoculation was done, and results were examined through enzyme-linked immunosorbent assay (ELISA). Five cultivars showed resistance to this virus (Yamatouri, Miyamauri, Mawatauri, Sanuki-shirouri, and Shinjong). To know the inheritance, pattern the resistance cultivar Yamatouri was crossed with susceptible cultivar Vakharman. In later generations, F_1, F_2 and reciprocal backcross populations it was confirmed that resistance was controlled by single dominant gene to which the symbol Creb-2 was assigned.

Sugiyama *et al* (2007) isolated genetic control of resistance to cucumber green mottle mosaic virus SH (CGMMV -SH) in melon 'Chang Bougi'. They observed from the artificially inoculated populations that all F_1 plants were susceptible to CGMMV–SH, but F_2 and backcross progeny showed resistance towards CGMMV -SH in 'Chang Bougi'. Disease resistance was dependent on two independent complementary recessive genes, which they advise to identify as cucumber green mottle mosaic virus resistance-1 (cgmmv-1) and cucumber green mottle mosaic virus resistance-2 (cgmmv-2).

Dhillon (2007) observed resistance to the colonization of *Aphis gossypii* and CMV transmission in three landraces of Indian snapmelon viz. IC 267353, IC 267384, IC 274010. Some dominant genes (Zym-1, Zym-2, Zym-3) showing resistance to ZYMV were detected in a snapmelon accession (PI 414723) from India (Pitrat and Lecoq 1984, Danin-Poleg *et al*

1997). Dhillon *et al* (2007) also identified some new resistance sources against ZYMV in Indian snapmelon landraces IC 274007 and IC 274014.

Sharma and Kang (2009) stated that Indian snapmelon landrace show some level of resistance to multiple viruses. They observed Indian snapmelon show resistance to Begomovirus and some level of tolerance to yellow disease.

McCreight *et al* (2008) observed that six introductions of melons namely, PI 124111, PI 124112, PI 179901, PI 234607, PI 313970, and PI 414723, along with one melon breeding line MR-1 show partial resistance to Cucurbit leaf crumple virus (CuLCrV) in both natural field and greenhouse tests. They noticed that genetic resistance of melons to CuLCr V was recessive because the progenies of four partially resistant entries with 'Top Mark' gave susceptible reaction against this virus.

McCreight and Wintermantel (2011) observed that Indian snapmelon landraces viz. PI 313970, Ames 20203, PI 614185, and PI 614213 show resistance to Cucurbit yellow stunting disorder virus (CYSDV). They observed resistance in PI-313970 against this virus which was recessive in nature. Germplasm of melons was screened against Cucumber mosaic virus (CMV) and Zucchini yellow mosaic virus (ZYMV) by Sharma *et al* (2014) and they found that three lines out of distinct germplasm lines show some level of resistance against these viruses.

2.6.3 Root-knot nematode incidence

Zhao *et al* (2014) used *Cucumis metulifer*, a species resistance to root-knot nematodes (*Meloidogyne* spp.), a potential rootstock for controlling RKNs in susceptible speciality melon cultivars. Two experiments were conducted, in green house and organic field. In the greenhouse experiment, honeydew melon ‘Honey Yellow’ was grafted onto *C. metulifer* and inoculated with *M. incognita* race 1 and it exhibited significantly lower gall and egg mass indices and fewer eggs compared with non- and self-grafted ‘Honey Yellow’. In a conventional and organic field experiment, honeydew melon ‘Honey Yellow’ and galia melon ‘Arava’ was used as scions. Both the cultivars exhibited significantly lower galling and reduced RKN population densities, but total and marketable fruit yields were not significantly different from non- and self-grafted plants.

Diniz *et al* (2016) aimed to evaluate the reaction of melon genotypes to *Meloidogyne enterolobii*. They evaluated 18 melon genotypes, two commercial cultivars 'Fantasy' and 'Louis', and as susceptibility control, the tomato 'Santa Cruz Kada'. The total number of eggs and juveniles in the roots (TNEJ) and the reproduction factor (RF) were determined the reaction of each genotype evaluated. The genotypes (Vendrantais, PI 140471, PI 432398, PI 420150, PI 5322830, PMR-5, PI 157082, WMR-29, Charentais Fom 1, PI 420145, C160, CNPH 01- 930, Nantais Oblong, PMR-45, PMR- 6, along with the cultivars 'Louis' and 'Fantasy') increased the initial population, categorized as susceptible, and only three

genotypes (PI 414723, AC 29, and PI 124112) did not increase the initial population and are therefore found resistant genotypes to this *M. enterolobii* nematode.

Smith *et al* (2019) evaluated the resistance to RKN (*Meloidogyne* spp.) and *reniform* (*Rotylenchulus reniformis*) nematode in rootstocks with known resistance to fusarium wilt in two season of spring 2015 and fall 2016. Six rootstocks were evaluated throughout four experiments. A nematode-susceptible interspecific hybrid [Cucurbita maxima (Duchesne) × Cucurbita moschata (Duchesne)] rootstock 'Carnivor' was included as a susceptible control in both years. Results demonstrated that several *Citrullus lanatus* var. *citroides* rootstocks ('Carolina Strongback', USVL246-FR2, USVL252-FR2, and USVL-360) and 'SP-6' exhibited resistance to plant-parasitic nematodes when compared with the susceptible control. Partial resistance was observed in USVL-482351. When compared with the control, these rootstocks also had fewer *Meloidogyne* spp. and *R. reniformis* in root tissue. They observed that rootstocks may also be available to manage both fusarium wilt and RKN in the grafted cucurbit production system.

2.7 Genetic diversity

Molecular markers have proven to be useful for the assessment of genetic diversity in several plant species. Various scientists used different molecular markers to be worked on the genetic diversity among the melon genotypes Neuhausen *et al* (1992) worked on melon's genetic diversity using restriction fragment length polymorphism (RFLP) method. Garcia *et al* (1998) managed to use random polymorphic DNA analysis (RAPD) in melons, while Amplification fragment length polymorphism (AFLP) analysis has been used by Garcia-Mas (2000). Later studies emphasized on use of simple sequence repeats as the molecular markers.

Staub *et al* (2000) have used the SSR markers to characterize forty-six melons samples belonging to two subspecies of melon, the subspecies *melo* (Cantalupensis and Inodorus) and *agrestis* (Conomon and Flexuosus). The SSR markers have some advantages over other types. In general, the SSRs have a high level of transferability to related species, and for this reason, these markers are very valuable (Varshney *et al* 2005). These simple sequences repeats can be used for performing the genome fingerprinting, for identifying the varieties/ lines, besides carrying out region-specific and high-resolution mapping, F_1 identification, seed testing, map-based gene cloning and provide complete information about gene structure and gene flow (Wang *et al* 2004).

Wanbo *et al* (2002) observed that RAPD and ISSR could be applied to detect genetic diversity among thirty-seven melon germplasm. A total of twenty-one RAPD primers and ten ISSR primers were identified showing polymorphism among the entries. Through RAPD markers 106 polymorphic bands were produced with 58.62% percentage of polymorphic bands (PPB) and mean polymorphism information content (PIC), a reflection of allele diversity and frequency was 0.47, whereas ISSR markers produced 73 polymorphic bands,

with 65.51% PPB value, and mean PIC value 0.53. Genetic similarity matrices revealed that the estimates of correlation coefficients of RAPD and ISSR were significantly correlated.

Sheng *et al* (2007) assessed genetic diversity among forty-six Chinese thin-skinned melon cultivars by using 50 simple sequence repeat (SSR) markers. Thirty of forty-eight primers amplified produced 179 bands and showed polymorphisms. The number of polymorphic markers detected within each accession was 1-8, where most of the SSR markers had an expected size of 150 bp or less. Escribano *et al* (2008) studied genetic variability of five winter muskmelon and four reference genotypes including single genotype from snake melon, using the allelic variation at 19 SSR loci. Seventy-two polymorphic bands scored which produce adequate discrimination among the accessions examined. Cluster analysis (UPGMA) resulted in a dendrogram with two major clades. Moreover, a high level of heterogeneity observed within the accessions indicates that the melons examined possess broad genetic diversity.

Monforte *et al* (2008) used a set of 18 simple sequence repeat markers to study genetic diversity in a collection of 27 melon accessions including wild and cultivated melons. The materials studied were highly polymorphic for SSRs and a total of 114 alleles were detected. Cluster analysis proposed to divide these accessions into two major groups, C. *melo* subspecies *agrestis* and *melo*. The transfer of the accession to the subspecies was generally in accord with published information, except for those related to the 'dudaim' and 'chito' cultivar groups, which, according to the observed SSR variability, should be included in subspecies *agrestis.* Based on cluster analysis, five groups of accessions were defined. The two most divergent groups include mainly accessions from the Mediterranean which form one group, and accessions from China, Japan, Korea, and India forming the other group both shared a low level of intra-accession variation due to genetic drift and inbreeding. The remaining accessions from Central Africa and India were more variable and maybe an important source of genetic variation for melon breeding.

Fernandez-Silva *et al* (2009) crossed the Spanish cultivar "Piel de Sapo" (PS) and the Korean accession PI -161375 ‘Songwang Charmi’SC using a set of near-isogenic lines (NILs) with contrasting phenotypes for fruit shape. The study found that allelic gene action for QTL inducing oblong fruit shape was dominance, whereas those inducing round fruits were additive or recessive. The most possible reason for fruit shape heterosis in this cross agrees with the dominance complementary distribution hypothesis. Tzitzikas *et al* (2009) used simple sequence repeat markers to explore genetic variability and population structure of Cypriot and Greek melon cultivars. All the SSR primers were polymorphic in nature with the total number of 81 alleles, having an average of 4.7 alleles/ locus.

Fergany *et al* (2011) presented a genetic characterization of fifty muskmelon accessions from south India. Assessment of genetic variability was done by using SSR

markers. Differences among accessions were observed in plant and fruit traits at seventeen SSR loci. Across the full set of muskmelon genotypes, total of 114 alleles was observed. Mean number of alleles/ markers was 6.8. The average polymorphic information content value was 0.544. The average observed heterozygosity for collected accessions was 0.23 whereas it was 0.13 for reference populations. Thirty-one alleles (24.2%) were present uniquely in collected genotypes and the reference individual had an identical proportion of specific alleles.

Roy *et al* (2012) reported large genetic variation within the wild melon germplasm. Diversity among forty-three wild melon genotypes and nineteen reference accessions assessed for fruit morphological traits, plant habit, and two yield-related traits by using16 simple sequence repeat markers. A total of 165 alleles were reported across the muskmelon genotypes. Mean number of alleles / simple sequence repeat locus was 10.3. The average polymorphic information content value was 0.692. Average observed heterozygosity for the wild melon genotypes was 0.51 compared with 0.17 for the reference accessions. Forty-seven alleles (34.5%) present exclusively in the wild melon genotype and reference accession had thirty-three (20%) specific alleles.

Kacar *et al* (2012) examined 81 melon genotypes and 15 reference accessions for genetic diversity by utilizing 20 SSR markers. A total of 123 alleles generated among 96 genotypes with polymorphism of 97.5%. The number of alleles identified by individual primer set varied from 2 to 12, with a mean of 6.15.

Trimech *et al* (2014) estimated the genetic diversity and associations among Tunisian melon landraces and established varieties of different varietal groups using 6 simple sequence repeat markers. All loci were polymorphic and provided a total of 56 alleles, with an average of 9.33 alleles per locus. The allelic frequencies differed according to accessions, and particular alleles were found inside many accessions. The polymorphism information content (PIC) values ranged from 0.56 to 0.86, with an average of 0.75, and the level of the genetic diversity differed according to sites.

Malik *et al* (2014) studied the genetic diversity of eighty-eight landraces melon and eight USA reference cultivar using 30 SSR markers. 77 alleles were found across the eighty-eight Indian accessions and reference cultivars. An average number of alleles/ SSR locus was 2.2. Mean Polymorphism Information Content (PIC) value was 0.57 and mean heterozygosity of 0.44. Sixteen alleles (23.8 %) were present within *momordica* accessions, and twelve alleles (17.9 %) were present in *cantalupensis* and *reticulatus* accessions of Indian origin. Twenty-five (37.3 %) alleles were present in USA reference cultivars were not observed in any of eighty-eight genotypes of the Indo-Gangetic plains of India. The eighty-eight Indian melons clustered into six groups in the NJ tree based on the variability of 30 SSR loci. The 16 *reticulatus* accessions and the eight USA reference cultivars formed a distinct group

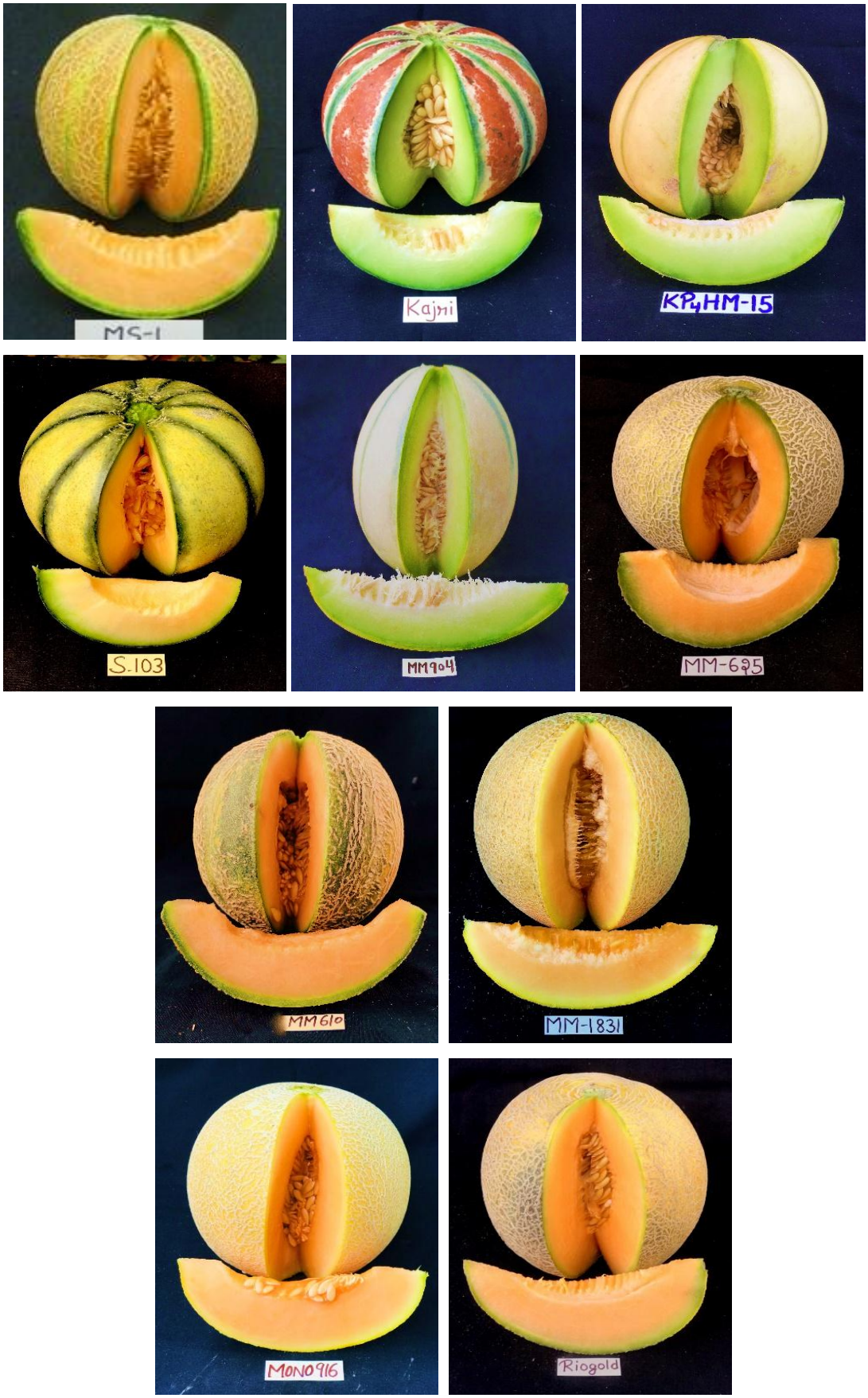


Plate 3.1: Photographs of Parental inbred lines

designated B. The 60 *cantalupensis* accessions clustered into the other four groups designated as A, C, D & E and twelve *momordica* accessions formed a distinct group designated as 'F'.

Ning *et al* (2014) observed genetic variation among 43 melon samples by using 36 SSR markers out of that 4 SSR markers (CMBR150, CMCTT144, CMBR84 and CMBR12) produced different sizes polymorphic bands between thick and thin-skinned melons for fruit maturity trait.

Henane *et al* (2015) analyzed the genetic divergence of Tunisian muskmelon genotypes (*Cucumis melo* L.) and Fakous (*Cucumis melo* var. *flexuosus*). Twelve SSR primer pairs were used for five Tunisian varieties and Fakous. Eleven simple sequence repeats were found to be polymorphic and reproducible. The number of alleles/ locus ranged from 2-3 alleles, with an average of 2.54 alleles per marker. They used Darwin 5 software to study the genetic relationship among Tunisian melon varieties and fakous. Dissimilarity coefficient varied from 0.09 to 0.82, with an average value of 0.45, which showed that varieties of muskmelon and fakous constituted an integral pool of genetic diversity.

Thirty-three SSR markers were used for molecular characteristics in 46 genotypes from 4 horticultural groups. The groups were classified into distinct clusters which were indicating the presence of a good amount of variability among the genotypes (Saha 2017).

From the review of the literature, it was inferred that heterosis breeding is beneficial for muskmelon the exploit the genetic variability among the genotypes and produce the hybrids with increased yield and quality traits. The genetic diversity indicates that SSRs can be effectively used for DNA fingerprinting of hybrids/ lines and to generate useful information for registration of breeding lines/ hybrids.

CHAPTER III

MATERIALS AND METHODS

This investigation was conducted at the Vegetable experimental farm of the Dept. of Vegetable Science, and in the molecular biology lab at School of Agricultural Biotechnology, PAU, Ludhiana (30.54° N, 75.48° E and 247 masl), India during the spring-summer season of the year 2019 and 2020. The experiment materials comprised 10 inbred lines and 45 F_1 hybrids and 3 standard checks. The description of materials and method used during the investigation are provided in this section.

Description of inbred lines in this study

1. **MS-1:** It is a male sterile line carrying *ms-1* gene. Fruits are oval round, dark green, sutured, netted, and weighing about 750 g. Fruit flesh is of medium thickness and having TSS around 11-12% (Plate 3.1).
2. **Kajri:** This inbred is resistant to Fusarium wilt and downy mildew diseases (Vashisht and Singh 2013). Fruits are flat round, reddish-brown striped skin, and non-netted with thin rind, green flesh and weighing about 800 g. Fruits having TSS around 10% with medium to large seed cavity.
3. **KP_4HM-15:** It is Fusarium wilt resistant line develop through introgression breeding utilizing snapmelon (Vashisht *et al* 2015). It also possesses tolerance to viral diseases. Fruits are oval round, green, sutured, non-netted, thin skinned and weighing about 800-1000g. Flesh is medium-thick, light green, medium juicy with TSS 12.4%. Seed cavity is medium. This line has melting texture, low shelf life and low firmness.
4. **MM Sel-103:** This line carries a good level of resistance to wilt and viral diseases. Fruits are flat round with green sutures and yellow skin, medium netted and weighing about 900 g. Fruit rind is thick, medium-thick. Flesh light orange having 10% TSS.
5. **MM-904:** Fruits are oval, light yellow, sutured, non-netted with weighing about 600g. Fruit flesh is medium-thick, highly firm, and green having TSS 15.2%.
6. **MM-625:** Fruits are round, dark golden skin, intensely netted, and weighing about 1000 g. Fruit rind and flesh are thick, orange colored, seed cavity small, high firmness, having 12% TSS.
7. **MM-610:** Fruits are oval round, yellow-green skin. Netted, and weighing about 800g. Fruit flesh is medium-thick, dark orange having TSS 13%.
8. **MM-1831:** Fruits are round, golden, intensely netted, and weighing about 1200 g. Thick orange flesh having 11% TSS.
9. **MM-916/NS-1:** Fruits are oval round, yellow skin, intensely netted and weighing about 1200g. Fruit flesh is orange and having TSS 10%.

10. **Riogold:** Fruits are oval round, green, yellow-colored, highly netted and weighing about 1200g. Fruit flesh is thick orange-colored having TSS 12%. This inbred carries resistance to race 2 of *Fusarium oxysporum* f. sp. *melonis* (Best *et al* 1991).

Procedure and Methodology of experiment

Seeds of melon genotypes were sown on 22nd February in 2019 in 100-gauge thick polythene bags of 15×10 cm size, filled with mixture of soil and farmyard manure in equal proportion. After 30 days of sowing, seedlings were transplanted in the field at a spacing of 3.0 m × 0.6 m. From 10 April 2019 onwards, the female's buds had emerged, these were hand emasculated and cross-pollinated for development of F_1 hybrids. Emasculation of hermaphrodite flowers was carried out in the evening from 5.00-7.00 PM and covered with parchment paper bags. The covered emasculated buds were pollinated with pollen from the bagged male flower of desired plant in the next morning from 6.00-8.00 AM. The pollinated flowers were protected with parchment paper bags. The bags were removed after setting of fruits. The fruits were harvested at full-slip stage and were cut-opened to collect seeds. The seeds were kept overnight in polythene bags at room temperature and were washed with tap water in mess sieves. The washed seeds were dried in partial shade for two days and were stored in paper bags at room temperature.

In 2020, harvested seeds were again sown with same procedure and eight plants of each F_1 hybrid including parents and checks were transplanted in the field with 3m x0.6 m spacing in a complete randomized block design with two replications. The observations of various quantitative and qualitative parameters on melon plants were recorded and average of four plants was used for statistical analysis.

3.1 Observations recorded

3.1.1 Growth characteristics

a) Vine length

The length of each vine was recorded at the final harvest of the crop. It was recorded from the base of the vine to the growing tip of the main branch.

b) Number of branches

At the final harvest of the crop all the primary and secondary branches on shoot of each of the vine were recorded in numbers.

c) Leaf shape

Sixty DAS leaf shape was recorded as entire (1), trilobate (2), Penta lobate (3), 3-palmately lobed (4) and 5-palmately lobed (5) (Plate 3.2).

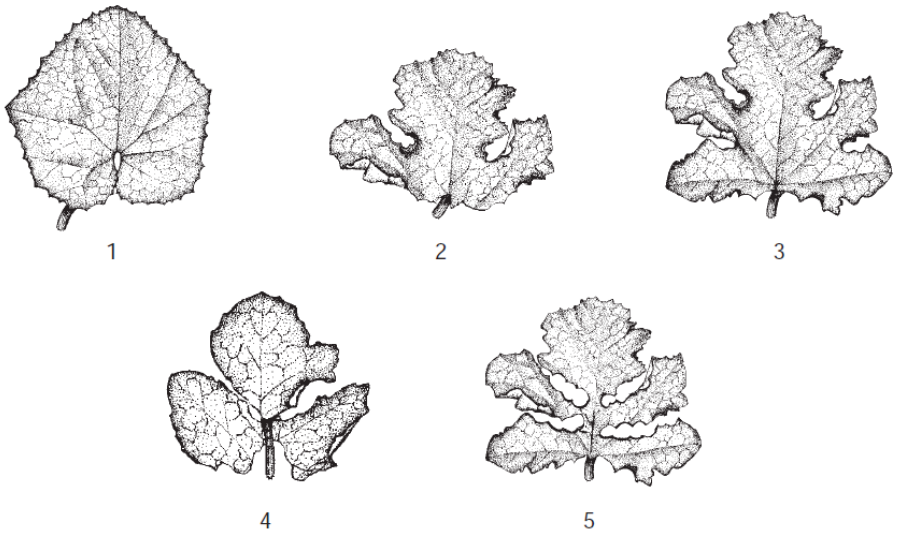


Plate 3.2: Different types of leaf shape

3.1.2 Flowering characteristics

d) Days to 1st female flower emergence

It was recorded when the first pistillate flower emerged after the date of transplanting. Data is recorded as no. of days taken to 1st hermaphrodite flower on each vine and the mean was calculated.

e) Days to 1st fruit harvest

It was recorded when the first fruit reaches full maturity after the date of nursery sowing. Data is recorded as number of days to first fruit ripens on each vine and the mean was calculated.

3.1.3 Yield traits

a) Number of fruits per plant

Total number of fruits harvested at all the pickings from each replication were added to work out the average number of fruits per plant.

b) Fruit weight

Representative fruits were harvested at full slip stage from three from each replication. The weight in (g) of each fruit was recorded and the mean was calculated after final harvest.

c) Fruit yield (t ha^{-1})

The average fruit yield per vine was calculated from the cumulative plot yield of multiple harvests. This average fruit yield was used to calculate the fruit yield in tons per hectare.

3.1.4 Fruit characters

a) Polar diameter of fruit (cm)

It was recorded as the length from flower end to stalk end. It was taken ‘with’ the help of a measurement scale.

b) Equatorial diameter of fruit (cm)

The fruits used to measure polar diameter were also used for measuring fruit width. Fruit width was recorded as the distance between two distal ends horizontally at the middle of fruit.

c) Fruit shape index

Fruit shape index (FSI) was computed by dividing polar diameter by equatorial diameter. FSI value equal to 1, less than 1 and more than 1, indicates round, depressed, and oblong fruit shape, respectively.

d) Seed cavity length (cm)

Seed cavity length of harvested fruits was recorded from flower end to stalk end with the help of measuring scale.

e) Seed cavity breadth (cm)

Seed cavity breadth was recorded as the distance between two distal ends horizontally at the middle of the fruit.

f) Fruit seed cavity area (length × breadth cm^2)

Seed cavity was measured longitudinally and equatorially with a measuring scale. The seed cavity size was calculated as a product of length and width dimensions.

g) Flesh thickness (cm)

The melon fruits were cut into two halves and flesh thickness was measured as a distance from rind to seed cavity.

h) Rind thickness(mm)

Rind thickness was recorded as pericarp thickness by using a measurement scale.

i) Shape of fruit

The fruit shape was noted at full slip stage after harvest by visual observation. It was noted as round, flat, oval, and oblong etc.

j) Fruit shape at flower end

Fruit shape at flower end was visually recorded as pointed and intermediate.

k) Size of flower end

Flower end scar size was measured as small, medium, and large size by visual observation.

l) Seed cavity type

Seed cavity type was measured as compact and loose by visual observation.

m) Fruit surface

Fruit surface was recorded as, grooved, or smooth by visual observation.

n) Fruit surface suture

Sutures on the fruit surface were recorded as, present, or absent. If present, then recorded as dark or light by visual observation

o) Fruit surface netting

Fruit surface netting was recorded as, present, or absent by visual observation.

p) Fruit rind color

Fruit rind color was visually observed, as creamy white, yellow, yellow-green, light green dark green, red, and orange.

q) Flesh color

Fruit flesh color was noted visually as creamy white, light green, light orange, orange, and dark orange.

r) Flesh texture

Flesh texture was recorded as, mealy, intermediate, or crispy by manual taste.

3.1.5 Quality traits

a) Total soluble solids (° Brix)

The TSS content of fresh juice extracted from fully ripened fruits was estimated by using a hand refractometer.

b) β-carotene (mg/100g of fresh weight)

For the β-carotene estimation 5g fresh sample was crushed in 25 ml (97%) petroleum ether with help of pestle mortar. After this 25 ml extract was transferred to a separating funnel and 25 ml distilled water was added and placed for an hour. After that, the extract was collected by removing the water and sample is collected in 50 ml flask. Petroleum ether was used to make up 50 ml final volume and OD was recorded at 452 nm. (Mc Collum 1955). The carotenoid content was calculated as µg/g of fresh weight of pulp.

c) Fruit Firmness (lb/inch^2)

Firmness of cut-fruits was estimated using hand-held penetrometer (Model ft-327, USA). The probe (11 mm) was inserted into flesh of fruits after peeling the thick skin and firmness was recorded in lb/ inch^2.

d) Ascorbic acid content (mg/100g)

Ascorbic acid content ‘was’ analyzed using a procedure as described in Heinze *et al* (1944). Take 2ml fresh extracted juice in conical flask and add mixture of MPA and acetic acid solution into it. Then titrated this whole solution against ‘standardized’ dye solution (‘dichlorophenol’ indophenol dye). Calculated ascorbic acid as:

$$\text{Ascorbic acid content} = (Y/X) \times (100/Z)$$

Where,

Y= Amount of the dye utilized in titration of “Z” vol. of fresh extracted juice

X= Amount of the dye utilized in titration of 1.0 mg of ascorbic acid

Z= ‘juice’ vol. taken for titration

e) Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)

For estimating titrable acidity, 2 ml fresh juice extracted from ripened fruits was

neutralized using N/10 sodium hydroxide solution. Indicator phenolphthalein was used for determining the end point at which it turned pink.

Titrable acidity was calculated as: $\frac{0.0064 \times a \times 100}{b}$

Where

a = Amount of sodium hydroxide used in titration in 'ml'

b = Amount of sample taken in 'ml'

f) pH

pH of fresh juice extracted from fully ripened fruits was estimated by using a pH meter.

g) Dry matter content (%)

50g fruit flesh was dried at 65° C in a glass plate for 48 hours till the constant weight attained. The weight of glass plate was again recorded and per cent dry matter was computed as

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.1.6 Screening for disease incidence

a) Reaction to Fusarium wilt disease

Muskmelon plant showing characteristic symptoms of wilting were collected from muskmelon growing areas and isolations were made from root samples. The infected plant parts (root regions) were cleaned carefully in fresh water constantly to make them free of soil particles. The ''infected root regions were sliced into 5-6 mm pieces and 'surface-sterilized' with AgCl (0.1 %) for a minute and again washed in distilled water. The root pieces were shifted aseptically to the petri dishes containing sterilized PDA media. The plates were kept at 25±2ºC for 72 hours. The most virulent isolate *Fusarium oxysporium* sp *melonis* was obtained and cultured and maintained on potato 'dextrose' agar medium (Nelson *et al* 1983), (Zink 1983). For preparation of potato dextrose (4g) medium, dissolved 4.0 g of potato dextrose broth (HIMEDIA) with 20.0 g agar per litre of the medium and maintained pH 6.2. With the addition of distilled water total volume was made to one liter. The total volume was made to 1000 ml by adding distilled water in a flask. The media was autoclaved at 15 psi for 30 min and after autoclaving media was dispensed in Petri plates and placed at room temperature until media solidified. The 5 mm bits of fusarium isolate from actively growing cultures were placed in Petri plates having media using sterilized blade and spatula. The cultures were then incubated for 7 days at $25^{\pm}2^{o}$C in an incubator for the fungal growth. After that, the cultures were stored at 4°C. The mass inoculation of *Fusarium oxysporum* was performed by culturing fusarium isolate on maize sand media using sucrose for the energy source. The maize sand flasks were prepared by, filling the flasks with the moistened seed, and then double

autoclaved at 15 psi for 60 minutes. The flasks were inoculated with 5 mm bits taken from the surface of 2-week-old cultures of *Fusarium oxysporum* using sterile inoculation needle under aseptic conditions in laminar airflow chamber. The inoculated flasks containing maize sand media were incubated at $25^{\pm}2^{o}$C for 2-3 weeks for the proper fungal growth (Plate. 3.3a).

The evaluation of F_1 crosses, parents, and check cultivars for a reaction to fusarium wilt was carried out in pro-trays at seedling stage. All the genotypes were sown in pro-trays containing autoclaved vermiculite and were inoculated at the true leaf stage (Dhingra *et al* 1995). For inoculations, maize sand medium was meshed and dissolved in double distilled water and a spore suspension of approximately 1×10^{6} spores/ml was prepared for inoculation. Spore concentration was determined using a haemocytometer and was adjusted to the appropriate density by diluting with sterile distilled water. Inoculations were done using the injection method (Plate. 3.3b) (Boyhan *et al* 2001).

The disease reaction of fusarium wilt was recorded on all the genotypes after 7, 14 and 21 days of inoculations following 0-5 scale of Zhang *et al* (2008) as given in (Table 3.1) and (Plate. 3.3c). Phenotypes with a rating of 0, 1, 2 or 3 had very little wilt development, whereas phenotypes with ratings of 4 or 5 had large wilt symptoms. The disease incidence was 'computed' by counting the no. of plants infested with fusarium wilt from each parent and their hybrids.

$$\text{Disease Incidence} = \frac{\text{No. of infected plants}}{\text{Total no. of plants}} \times 100$$

The PDI was 'computed' with given the formula:

$$\%\ \text{disease intensity (PDI)} = \frac{\text{Sum of numerical rating}}{\text{Total no. of plants assessed} \times \text{Maximum rating}} \times 100$$

Table 3.1: Fusarium wilt disease scoring (0-5)

Score	Symptoms	Reaction category
0	All alive	Highly resistance
1	One cotyledon leaf become yellow	Resistance
2	Two cotyledon leaf become yellow	Moderately resistance
3	Two cotyledon leaf and one true leaf become yellow	Moderately susceptible
4	Wilting from stem end	Susceptible
5	Dead	Highly susceptible

b) Reaction to Cucumber mosaic virus (CMV)

Sap transmission method was used for artificial inoculation of CMV. Young leaf of the identified infected plants collected from field and was crushed in phosphate buffer (Plate. 3.4a). The buffer was prepared by dissolving 8.7 g of potassium phosphate dibasic anhydrous (K_2HPO_4) + 6.8 g potassium dihydrogen phosphate (KH_2PO_4) in 500 ml of deionized water (Plate 3.4b). Maintain the pH of buffer to neutral 7.0. The evaluation of F_1 crosses, parents

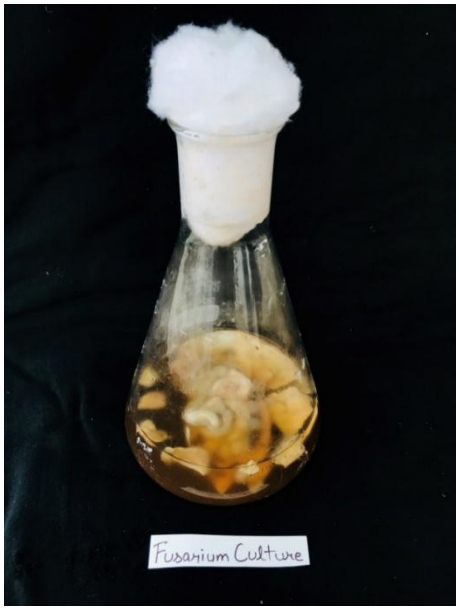


Plate 3.3a: Fusarium culture

Plate 3.3b: Inoculum suspension of fusarium culture

Plate 3.3c: Scoring of fusarium disease symptom (0 -5)

and check for a reaction to CMV were carried out under natural conditions. All the genotypes were sown in pots containing sterilized soil and were inoculated at the true leaf stage. For inoculations, the surface of leaf gets injured with celite powder and suspension made was applied on injured surface with the help of cotton. Celite powder helps to make small pores on leaf surface so that the molecules of virus get penetrate in to plant (Plate 3.4c).

After inoculation, do not watered the plants so that suspension on leaf surface remained for proper disease development. The disease reaction of CMV was recorded on all the genotypes after 7, 14 and 21 days of inoculations following 0-4 scale as given in Table 3.4. Phenotypes with a rating of 0, 1, and 2 had mild to moderate development, whereas phenotypes with ratings of 3 and 4 had severe symptoms (Table 3.2). The disease incidence was computed by counting the no. of plants affected with virus from each parent and their hybrids. The assessment of the severity of viruses was recorded according to the %age of infected plants (PPI) in each parent and their hybrids and was computed as under:

$$\text{PPI} = \frac{\text{No. of infected plants}}{\text{Total no of plants}} \times 100$$

The PDI was computed with the given formula

$$\% \text{ disease intensity (PDI)} = \frac{\text{Sum of numerical rating}}{\text{Total no. of plants assessed x Maximum rating}} \times 100$$

Table 3.2: Viral disease scoring (0-3)

Score	Symptoms	Reaction category
0	No Symptoms	Immune
1	No stunting or leaf deformity	Mild
2	Stunting approximately 3/4th of normal size, leaf puckering	Moderate
3	Plant stunted between ½-1/4th of normal size, leaf deformed	Severe
4	Plant severely stunted, severe mosaic	Very severe

c) Reaction to Root-knot nematode

The fresh pots were filled with sterilized soil and seeds of all the genotypes were sown in two replications. After 30 days when the roots were properly established this is the proper stage for inoculation. The brinjal roots infested with *Meloidogyne incognita* nematode having egg masses or galls were collected from the infested fields. After collecting the infested roots, it was chopped with the help of *khurpa* so that the egg masses separated in the soil. Then this infested soil was manually added to the pots near the root zone of each plant. After that apply irrigation to the pots. Take care of plants during the period of the experiment by applying water regularly and hand hoeing to remove the weeds so that the roots of actual plant develop properly. After 15-20 days, the galls developed in the roots of plants. To check the gall development, soil near to plant was smoothly removed from 4-5 selected pots and

after checking soil was again placed back to the pots. Forty-five days after inoculation the plants were carefully uprooted by lifting the roots, washed under running water to get it free of soil particles and placed on the black sheet for counting galls. Based on the number of galls per root, it was graded using 0-5 scale (Table.3.3) by Taylor and Sasser (1978) as given below:

Table 3.3: Root-know nematode disease scoring (0-5 scale)

Rating Index	Number of Galls	Category index based on RGI
0	No galls or egg masses	Immune
1	1-2 galls or egg masses	Resistant
2	3-10 galls or egg masses	Moderately Resistant
3	11-30 galls or egg masses	Moderately Susceptible
4	31-100 galls or egg masses	Susceptible
5	More than 100 galls or egg masses	Highly susceptible

According to the scoring of number of galls in each plot genotype and was calculated as under

The formula for calculating root galling index (RGI) was:

$$RGI = \frac{\text{Sum of grades of all the plants observed}}{\text{Total number of plants observed}}$$

3.2 Statistical analysis

3.2.1 ANOVA

The average values of 10 parents and 45 F_1 cross combinations from each replication were utilized for ANOVA. The ANOVA for 'RBD was computed using following methods.

$$Yijk = m + gij + bk + eijk$$

Where,

Yijk = phenotypic value of the ijth genotype grown in the k^{th} replication

m = population mean

gij= effect of the ij^{th} genotype, where i, j, = 1.....g

bk = effect of the k^{th} replication, where k = 1.....r

eijk= environmental effect

Table 3.4: ANOVA based components of variance

Source of variance	df	SS	MSS		F value
Replication	r-1	Sr=∑x2/g-(∑x)2/N	Mr = Sr/ r-1	Σe + gσr	Mr/Me
Genotypes	g -1	Sg = ∑g2/r-(∑x)2/N	Mg = Sg / g-1	Σe + rσg	Mg/Me
Error	(r-1)(g-1)	Se = St – Sr - Sg	Me = Se / (r-1) (g-1)	σe	
Total	gr-1	St			

Plate 3.4a: Infected leaves collected from infected plant and crushed in phosphate buffer

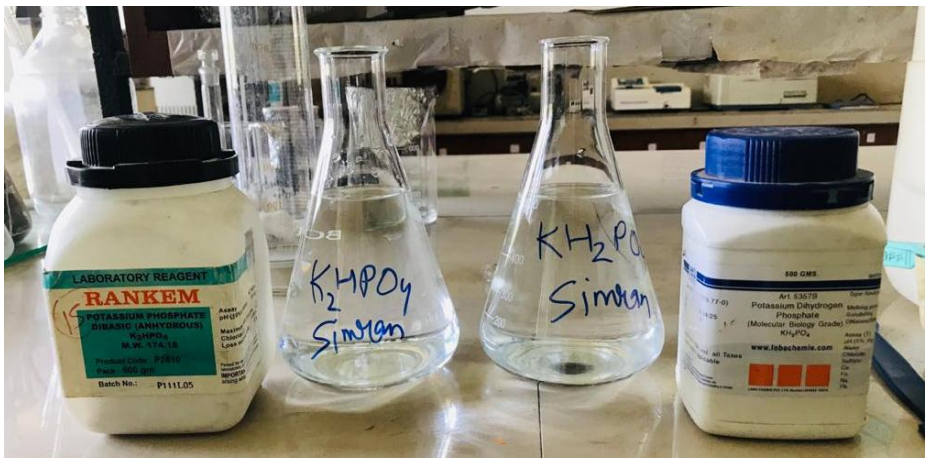


Plate 3.4b: Phosphate buffer suspension

Plate 3.4c: Sap transmission method of inoculation of virus disease

Where,

r = number of replications

g = number of genotypes

N = total number of observations

Sr = replication sum of squares

Sg =genotype sum of squares

Se= error sum of squares

St = total sum of squares

σ_r = replication variance

σ_g = genotypic variance

σ_e = error variance

The genotypic variance was tested against error variance by 'F' test for (g-1) and (r-1) (g-1) degree of freedom. Similarly, the replication variance was tested against error variance for (r-1) and (r-1) (g-1) degree of freedom.

The standard error of difference between the genotypic means is based on r replications. It was estimated as follows:

$$SD\ (d) = \pm \quad \sqrt{2M\ e\ /r}$$

Least significance difference (LSD) = SE (d) x $t_{(r-1)\,(g-1)}$ at 5% level of significance.

3.2.2 Combining ability analysis

Diallel tables were assembled from progeny means, obtained on an average of two replications for parents and their F_1 progenies. The data were 'subjected' to analysis for general and specific combining ability variance effects and components analysis. The experimental data were subjected to BMM computer software programme (Singh, 2000). The general combining ability and the specific combining ability analysis was carried out by Method II (parents and one set of F_1's were included 'but' not reciprocal F_1's) and Model I (Fixed effect model) as suggested by Griffing (1956). The analysis of variance for combining ability analysis was depend on the succeeding mathematical tools:

$$P_{ijk} = \mu + g_i + g_j + s_{ij} + r_k + e_{ijk}$$

Where,

Ij = 1…p (number of parents)

k = 1…r (number of blocks or replication)

P_{ijk} = phenotype of ijk^{th} observation

μ = population means

g_i (or g_j) = GCA of i^{th} or j^{th} parent

s_{ij} = specific combining ability of the cross between i^{th} female and j^{th} male parent

r_k = effect of k^{th} replication

e_{ijk} = the environmental effect particular to the ijkth observation

Based on 'this' model, the following are the components of variance

Table 3.5: Analysis of variance for combining ability

Source of variation	Df	Sum of Squares	Mean sum of squares	Expected mean sum of squares
GCA	p-1	Sg	MSg = Sg/p-1	$\sigma^2 + (p+2)\ (1/p-1)\ \sum igi^2$
SCA	P(p-1)/2	Ss	MSs = Ss/[p(p-1)/2]	$\sigma e^2 + 2[1/p(1/p-1)]\ \sum i\sum jSij^2$
Error	(r-1)(g-1)	Se	MSe	$\sigma^2 e$

Where,

Sg = 1/ p+2[Σi (xi + xii)2 - (4/p) x2..]

Ss = Σi < Σj x2ij – 1/ p+2 Σi (xi + xii)2 + 2/ (p+1) (p+2) x2..

M1 = Me/b

Where, b is the number of 'replications' and Me is error mean squares from ANOVA Table-I.

Expectations of combining ability variances

The estimated and were worked out as follows

ó²g = 1/(p+2) {Mg-Ms}

ó²s = Ms - Me'

Estimation of general and specific combining ability effects

The effects were estimated as follows:

Population mean (μ) = 2/(p+1) x.

GCA effects of ith parent (gi) = 1/ p+2 (xi. + xii – 2/p x.)

SCA effects of ijth cross (sij) =xij – 1/p+2 (xi. +xii+xj.+xjj)+ 2/ (p+1)(p+2)x..

Where,

p = number of parents

gi = GCA effect of ith parent

sij = SCA effects of cross involving ith and jth parents

xi = total of array involving ith parent

xj = total of array involving jth parent

xii = parental 'value' of ith parent

xjj = parental value of jth parent, and

x… = total of all p (p+1)/2 items in the diallel table.

Standard error (SE) estimation

The standard error of difference 'between' the two estimates was computed from the following formulas:

$$\text{SE for GCA effects} = \frac{\sqrt{(p-1)}}{(p+1)(p+2)}\sigma^2 e$$

$$\text{SE for SCA effects} = \frac{\sqrt{(p2+p+2)}}{(p+1)(p+2)}\sigma^2 e$$

Critical difference (CD) of the estimate

Critical differences were estimated by multiplying the 'corresponding' SE of difference with the table value 't' at the error degree of freedom 'at' both 5% and 1% level of 'significance'.

3.2.3 Estimation of heterosis

Heterosis was determined as a proportion of F_1 appearance in the desirable direction over a better parent and standard check was calculated 'for' every parameter using the following formulas below:

3.2.3.1 Heterobeltiosis (%)

$$\% \text{ heterosis over top/better parent (BP)} = \frac{F1 - BP}{BP} \times 100$$

3.2.3.2 Standard heterosis (%)

$$\text{Per cent heterosis over check/standard parent (SC)} = \frac{F1 - SC}{SC} \times 100$$

Where,

F_1 = Mean value of the F_1

MP = Mean performance of parents

BP = Mean performance of better parent

SC = Mean performance of standard check

Test of significance

The heterosis was tested by least significant difference as below at 5 % and 1 % level of significance for error degree of freedom.

L.S.D. for BP = 2EMS/r × t value error at d. f.

Where,

EMS = error mean sums of squares

r = number of replications

t = t value at 5% and 1% level of significance for error d.f.

3.2.4 Study of inheritance of different characters

Hayman (1954) proposed genetic parameters for estimation.

$D = V_{0L0} - E$

$H_1 = V_{0L0} - 4\,W_{0L01} - 4\,V_{1L1} - (3n-2)\,E/n$

$H_2 = 4\,V_{1L1} - 4\,V_{0L1} - 2E$

$F = 2\,V_{0L0} - 4\,W_{0L01} - 2(n-2)\,E/n$

$h^2 = 4\,(ML_1 - ML_0)^2 - 4(n-1)\,E/n^2$

Where,

D = additive effects of genes expected for variance components

H_1 = dominance' effects of genes expected for variance components

H_2 = non-additive effects of genes correlated for gene distribution expected for variance components

F = covariance of additive and non- additive gene effects in all the arrays

E-M'$_e$ = environmental or 'non-heritable' distinction correlated with an individual mean and its calculated by dividing the error mean squares of the design analysis by the number of replications

h^2= overall dominance' effects' of the heterosis loci accuracy of estimates of genetic parameters

W_{0L01} = covariance between the mean of inbred and F_1 hybrids

ML_1= means of all $F_{1's}$

ML_0 = mean of parents

V_{1L1} = means of 'array variance

V_{0L1}= variance of means of arrays

V_{0L0} = variance of parents

To assess the S.E of these genetic parameters following equations were utilized.

$$\text{Var D} = S^2 \frac{(n5+n4)}{n5}$$

$$\text{Var F} = S^2 \frac{4n5++20n4-16n3+16n2}{n5}$$

$$\text{Var } H_1 = S^2 \frac{n5+41n4-12n3+n2}{n5}$$

$$\text{Var } H_2 = \frac{S2}{n5}(36n4)$$

$$\text{Var E} = \frac{S2\,(n4)}{n5}$$

$$\text{Var } h^2 = \frac{S2}{n5}(16n4+16n2-32n+16)$$

Where,

S^2 = ½ Var (Wr-Vr)

N = No. of parents included in the diallel for S. E's were computed by taking the square root of these equations.

For significant genetic parameters some estimates, and ratios were calculated as following

1. **$(H_1/D)^{1/2}$**: A weighed calculate of dominance of each locus. It indicates the full dominance if the value is equal to 1, overdominance if the value is more than 1 and shows partial dominance if the value is less than 1.
2. **$H_2/4H_1$:** Provides the proportion of positive alleles (u) and negative alleles (v) and u + v =1. The maximum value of $H_2/4H_1$ will be 0.25 (when u =v= ½). It represents the symmetry at the loci (exhibiting dominance) if the value is near to 0.25, if not then genes are asymmetrically distributed.

3. **(4DH1)1/2+ F/(4DH1)1/2-F:** This represents the proportion of total number of dominants genes to recessive genes in all parents. The equality between the no. of dominant and recessive alleles of parent only if the proportion is near to unity. This is essential result of u = v = ½.
4. **h^2/ H_2:** Number of actual factors which regulate the character and exhibit dominance or number of gene blocks exhibiting dominance.

If the components were significant then these proportions are calculated and 'interpreted'.

3.2.5 Correlations

Pearsons (1930) gave this formula to understand simple correlation between two or more different characters of the fruit.

$$r = \frac{\sigma xy}{n\sigma \times \sigma y}$$

Where,

x = (X-X)

y = (Y-Y)

σ x = standard deviation of X series and is equal to $\sigma x^2/n$

σ y = standard deviation of Y series and is equal to $\sigma y^2/n$

n = number of pairs of X and Y observed.

3.2.6 Path coefficient analysis

Path co-efficient is a 'standardized' partial regression coefficient which measures the direct and indirect effects of one variable on the other (Wright 1921) and allow to divide the total correlation coefficient 'between' two variables into direct and indirect factors. Dewey and Lu (1959) calculated the direct and indirect effects at both phenotypic and genotypic levels.

Following equations were created and resolved for assessing the different direct and indirect effects.

Ry_1= Py1 + Py2.r12+ Py3.r13 + ……. Pyn.r_1n

Ry_2= Py1.r_{12}+ Py_2+ Py_3. r_{23} + …….. Pyn.r_2n

Ry_3 = Py_3.r_{13}+Py_2.r_{23}+Py_{1+}..... Pyn.r_3n

Ryn= Py_2.rn_{12} + Py_2 +Py3.rn13 + ……. Pyn

Where,

Ry_1 = Correlation between first character (independent) and y (dependent character)

Py_1 = Direct effect of first character (independent) and y (dependent character)

Py_1.r_1 …n = Independent effect of first character on y (dependent character)

Residual effects:

The residual effects were calculated as follows:

Residual factor (X) Pxy = $(1-R^2)1/2$

Where,

$R^2 = Py_1ry_1 + Py_2.ry_2 + \ldots\ldots\ldots\ldots Pyn.ryn$

3.3 Experiment 2: Molecular characterization of muskmelon genotypes using microsatellite markers

a) Genomic DNA extraction

Firstly, the fresh young leaves from the field were collected from 15-20 days old seedlings of each melon genotype. Then the collected leaves were cleaned with ethanol. The 100gm leaves sample is sufficient for DNA extraction. DNA was extracted with help of standard Cetyl Trimethyl Ammonium Bromide (CTAB) procedure which was given by Doyle and Doyle (1990) (Table 3.6) with some changes. For getting the high-quality genomic DNA, the treatment of polyvinyl pyrrolidone was done to remove the polyphenols, which interrupted the DNA in later stages. Following the steps of DNA extraction and storage:

1. Leaf samples were crushed into the liquid nitrogen to form fine powder with the help of pestle and mortar.
2. Then the fine powder of leaf samples was transferred into 2 ml centrifuge tubes and add 800 µl of pre-heated (65˚C) CTAB buffer and mixed thoroughly.
3. After extraction, the tubes were incubated in the water bath for one hour at the temperature (65˚C).
4. Collect the tubes from the water bath and add the mixture of 800 µl of chloroform and iso-amyl alcohol (24:1 v/v) and place these sample on shaker for 40-45 min.
5. After that, the mixture was centrifuged for 10 minutes at 15000rpm.
6. Then the supernatant (which contain DNA) was carefully transferred into the 1.5 ml tubes.
7. Add 400-500 µl chilled isopropanol and mix it well, then put it in the -20° C refrigerator for 2 hours then again centrifuged these chilled mixtures at 10000 rpm for 10 min for precipitation of nucleic acid.
8. After the completion of the centrifugation process, the supernatant was removed by inverting the tubes and genomic DNA pellet was reserved.
9. Then the DNA pellet was washed with 300 µl of ethanol 70% for 2-3 times with the help of centrifuged for 3 min. at 10000 rpm.
10. At last, the pellet of genomic DNA was dried at room temperature and dissolved int 100 µl TE buffer and store DNA in the refrigerator.

b) Quantification of genomic DNA

To know the exact concentration of DNA the quantification was done using Thermo Scientific NanoDrop™ 1000 Spectrophotometer. The procedure for performing the

experiment was elaborated by Desjardins and Conklin (2010). The concentration of DNA was approximate by the absorbance of light at 260 and 280nm wavelength and measured in ng/µl. The 260/280 ratio varies from 1.8 - 2.2 for good 'quality DNA' samples.

c) Estimation of quality of genomic DNA

Purity of isolated genomic DNA was estimated with agarose gel electrophoresis method. Agrose gel electrophoresis experiment was performed as described by Voytas (2000). The DNA samples were loaded into the gel in which they produce different size fragment based on their weight. The gel separates the DNA fragments from 0.5 to 25kb. The quality of DNA was estimated based on the weight of the molecular band or DNA fragment size. The high weight DNA band considered as good quality DNA, otherwise the lower weight DNA fragment produced smear bands, which is identified as poor-quality DNA.

d) PCR amplification

Seventy SSR markers amplified DNA through polymerase chain reaction. PCR product was prepared with eight components shown in Table: 3.7. PCR profile given initial denaturation at temperature of 94°C for 4 minutes and later thirty-five cycles each of with denaturation at temperature of 94°C for 1 minute, marker annealing at temperature of 48-57°C for 1minute and marker extension at temperature of 72 °C for 1 minute. The last step of extension completed at temperature of 72°C for 7 minutes (Table: 3.8). For the optimization of reaction conditions, annealing temperature get modified for the individual marker. Before the analysis polymerase chain reaction products (PCR) stored at a temperature of 4°C. All the polymerase chain reaction runs in duplicate. Amplified DNA fragments separated on a 6% polyacrylamide gel.

Table 3.6: Composition of CTAB buffer (100 ml)

Component	Quantity	Final concentration
1M Tris, pH-8.0	20.0 ml	100 mM
5M NaCl	28.0 ml	1.4 M
0.5M EDTA	4.0 ml	20 mM
10% CTAB	20.0 ml	2.0%
Sodium bisulphate	0.5 g	0.5%
Mercaptoethanol	1.0 g	1.0%
dd H2O	28.0 ml	-

Table 3.7: Polymerase chain reaction (PCR) mixture

Component	Stock conc.	Final conc.	Volume
DNA sample	25.0 g	50.0 ng	3.5
Polymerase chain reaction buffer	5X	1.0X	4.0
MgCl2	25.0 mM	1.5 mM	1.2
dNTP mix	10.0 mM	0.5 mM	4.0
Forward marker	5.0 mM	0.25 mM	1.0
Reverse marker	5.0 mM	0.25 mM	1.0
Taq polymerase	5 units	1 unit	0.2
Nuclease free water		5.1	
Total		20.0	

Table 3.8: Profile for Polymerase chain reaction (PCR)

Step No.	Cycling conditions	Temperature and Time
1st	Initial Denaturation	94ºC for 4 minutes
2nd	Denaturation	94 ºC for 1 minute
3rd	Annealing	46-60ºC for 1minute
4th	Extension	72 ºC for 2 minutes
5th	Go to 2nd	35 cycles
6th	Final extension	72 ºC for 7 minute
7th	Hold	4 ºC

Table 3.9: Composition of 6% poly acrylamide gel preparation

Components	Concentration	Quantity
Acrylamide bis-acrylamide solution	40.00%*	22.5ml
TBE	10X	7.5ml
Ammonium persulphate in 20 ml of ddH_2O	0.07%(w/v)	0.105g
TEMED	0.08%(w/v)	120µl
Double distilled water (ddH_2O)	-	99.88ml
Total	**6%**	**150ml**

***Preparation 40% acrylamide bis-acrylamide solution:** In case to make a solution of 100 ml, 38.0g acrylamide and 2.0g bis-acrylamide were dissolved in 60ml ddH_2O and the final volume will result into 100 ml of solution.

Preparation of 6% poly acrylamide gel

1. Clean the two glass plates and spacers thoroughly with water and sterilized with 70% ethanol. Then assemble the glass plates with spacer with gas cut rubber and tighten with clips to make sure that solution should not get leak.
2. Prepare the gel solution with the ingredient mentioned in (Table 3.9) and immediately pour between two plates and insert the combs into the gel. Carefully pour the gel solution so that the air bubbles will not be formed.
3. Then allow the acrylamide to polymerize for 45-60 minutes at room temperature.
4. After polymerization is complete, remove clips and gas cut from the plates and carefully place these plates into the into Hoefer gel box.
5. Add ethidium bromide of concentration 10 mg /ml to lower tank and start the pre run electrophoresis so that gel gets stained. Load the amplified product into the wells using a micropipette.
6. Run the gel until the marker dyes have travelled the desired distance. Turn off the electric power and the gel was then visualized under UV transilluminator.

e) Microsatellite markers

For the assessment of genetic variability in melon genotypes, 121 SSR markers were selected. These primer pairs were nicely dispersed and extend over all 12 chromosomes of muskmelon selected from http://cucurbitgenomics.org/pub/cucurbit/marker/**.** Following markers were manufactured from Integrated DNA Technologies Canada for in vitro DNA amplification. Below list of markers used for evaluation, identification of genetic variability and detection of parental polymorphism presented in Table 3.10.

f) Recording of SSR alleles

In each of the genotype, observations recorded in the binary format. Simple sequence repeat alleles were recorded for absence (0) and presence (1) of the band. Those bands considered as missing (9) which were difficult to score or diffused. Consistently produced and well-resolved fragments obtained through amplification were considered and scored manually. In each accession unique or specific alleles along with the total alleles were also identified.

g) Statistical analysis

Polymorphic information content values were estimated by using the formula given by Anderson *et al* (1993) which provides an estimation of discriminatory locus or loci power. PIC values reflected the relative frequencies of alleles, with number of alleles.

$$PIC = \sum_{i=1}^{n} (Pij)2$$

Here,

Pij is the frequency of j^{th} allele in i^{th} marker and summation extends to "n" pattern.

Table 3.10: Microsatellite markers used in diversity analysis

S. No.	Marker Name	Forward Primer (5'-3')	Reverse Primer (5'-3')	Annealing Temp. (°C)
1	**CMTTCN273**	ATGACCATGATGACTCGC	CTCCAAATAAACGCAAAG	51
2	**DE1256**	GCTCCAAAGTCAAAACACC	TTGAGACCCAGAAGGAGAG	44
3	**DM0300**	CATTATTGAAGTTAGGTCCC	GGGGGTTGAGTTAGAAAAG	52
4	**DM0803**	CCTTTGAAGTGAATGTTTCC	CTCCTTCCATTTAACTTGAAC	52
5	**DE1374**	CGTGTTTCGTTCCTACACC	CACAATCACACAACTCAAAAAG	54
6	**TJ27**	AAGCGGAACAAGCTCATCTC	CAAAAGCATCAATTGCTTGAA	53
7	**DE1337**	CTTCATCTTCTCGCAGAGC	ATAGACCTAGTCGCCCTCC	56
8	**DM0060**	AAAACAGAGGCAGGAAATC	TTTGTGGGATAAGAATTGC	49
9	**CMMS35_3**	CGGAGAAGAAGGAAGGGTTTTAAGA	ATTCGTAGTTCATACTCTCTTTCTC	59
10	**CMCTN4**	AAAACAAAAGCTCTCCACGA	CTTTCCTTTATTATGCCTACG	52
11	**DE1177**	CTTCCGCAGTTAAAACAGG	GAGCCTGTTTCGTTCACTC	54
12	**DE2033**	AGCTTTGAGAACAAGCCAC	CATCAAAATTAACTTCATGC	50
13	**DM0298**	GTTCGACGTTTACTCATCC	AGTGAAAGATGGGTGCTTC	53
14	**CMBR120**	CTGGCCCCCTCCTAAACTAA	CAAAAAGCATCAAAATGGTTG	54
15	**CMAAGN283**	GCAACAAAGAAGAAGAAG	GGAGAAGAAATTGGAAACG	49
16	**CMCGGN210**	GTCAGCTCCCTTCAAAGTC	GTCTAGTGGGCGTTGTTG	54
17	**CMBR066**	TCAAGCAAAAACCATAATCAGAA	TCCCTTTTCATCATTTCTCTTCA	52
18	**CMCTTN179**	CCCACCATGAATTTCCTC	CTTGAATTCCTTGGAGACG	52
19	**CMGCTN187**	GTCTACTCTCTGCCTTTCAAC	TAATGCCTCTATCTTCTCG	53
20	**DE1329**	AATGCCACCTTTTTACTCATC	AAACCAAACTGATTTCCCC	51

S. No.	Marker Name	Forward Primer (5'-3')	Reverse Primer (5'-3')	Annealing Temp. (°C)
21	**DE1630**	ACAGATGGTTGCGAAAAAG	TCAATCTGGAGAGTGGGAC	53
22	**DE1187**	CACTCCTTTTCCGTTTCAC	GAAAAGCAGGGATCTAGGG	54
23	**CSWCT10**	AGATCGGAATTGAAAAAG	AAAGGGGCTTCCTCTCTA	48
24	**DE1239**	TTTTCGTCCAACATCAACC	TTTTCGGGTTGATGAAATC	49
25	**CMBR026**	CCAAAAGAAAAACCAAACGA	ATCACAAGCCTTTGCACTCA	51
26	**CMBR023**	TTTAACCCCAGCAGATGACC	CAACGTTATGGGGATGAAGG	55
27	**DE1462**	TGATTCCCGTTCTTGAGTC	AAATTCACATTATCCATAAAAGG	51
28	**DM0487**	TTTCCGTTTGGTTAATTTG	AGAAGAATAGAGAAGCGCC	49
29	**TJ125**	GGAAAACGCAAAATCAGTGAG	CTGAACGTGGACGACATTTTT	54
30	**DE1753**	CGCTTCAAGATTAAGGGAG	TTCGCTGATTCCTTTCTTC	52
31	**DM0854**	GCACCCAAAATTGTAATGG	AGAAGGGATCAAAGTTAATATCAC	52
32	**DM0369**	AGAGCTAAAGGAGAGGCAG	AAATAGGGTGAAGAATACGC	53
33	**CSCCT571**	CCTTTCTGCTGTTTCTTCTTC	GAAGGAAGGAGTGAGGGGAAG	57
34	**CMTTTGN20**	CCATTCATTAGCTTTCCTC	GCCATTGAAACTCTGAAAC	50
35	**DM0551**	CTTTCTAGCTAATTCCCGC	TTATCGAGTATTTGGCGAG	51
36	**DM0055**	GATGAAGCTTTGGAGGATAC	CAAATGAGGAATCTGAGTTTAG	53
37	**CMBR106**	GTACCTCCGCCGTTGATCT	TGAGATAATAAGAAATCCAACCCA	55
38	**CMTTCN270**	CAGTGTTAATTCCTCTCTTC	GAGATGACTGCGATGTAAG	52
39	**DM0107**	GCTTTTGTTGATTTGTTGG	TGTAGATGAAGTAATTTGTATTTG	49
40	**CMTC168**	ATCATTGGATGTGGGATTCTC	ACAGATGGATGAAACCTTAGG	54
41	**CMGAN59**	CCAAATATTTGTTGAGAGAG	CCCTTATTTCAGCCAATTTC	50

S. No.	Marker Name	Forward Primer (5'-3')	Reverse Primer (5'-3')	Annealing Temp. (°C)
42	**DM0934**	TGTTAGCTGTACTGCCACG	AAAGTTAAATTTGGTTATGTCCC	53
43	**CMMS2_3**	ATCACCCACCCCACCACTGCCAAAA	CCTTGAAAAACCACCAACATAACAC	54
44	**DE1279**	TAAACCTCACCCCAAAAAC	AGGATGAGGGTGGAAAGAG	53
45	**DE1840**	TGAAAGAAAGGTGACCGAC	ATGATTCAATTTCGGGTTG	50
46	**DE1557**	CAAAGACATAAGCCCGATG	AAAAGAAAGATACAAGTTAGGGC	53
47	**DE1354**	AGAGAATTTGGAATTCGGC	CGTTAAAATTCCCAACGG	50
48	**DM0454**	GCCAATACAAAACTGGTG	TCCGCTTAAACTAAACTCC	48
49	**DM0561**	AGGTTGGTTACCTGGAGTC	CTCCCTTCCCTAGAACAAC	55
50	**DM0214**	TTCTCCTGAGGTCACATTC	TTTGTTCAAGGGATGCTAC	51
51	**CMBR123**	TCCGAAGTAAACATCAAAGACA	GGTCAGTCAAGATAGTTACGGTTG	56
52	**DM0159**	TTATTGACGAAATGAGCTG	TTTGTATTTTTGGAAAGGG	47
53	**DE1875**	AACGTACAAAATGTACAAAACAC	ACCGTTGGATTGCATTAAC	51
54	**DE1345**	GACTGGTTCAGCTGATAAGG	CTAAGAGGGCTTTGACACG	55
55	**DM0550**	AGTTAGGGCAACTCTCCTC	TTCTTTCCCTTTGAAATCC	51
56	**CMCTN85**	TGATGTGTCTGGCAAGAACC	GGTAAGAAACTTGGCAGTTGC	56
57	**CSCT335**	CCTTCACTTCCATCTTCATC	CGGTCCTTCATTTCATAGAC	53
58	**CMTCN41**	CCCCAAGATTCGTATTAATC	TGGTAGTAGAGATGATATAC	51
59	**DM0749**	TTTTTCCCCTAACATCATTC	TTTTCTTTTGTCTTAGCGG	49
60	**DE1487**	TCTAAAATCCCAAAACCCC	AAAACCCAATAAGGATCGG	50
61	**DM0145**	ATCTGAGGTTGAAGCAAAG	GTCGAAGATATTGTCAGGC	51
62	**DE1585**	GCACTGTGAAACACTCACAC	AAAGCGTAAGAGCAACACG	54

S. No.	Marker Name	Forward Primer (5'-3')	Reverse Primer (5'-3')	Annealing Temp. (°C)
63	**DM0104**	TCTTGGACACATGGAAGTC	CGAGATGCACATAAACTTTC	51
64	**CMTAAN87**	TGACATCAGTCTTTGGGAGATC	GCAGTCAGGATAATATGGTTGG	55
65	**DE1181**	ATCCCGCAAATTAAAAATG	AAAAACAAAAATTGCAGCC	46
66	**DE1836**	GTTTCAGGGACAGATGTGG	CCTTGATTCTATGTAGGCTGG	55
67	**DE1378**	TGTTGTTCTTCATTGCGAC	ACTCTGTACATTGCCCAAC	51
68	**DE1083**	TATGACCAATTGGAGAATG	GATACCGAGAAAAAGCTTCC	51
69	**CMGA15**	CGGCAAGACGATTGGCAGC	ATCACCGTAGCGAAGCACC	56
70	**DM0024**	AAGGCCAAGAGATAATAGTG	TCCAACTCAATTTTACGAAC	50
71	**DE1457**	AGGATGCAAAGGTAGTTGC	CGACCAAACCTAAACCAAG	53
72	**DM0196**	GTCAACTGCGTTACTGTTG	TAGTGCTGAAAGCAATGTC	51
73	**DE1292**	AGGGAGAGTATTTTAAGTTAATTG	ACAAAGGAAGCTAAAGCCC	52
74	**DE1101**	AGGAAAATACAAAATGGGTTG	AATTAAATCAGGGGGTTGG	50
75	**DM0463**	AGTAATCGGTAAACTAGGAGG	TTTCATTCACCTCTTGTGG	52
76	**DE1073**	TGGAATTGAAGAGCATTTTG	AAGAGAGGGGAGGTGTGTC	53
77	**DE1231**	TATGCGTCTTACCGAAACC	AATTTTTCATCAAGATTTGC	49
78	**DE1853**	AAAAGGGGTAAAAGAATTGC	CATCAAACAGAACAAATGTACG	51
79	**CMTTCN163**	TTTACTCCCAATACTTTCATCG	AACCTTTGAAGAATCTCCGTG	53
80	**CNGAN224**	AATCGAAATCCATCTCAC	TCTAAGCCACGACATCAC	49
81	**CMTCN56**	CTTTTCTCTTCTTCTATTCTC	ATCCAAAAGGAATCGGAAAG	51
82	**DM0220**	GAAGAGGGGTTGGTAGAAG	AAGGGTTTGAGCACATAAG	53
83	**CMTC47**	GCATAAAAGAATTTGCAGAC	AGAATTGAGAAGAGATAGAG	49

S. No.	Marker Name	Forward Primer (5'-3')	Reverse Primer (5'-3')	Annealing Temp. (°C)
84	**TJ150**	ACACACCTAATCTCCCTACCTTC	CTCAAACAACGTCAGCTGGT	57
85	**DE1215**	TTTCTCTTTTTGGAACTCCC	TTGGGAGATCGTAAGGTTG	52
86	**DM0468**	CCCCTCTTATCTTTTCCTG	CATCAAGAAGTCACGGAAG	53
87	**DM0490**	TAGCAAACGACAACTAGGC	GTGGAAAAGAGAGGAAAGG	53
88	**DM0500**	TTTGCTCTCTTTCTTGGTG	TTTGATGTGTTGCAATGTC	49
89	**CMATN22**	CGGCAATCATCTTATCTTTC	AAGATTGAAGTGGGAAAATG	89
90	**DE1326**	TCGTTTAGGAAGCCTTTTG	GACGGGAAAGAACACAATG	51
91	**CMMS35_5**	AACGGGATTTTGGAGGCATATTCGG	CTCCCCAGTGTATCAGCCAAATCTC	62
92	**DM0706**	GAAAGGAAACGAGAAAAGG	TCTATCTTGCAGGCTATGG	51
93	**CMBR115**	AGGGTGGAAAGACCCCTATG	TGTGAATGTATCTTTTCTGATACTGC	57
94	**CMGAAN233**	TGCAGGCTTTTTCATAAC	TGTTTATCAATGGCAGCG	48
95	**DE1172**	CACATTGCAGAAGATGCAG	ATGAATGATACTCGGGCTG	53
96	**DM0757**	TAGAAAAGCAGCCAACAAC	GCCACTCCTCTAGAACTCC	54
97	**DM0932**	CAAATTAAAAGAACGTAGAAATAG	TCCCAAAAACAATAACTCTCC	51
98	**DM0570**	TATCTTCTGGGCTGAGTTG	AAAGGAAACCGGAAGAAC	51
99	**CMTA134a**	ACGTGCTTCAGTAAACATG	CCGACATTGAAAACCAACTTC	52
100	**DM0098**	CTATTCCCACTAGAACGAAG	GTCATGATTGAGTTCTTTGC	52
101	**DM0618**	ATATAGCAGCCGAGTGATG	GCGAATCATGTTTACATCC	55
102	**DM0913**	GCTCTGTTATAACCGTAACTGG	ACGTGGCTAAATCTCGTTC	54
103	**DM0752**	TTCGGTCAATAGAAACTGC	CCCCATTTCACTGTCTTTC	55
104	**DE1410**	AACTCATCACATGGAGAAGC	GAGGGAGCTGTTGTTTTTG	53

S. No.	Marker Name	Forward Primer (5'-3')	Reverse Primer (5'-3')	Annealing Temp. (°C)
105	**DE1321**	GAAGAAAACGGCTGCCAC	ACGGACTGTTGGTGTTTTC	53
106	**CMAGN45**	CCCACAAGAGAGAGAGAG	GTGTGACAGGTAGATTGTTGG	55
107	**CMGAN51**	AAACCTTAACGATCTATTCG	TCAAGAAGACGAAACTATTC	49
108	**DM0229**	GACTTGACGAAAATTCCAC	TCTTCTTGTCCACCATCTC	55
109	**CMAAAGN14**	CCATGAGGAACTAAATAGAGCC	CGGTCTCTGCTTGCTTTC	55
110	**TJ147**	GAAAGGTAGGAAGAAAGTGAAGA	ACTCTTGAAGCTGACCGATG	55
111	**DM0503**	GTGTGTATGAGATAGGCGG	AGAAAGGATGGAGAACTGG	54
112	**DE1534**	CACAAGTTGCGAGTGTCAG	TCGTTGCTGGTTAGTTTTTC	53
113	**CMAAGN255**	GAAGAAGAAGAAGAAGAAAAGC	GATTCAAAACAAAAAGAAAGAG	55
114	**DM0634**	AGAGTCGGAAATTGAGAGG	TTCCTTCAAGCATCTTTTG	50
115	**CMACGN289**	TCATGTCAACCGAAGCTAG	CAGATACTGTCCGAACGTG	54
116	**DM0555**	CACAAGAAAAGTCCGACAC	GCAATTTGTTCTCATTTCG	50
117	**DE1957**	CAATAAAGGAAAAACTAGAAATG	TTGGATTTTCTCATACCCG	50
118	**DE1610**	AACCATGGAGACGAGATTG	ACGACTCCTCCCCAGCTC	56
119	**DE1980**	ACGAAGGGGATCTTTTGAG	GAGCTATTCCCTTTCACCC	54
120	**DE1081**	CAAACAAAAGAAGTTGAAAATTG	AAAACCATGGACTTTGGC	50
121	**DM0839**	AACACCATCGAGGTAGTGC	GTTAGGGACGAAAGGAAGG	55

h) Number of alleles / locus

No. of alleles (A) observed and effective no. of alleles (Ae) / locus was computed by below mentioned formula.

$$Ae = 1/ \Sigma pi^2,$$

Where *pi* is the frequency of the i^{th} allele

i) Analysis using DARwin 6.0 software package

The genetic diversity present among the genotypes was calculated with the computer-generated software DARwin 6.0 Programme (Perrier and Jacqumoud-Collet 2006). For the generation of dendrogram, data was set to unweighted pair group's method with arithmetic mean (UPGMA) analysis. Data of 70 markers used to estimate the dissimilarity content based on no. of amplified bands.

$$dij = b+c/2a+(b+c)$$

where, dij: dissimilarity between units i and j

a: no. of the variables, where 'xi = presence and 'xj = presence

b: no. of the variables, where 'xi = presence and 'xj = absence

c: no. of the variables, where 'xi = absence and 'xj = presence

Here ''a'' described matched fragments, b and c represented unmatched fragments. While 2a+(b+c) are total no. of fragments amplified in specific set.

For the estimation of dissimilarity coefficients allelic data developed from 70 SSR primers by using software DARwin 6.0 as presented below:

$$Dij = 1 - \frac{1}{L} \sum_{i=1}^{L} \frac{m1}{\pi}$$

Where, Dij: Dissimilarity between i and j allele

L: Number of loci

π: Poloidy

m1: Number of matching alleles for locus l

The neighbor joining tree was created based on UPGMA showing relationship among the melon genotypes.

CHAPTER IV

RESULTS AND DISCUSSION

In the present study ten inbred lines of muskmelon were identified and crossed in a half mating design to develop 45 F_1 hybrids. These 45 F_1 hybrids along with their parental lines and commercial checks were evaluated for heterosis and combining ability for various traits of interest. The results of the present study have been presented and discussed in the following subheadings:

4.1 Analysis of variance

4.2 Estimation of combining ability effects

4.2.1 Analysis of variance for combining ability effects

4.2.2 Estimation of general combining ability effects

4.2.3 Estimation of specific combining ability effects

4.3 Estimation of heterosis

4.3.1 Heterobeltiosis

4.3.2 Standard heterosis

4.4 Study of inheritance of different characters

4.5 Estimation of correlation coefficients

4.6 Estimation of path coefficients

4.7 Screening for disease incidence

4.8 Molecular characterization of parental lines and F_1 hybrids

4.1 Analysis of variance for the experimental design

ANOVA for twenty-three traits are presented in Table 4.1. All the genotypes studied revealed significant variability for all the characters *viz.*, average fruit weight (g), number of fruit per plant, yield (t ha^{-1}), days taken to 1^{st} female flower emergence, days taken to 1^{st} fruit harvest, polar diameter (cm), equatorial diameter (cm), flesh thickness (cm), rind thickness (mm), fruit cavity area (cm^2), fruit shape index, vine length (m), number of branches, total soluble solids (TSS), ascorbic acid, acidity, β-carotene, firmness ($lb/inch^2$), pH, dry matter (%), reaction to root-knot nematode, reaction to fusarium wilt infestation and reaction to viral disease infestation. It implied that further analysis of variance for combining ability could be conducted as significant variation were present among all the genotypes.

4.2 Estimation of combining ability effects

4.2.1 Analysis of variance for combining ability effects

The results of the ANOVA for combining ability for 23 parameters are given in Table 4.2. Mean sum of squares due to general combining ability (GCA) and Specific combining ability (SCA) effects were found to be highly significant for all the studied parameters. These results indicated the existence of large quantity of variability among the hybrids for these

parameters.

4.2.2 Estimation of general combining ability effects

Estimation of GCA of parents has been reported in Table 4.3 and had been discussed below character-wise.

4.2.2.1 Average fruit weight

For average fruit weight (g) among parents, six inbred lines exhibited positively significant GCA effects *viz.*, MM-610, Riogold, MM-625, MM-1831, and MM 916/NS-1 and MM Sel-103 were regarded as good combiners, while the parents MM-904, Kajri, KP_4HM-15 and MS-1 showed negative and significant GCA value and, thus were found to be poor general combiners. The results are in accord with Choudhary *et al* (2006), and Saha (2017).

4.2.2.2 Number of fruits per plant

Four parents registered positively and substantial GCA effects for this character**.** The inbred KP_4HM-15 was the best combiner followed by MM-904, MM Sel-103 and MM-625. Inbreds showing negative and significant GCA effect were MM-610, Riogold, Kajri, and MM 916/NS-1 and were regarded as poor general combiners. Tomar and Bhalala (2006b) also observed positive and significant GCA effects for this no. of fruits per plant.

4.2.2.3 Fruit yield

Four parental lines had positively and substantial result for fruit yield (t ha^{-1}) were MM-625, KP_4HM-15, MM Sel-103 and Riogold and were regarded as good combiners, while Kajri, MM-904, and MS-1 showed negative GCA effect and found to be poor combiners.

4.2.2.4 Days taken to 1st female flower emergence

The parent line MM-625 was good combiner for days taken to 1st female flower exhibiting negative and significant GCA effects for earliness in female flowering trait. While one parent line Kajri showed positive and significant effect, regarded as poor combiner for the trait. Similarly, some scientists were also documented significant result by Aravindakumar *et al* (2005), Kumar *et al* (2005), Tomar and Bhalala (2006), Choudary *et al* (2006), Shahsi kumar *et al* (2016) and Saha (2017).

4.2.2.5 Days taken to 1st fruit harvest

Since earliness is important trait in muskmelon, thus the negative value of GCA effects was desirable for this trait. The inbred lines Riogold, MM-904, MS-1, and MM 916/NS-1 showed highly significant and negative GCA effects and regarded as best general combiners for this trait. However, the maximum positive and substantial GCA value was shown by Kajri followed by MM-610, MM Sel-103, and MM-1831 were considered as poor combiner for earliness.

4.2.2.6 Polar diameter

Among the parents, two parents, Kajri and KP_4HM-15 had highly significant and positive GCA effects for polar diameter and MM Sel-103 and MM-625 possess highly

significant and negative GCA effects for polar diameter.

4.2.2.7 Equatorial diameter

The parents, MM-1831, MM-916/NS-1 and MM-904 exhibited significant and positive GCA effects and identified as good general combiner whereas, Riogold, MM Sel-103 and MS-1 were recorded as poor general combiners for this trait showing significant and negative GCA effects.

4.2.2.8 Flesh thickness

The estimates of positive and highly significant GCA effects were shown parents Riogold followed by MM-1831 and MM-625 and were regarded as good general combiners for this trait. However, four parents *viz.*, MM-904, KP_4HM-15, Kajri and MM-916/NS-1 recorded as poor general combiners for flesh thickness. The GCA effects for this trait were also reported by Sedera *et al* (2016), Rolania and Fageria (2018) and Costa *et al* (2019).

4.2.2.9 Rind thickness

The parents MM-625, MM-610 and MS-1 exhibited positive and highly significant GCA effects for this trait and considered as good general combiners. Whereas parents MM-904, KP_4HM-15 and Kajri recorded as negative and significant GCA effects and were poor general combiner for rind thickness (mm). Similar results were shown by Sedera *et al* (2016).

4.2.2.10 Fruit cavity area

Since small seed cavity is the desirable trait in muskmelon, thus negative GCA effects are appropriate for fruit cavity area. Three parents MM-904, KP_4HM-15 and Kajri were found to be good combiners for this trait exhibiting negative GCA effects. While parents *viz.*, MM-625, Riogold, MM-1831 and MS-1 exhibited positive and significant GCA values for fruit cavity area and were regarded as poor general combiners. Similarly, Hassan *et al* (2018) also observed significant GCA effect for this trait.

4.2.2.11 Fruit shape index

Four parents, MM-904, MM-610, MS-1, and KP_4HM-15 had significant and positive GCA effects while, three parents *viz.*, MM Sel-103, Kajri and MM-625 were found to possess highly significant and negative GCA effects for fruit shape index. Likewise, Vashisht *et al* (2010), Shahsikumar *et al* (2016) and Costa *et al* (2019) also observed positive GCA effects for fruit shape index.

4.2.2.12 Vine length (m)

Four parents registered significant and negative GCA effects viz., Riogold, MS-1, MM-625 and MM-904 and were found to be the best general combiners. However, parents KP_4HM-15 and MM Sel-103 were poor combiners. Similar observation was recorded by Choudary *et al* (2006) and Rolania and Fageria (2018).

Table 4.1: ANOVA for different characters of muskmelon

Source of variation	df	Mean sum of squares											
		Average fruit weight (g)	No. of fruits per plant	Fruit yield (t ha^{-1})	Days taken to 1st female flower	Days taken to 1st fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)
Replications	1	1506.4	0.16	1.0	2.6	0.009	0.06	0.12	0.07	0.07	0.001	0.004	0.19
Genotypes	54	49615.1**	1.1**	87.7**	16.4**	26.0**	2.7**	1.3**	0.25**	2.5**	29.1**	0.01**	3.2**
Error	54	25492.5	0.02	0.65	2.2	0.95	0.19	0.16	0.05	0.33	1.2	0.001	0.09

Table 4.1: Continued…

Source of variation	df	Mean sum of squares										
		No. of Branches	TSS (□ Brix)	β-carotene (mg/100g)	Firmness (lb/ $inch^2$)	Ascorbic Acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter (%)	Reaction to Root-knot nematode (GI)	Reaction to viral disease (PDI)	Reaction to Fusarium wilt (PDI)
Replications	1	0.1	1.1	0.01	0.06	1.1	0.000	0.09	2.0	1.1	2.7	0.10
Genotypes	54	0.48**	5.6**	1.08**	14.0**	44.1**	0.003**	0.77**	43.9**	0.93**	64.5**	102.5**
Error	54	0.3	0.7	0.006	0.07	0.86	0.001	0.04	2.8	0.29	0.63	0.79

* Significant at 5% level and ** Significant at 1% level

Table 4.2: ANOVA for combining ability effects for different characters of muskmelon

Source of variation	df	Mean sum of squares											
		Average fruit weight (g)	No of fruits per vine	Fruit yield (t ha^{-1})	Days taken to 1st female flower	Days taken to 1st fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)
GCA	9	73799.3**	0.73**	51.7**	7**	12.6**	0.73**	0.5**	0.42**	3.9**	46.7**	0.025**	2.9**
SCA	45	15009.2**	0.53**	42.2**	8.4**	13.0**	1.4**	0.71**	0.06**	0.71**	8.1**	0.002**	1.3**
Error	54	907	0.01	0.32	1.1	0.47	0.09	0.1	0.02	0.16	0.64	0.0008	0.05

Table 4.2: Continued…..

Source of variation	df	Mean sum of squares										
		No. of Branches	TSS (□ Brix)	β-carotene (mg/100g)	Firmness (lb/ $inch^2$)	Ascorbic acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter (%)	Reaction to root-knot nematode (GI)	Reaction to viral disease (PDI)	Reaction to fusarium wilt (PDI)
GCA	9	0.20**	3.5**	1.2**	19.8**	28.8**	0.001**	0.26**	8.2**	1.3**	38.8**	56.5**
SCA	45	0.25**	2.6**	0.40**	4.4**	20.7**	0.002**	0.40**	24.6**	0.28**	30.9**	50.2**
Error	54	0.15	0.35	0.003	0.03	0.43	0.00	0.02	1.4	0.14	0.31	0.39

* Significant at 5% level & ** Significant at 1% level

4.2.2.13 Number of branches

None of the parents exhibited positively significant GCA effects value for this trait. However, only one parent MM-904 exhibited highly significant, but negative GCA effect and identified as poor general combiner for number of branches. Whereas Tomar and Bhalala (2006) observed positive GCA effects for trait.

4.2.2.14 TSS

Three parents exhibited significant GCA value out of ten parents and identified as good general combiner for this trait. Parent MM-916/NS-1 showed positively significant GCA effects followed by MM-1831 and KP_4HM-15. However, the parents, Kajri, MM-904 and MS-1 were found to be poor general combiners. These results were in concord with Tomar and Bhalala (2006), Choudary *et al* (2006), Vashisht *et al* (2010), and Sedera *et al* (2016) for TSS content.

4.2.2.15 β-carotene content

Five parents *viz.*, MM-625, Riogold, MM-610, MM916/NS-1, and MMSel-103 observed as good general 'combiners' for this trait, exhibiting significant and positive GCA' effects. While 3 parents viz., MM-904, KP_4HM-15 'and' Kajri were found to possess significant and negative GCA effects for β-carotene and said to be poor general combiners. Shahsikumar *et al* (2016) reported positive significant GCA effects for β-carotene content.

4.2.2.16 Firmness

The estimates of GCA effects were positively significant for firmness in six inbred lines. The parents, Riogold, MS-1, MM-625, Kajri, MM-916/NS-1, and MM-1831 were recognised as good combiner for high firmness. However, three parents namely MM-904, KP_4HM-15 and MM Sel-103 were recorded as poor general combiners for firmness.

4.2.2.17 Ascorbic acid

Six parents, *viz.,* MM-610, MS-1, MM-625, MM-904, Kajri, and MM-916/NS-1 showed highly significant and positive "GCA effects and were regarded as good general combiners for this trait. Three parents *viz.,* KP_4HM-15, MM Sel-103 and Riogold exhibited "negative but significant values for ascorbic acid and found to be poor combiners. Tomar and Bhalala (2006), and Shahsikumar *et al* (2016) documented positive significant GCA effects for this trait.

4.2.2.18 Titrable acidity

The two parents, Kajri and Riogold demonstrated 'significant and negative effects. Whereas KP_4HM-15 was recorded highly significant and positive effects for acidity and identified as poor combiners for this trait. Tomar and Bhalala (2006) demonstrated significant "positive GCA effects for this trait.

Table 4.3: Estimation of GCA effects of parents for different characters of muskmelon

Parents	Average fruit weight (g)	No of fruits per vine	Fruit yield (t ha^{-1})	Days taken to 1st female flower	Days to 1st fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)
MS-1	-33.3*	-0.02	-0.73**	-0.54	-0.5**	-0.15	-0.17*	-0.05	0.40**	0.83**	0.02**	-0.51**
Kajri	-83.7**	-0.18**	-3.67**	1.9**	1.6**	0.34**	0.04	-0.13**	-0.54**	-1.64**	-0.06**	-0.02
KP_4HM-15	-35.1**	0.40 **	2.34**	-0.5	-0.01	0.26**	-0.08	-0.23**	-0.83**	-2.86**	0.01*	1.21**
MM Sel-103	24.4**	0.15 **	1.87**	-0.12	0.77**	-0.44**	-0.19*	0.06	0.12	1.03**	-0.06**	0.27**
MM-904	-160.8**	0.35 **	-2.59**	0.12	-1.2**	0.04	0.16*	-0.26**	-0.86**	-3.24**	0.08**	-0.21**
MM-625	74.2**	0.10 **	2.91**	-0.79**	0.02	-0.25**	-0.13	0.17**	0.90**	2.55**	-0.03**	-0.23**
MM-610	81.1**	-0.33 **	0.04	0.20	1.06**	-0.06	0.08	0.04	0.40**	1.20**	0.03**	-0.02
MM-1831	31.5**	-0.10 **	-0.21	0.33	0.48*	0.17	0.34**	0.18**	0.28*	1.14**	0.001	0.11
MM 916/NS-1	25.9**	-0.16 **	-0.47**	-0.16	-0.55**	0.16	0.18*	-0.09*	-0.05	-0.54*	0.000	-0.04
Riogold	75.7**	-0.21 **	0.50**	-0.45	-1.6**	-0.07	-0.23**	0.30**	0.17	1.51**	0.001	-0.54**
LSD ($p \leq 0.05$)	**18.6**	**0.06**	**0.35**	**0.65**	**0.42**	**0.19**	**0.17**	**0.10**	**0.25**	**0.49**	**0.01**	**0.13**
LSD ($p \leq 0.01$)	**26.8**	**0.09**	**0.50**	**0.93**	**0.61**	**0.27**	**0.25**	**0.15**	**0.36**	**0.71**	**0.02**	**0.19**

* Significant at 5% level & ** Significant at 1% level

Table 4.3: Continued.

Parent	No. of Branches	TSS (□Brix)	β-carotene (mg/100g)	Firmness in (lb/ inch^2)	Ascorbic acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter (%)	Reaction to root-knot nematode (GI)	Reaction to viral disease (PDI)	Reaction to fusarium wilt (PDI)
MS-1	0.05	-0.33*	-0.01	1.35**	1.48**	0.003	0.08*	-0.18	0.19	-3.17**	-0.14
Kajri	0.11	-0.77**	-0.26**	0.66**	0.53**	-0.01*	0.31**	0.44	-0.70**	0.96**	-2.32**
KP_4HM-15	-0.08	0.34*	-0.42**	-2.13**	-2.09**	0.02**	-0.15**	-1.42**	-0.14	-0.43**	1.36**
MM Sel-103	0.11	-0.05	0.06**	-1.08**	-2.71**	0.000	-0.01	-0.86*	-0.04	3.78**	-2.84**
MM-904	-0.30**	-0.50**	-0.53**	-1.77**	0.73**	0.004	-0.003	0.37	-0.01	-1.06**	2.04**
MM-625	0.01	0.14	0.48**	0.79**	1.00**	-0.007	-0.21**	0.94**	-0.10	1.05**	1.14**
MM-610	-0.09	-0.14	0.22**	-0.34**	1.82**	0.004	0.04	1.39**	-0.19	0.18	-3.57**
MM-1831	0.02	0.59**	0.02	0.28**	0.32	-0.005	0.04	-0.33	0.26*	-1.09**	0.19
MM 916/NS-1	0.05	1.04**	0.18**	0.65**	0.40*	0.006	-0.03	-0.006	0.54**	-0.31*	2.40**
Riogold	0.11	-0.30	0.24**	1.57**	-1.51**	-0.01*	-0.08*	-0.34	0.54**	0.09	1.73**
LSD (p≤0.05)	**0.24**	**0.36**	**0.03**	**0.11**	**0.40**	**0.01**	**0.09**	**0.74**	**0.54**	**0.34**	**0.39**
LSD (p≤0.01)	**0.34**	**0.52**	**0.05**	**0.16**	**0.58**	**0.01**	**0.12**	**1.09**	**0.54**	**0.49**	**0.56**

* Significant at 5% level & ** Significant at 1% level

4.2.2.19 pH

Three parents *viz.,* MM-625, KP_4HM-15 and Riogold showing negative and significant GCA value for pH content and were observed as good' combiners'. Only one parent Kajri showed significant" 'and 'positive GCA value and was said to be poor combiner for this trait.

4.2.2.20 Dry matter

Two parents, MM-610 and MM-625 exhibited significant and positive GCA effect while, KP_4HM-15 and MM Sel-103 exhibited negative GCA effects for this trait.

4.2.2.21 Reaction to root-knot nematode

Since resistance is desirable against this trait, thus negative GCA effects are appropriate for this trait. Among ten parents only one parent Kajri exhibited negative and highly significant GCA effects value for this trait. While, MM-916/NS-1 and MM-1831 had shown positive and significant GCA effects.

4.2.2.22 Reaction to Fusarium wilt

Three parents, *viz.,* MM-610, MM Sel-103, and Kajri exhibiting favorable negative and significant values and were regarded as good combiners for this trait as negative GCA effects for Fusarium wilt incidence are desirable. However, parents MM 916/NS-1, MM-904, KP_4HM-15 and Riogold were observed as poor combiners for higher incidence of Fusarium wilt having positive significant values.

4.2.2.23 Reaction to viral disease

. The inbred lines, *viz.,* MS-1, MM-1831, MM-904, KP_4HM-15 and MM 916/NS-1 exhibiting favorable negative and significant GCA values and regarded as good combiners for this trait as negative GCA effects were significant for virus incidence. However, parents MM Sel-103, Kajri, and MM-625 were poor general combiners for higher virus incidence having positively significant values.

Among the parents, MM-625 was the top general combiner for five traits viz., fruit yield (t ha-1), Days taken to 1st female flower emergence, rind thickness, β-carotene content, and pH content. Further, KP_4HM-15 and MM 916/NS-1 were the top combiners for number of fruits per plant and TSS content, respectively. While, Riogold was the best general combiner for Days taken to 1st fruit harvest, flesh thickness, and vine length, the parent line Kajri was the best combiner for polar diameter, titrable acidity, and reaction to root-knot nematode. Parent MM-904 was best combiner for fruit cavity area, and fruit shape index. The parent MM-610 was good general combiner for average fruit weight, ascorbic acid, dry matter content and reaction to Fusarium wilt infestation. Only the parent line MS-1 performed best for reaction to viral disease (Table 4.4).

Tomar and Bhalala (2006) reported that parental line AMM-01-18 good combiner for fruit yield, no. of primary branches, no. of fruits per plant, fruit weight, moisture content,

TSS, acidity, and total soluble sugars. Vashist *et al* (2010) documented that parent Hara Madhu was the best combiner for total fruit yield per vine, fruit weight, No. of fruits per plant, TSS and fruit shape index while Punjab Rasila was the best general combiner for fruit/cavity ratio, flesh thickness, and female flower node. Similar results reported by Moon *et al* (2006) DVRM-1 and Hara Madhu showed the maximum values for carotenoid content and ascorbic acid content, respectively.

4.2.3 Specific combining ability effects

SCA effects for all the parameters are presented in Table 4.4 and had been discussed below character-wise.

4.2.3.1 Average fruit weight

Estimates of SCA effects indicated that out of forty-five F_1 hybrids, twelve hybrids demonstrate positive and significant effect for average fruit weight. The highest SCA effects was shown by hybrids *viz.,* MS-1 × MM-610, MM-610 × MM 916/NS-1, MM 916/NS-1 × Riogold, MM Sel-103 × MM-1831, and Kajri × Riogold etc. These cross combinations were regarded as the best specific combiners for average fruit weight.

4.2.3.2 Number of fruits per plant

Eight best specific combiner were observed among the crosses, exhibited significantly and positive effects for number of fruits per plant. The best cross combination with positive SCA value was MM Sel-103 × MM-904, MM-904 × MM-1831, KP_4HM-15 × Riogold, KP_4HM-15 × MM-904, and MS-1 × MM-610. These cross combinations regarded as best combiners for having higher number of fruits per plant.

4.2.3.3 Fruit yield

In case of fruit yield (t ha^{-1}), SCA effects were significant for eighteen cross combinations. Crosses showing highest positive and substantial SCA value were MS-1 × MM-610, KP_4HM-15 × MM-904, KP_4HM-15 × MM Sel-103, MM Sel-103 × MM-610, MM Sel-103 × MM-625. These cross combinations were regarded as the best specific combiners for having higher fruit yield (t ha^{-1}) among the other cross combinations.

4.2.3.4 Days taken to 1st female flower emergence

Nine F_1 hybrids exhibited significantly negative SCA effect among the forty-five hybrids. The best combiners for SCA effects were Kajri × Riogold, Kajri × MM 916/NS-1, MM Sel-103 × Riogold, MS-1 × MM-904, and MM Sel-103 × MM-904. These cross combinations regarded as good specific combiners for Days taken to 1st female flower emergence.

4.2.3.5 Days taken to 1st fruit harvest

The estimation of SCA effects for trait showed negative and significant effects in nineteen crosses combination. The best cross combination with highest negative SCA value were MM Sel-103 × MM-1831, MM-625 × MM-1831, Kajri × Riogold, MM-904 × MM-610,

and MM-625 × MM 916/NS-1. These cross combinations were regarded as good specific combiners for earliness.

4.2.3.6 Polar diameter

Fifteen hybrids showed positive and significant SCA effects and the desirable hybrids with highest positive SCA values was MM Sel-103 × MM-904 followed by KP_4HM-15 × Riogold, MM Sel-103 × MM-625, Kajri × MM-916/NS-1, and MS-1 × MM-610. These cross combinations were regarded as good combiners for this trait.

4.2.3.7 Equatorial diameter

Fifteen hybrids observed as good combiners for this character. The top cross combination with highest SCA value was Kajri × MM-610 followed by MM-625 × Riogold, MM-625 × Riogold, MM-904 × MM-916/NS-1, and Kajri × MM-625.

4.2.3.8 Flesh thickness

The positive and significant SCA effects displayed significant and positive SCA effects, were four. The best hybrids displayed highest SCA values were MM Sel-103 × MM-625 followed by MM-916/NS-1 × Riogold, MS-1 × MM-610 and MS-1 × MM-916/NS-1. These cross combinations were regarded as good specific combiners for this trait.

4.2.3.9 Rind thickness

Ten hybrids showed positive and significant SCA effects and the desirable hybrids with highest positive SCA values were Kajri × MM-625, MM-610 × Riogold, MM-610 × MM-1831, MM-610 × MM 916/NS-1, and MM-904 × MM-625. These cross combinations were regarded as good specific combiners for this trait.

4.2.3.10 Fruit cavity area

For this character negative SCA effects were desirable. Eleven crosses showing desirable significant SCA effects. Hybrid MM-625 × MM 916/NS-1 was exhibited highest positive and significant SCA effects values followed by MS-1 × Riogold, KP_4HM-15 × MM-1831, MM Sel-103 × MM 916/NS-1, and Kajri × Riogold. These cross combinations regarded as good specific combiners for fruit cavity area (cm^2).

4.2.3.11 Fruit shape index

The fruit shape index with positive and significant value was displayed by four crosses showing desirable SCA effects. Hybrid MS-1 × MM 916/ NS-1 was exhibited highest positive and significant SCA effects values followed by Kajri × MM-625, MM-904 × Riogold, and KP_4HM-15 × MM-904. These cross combinations regarded as good specific combiners for this trait.

4.2.3.12 Vine length

Seventeen hybrids showed negative and significant SCA effects value and the desirable hybrids with highest negative SCA values was Kajri × KP_4HM-15 followed by KP_4HM-15 × Riogold, Kajri × MM -625 and MM-625 × MM-916/NS-1, MS-1 × MM-1831,

Table 4.4: Estimation of SCA effects of cross combinations for different characters of muskmelon

Crosses/Traits	Average fruit weight (g)	No. of fruits per plant	Fruit yield (t ha^{-1})	Days taken to 1st female flower	Days taken to 1st fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)
MS-1 × Kajri	122.0**	0.15	4.3 **	-1.14	-0.24	-0.81**	-0.44
MS-1 × KP_4HM-15	49.6	-0.41**	-2.2**	0.76	1.42*	-0.14	0.61*
MS-1 × MM Sel-103	-114.9**	-0.16	-4.7**	0.39	-0.87	0.48	0.33
MS-1 × MM-904	49.9	-0.41**	-1.1*	-3.35**	-0.87	-0.25	-0.54*
MS-1 × MM-625	49.4	0.13	2.2**	0.06	-0.62	-0.07	-0.42
MS-1 × MM-610	226.7**	0.94**	14.4**	0.06	-1.66*	1.52**	0.52
MS-1 × MM-1831	-210.3**	-0.22 *	-6.7**	-0.06	-1.08	-0.05	-0.74**
MS-1 × MM 916/ NS-1	-77.7**	-0.16	-3.2**	-1.56	-0.03	-0.26	-0.11
MS-1 × Riogold	-96.3**	-0.53**	-6.2**	-0.77	1.04	0.47	0.87**
Kajri × KP_4HM-15	-67.4*	-0.65**	-6.1**	-1.68	2.21 **	-0.24	0.04
Kajri × MM Sel-103	143.2**	-0.85**	-2.6**	0.43	1.42*	0.89 **	-0.60*
Kajri × MM-904	-19.9	-0.70**	-3.6**	-0.31	-0.08	-0.04	-1.26**
Kajri × MM-625	-84.2**	0.60**	1.5**	-0.39	-3.33**	1.29**	0.92**
Kajri × MM-610	-135.4**	-0.21*	-4.4**	-0.39	2.12**	0.94**	1.90**
Kajri × MM-1831	-30.6	-0.58**	-4.0**	-0.02	2.71**	0.88**	0.92**
Kajri × MM 916/NS-1	-34.5	-0.43**	-3.3**	-5.02**	-2.26**	1.61**	0.86**
Kajri × Riogold	178.8**	0.099	5.5**	-5.23**	-4.66**	1.08**	0.53*
KP_4HM-15 × MM Sel-103	116.7**	0.97**	11.4**	-0.64	-0.91	0.58*	0.89**
KP_4HM-15 × MM-904	140.0**	1.16**	11.4**	-0.39	0.08	0.26	0.02
KP_4HM-15 × MM-625	124.2**	0.62***	9.3**	0.01	-1.16	-0.32	-0.79**
KP_4HM-15 × MM-610	-92.3**	-0.56**	-6.8**	-0.98	-2.70**	-0.25	-0.48
KP_4HM-15 × MM-1831	6.3	0.50**	3.8**	-0.6	-2.12**	1.22**	0.46
KP_4HM-15 × MM 916/NS-1	-140.7**	-0.09	-5.2**	-1.1	-3.58**	1.05**	0.06
KP_4HM-15 × Riogold	-43.6	1.24**	7.3**	-0.81	-2.99**	1.85**	0.23

Crosses/Traits	Average fruit weight (g)	No. of fruits per plant	Fruit yield (t ha^{-1})	Days taken to 1st female flower	Days taken to 1st fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)
MM Sel-103 × MM-904	-50.5	1.57**	6.5**	-3.27**	-1.20	2.08**	0.14
MM Sel-103 × MM-625	31.6	0.85**	8.3**	-1.85	2.54**	1.70**	0.80**
MM Sel-103 × MM-610	138.7**	0.68**	9.9**	-1.35	-1.99**	-0.11	-0.34
MM Sel-103 × MM-1831	191.1**	-0.75**	-1.0 *	-0.98	-5.91**	-2.26**	-1.56**
MM Sel-103 × MM 916/NS-1	-181.7**	-0.35**	-7.1**	-0.98	-2.87**	-2.54**	-1.31**
MM Sel-103 × Riogold	-51.7	0.04	-0.9	-4.68**	-2.78**	-2.63**	-0.69*
MM-904 × MM-625	-122.9**	0.01	-4.0**	1.89	1.04	-1.84**	-0.60*
MM-904 × MM-610	-76.1**	-0.09	-2.2**	0.39	-4.49*	-0.16	0.44
MM-904 × MM-1831	-118.5**	1.30**	3.2**	-1.73	-3.91**	-0.45	0.58*
MM-904 × MM 916/NS-1	-169.1**	0.11	-4.2**	-0.23	-2.87**	0.28	0.97**
MM-904 × Riogold	-39.4	-0.49**	-3.4**	-0.93	-2.28**	-0.64*	-0.5
MM-625 × MM-610	109.9**	0.15	4.0**	-0.1	-1.24	-1.25**	-1.13**
MM-625 × MM-1831	0.5	-0.13	-0.6	-0.3	-5.66**	-0.18	-0.03
MM-625 × MM 916/NS-1	-31.5	0.28**	1.4**	-3.31**	-4.12**	0.45	0.61 *
MM-625 × Riogold	27.5	-0.65**	-4.9**	-2.52 *	-3.03**	0.95**	1.23**
MM-610 × MM-1831	1.9	-0.32**	-2.6**	-2.81**	-0.20	-0.01	-0.25
MM-610 × MM 916/NS-1	212.4**	-0.20	2.6*	-2.81**	-0.16	-0.21	-0.43
MM-610 × Riogold	-21.1	-0.21*	-2.9**	2.4*	0.92	-0.96**	-0.67*
MM-1831 × MM 916/NS-1	64.9*	-0.31**	-0.4	0.5	1.42*	-0.39	-0.55*
MM-1831 × Riogold	-5.7	-0.44***	-3.4**	-0.14	2.00**	0.94**	1.04**
MM 916/NS-1 × Riogold	182.7**	0.29**	7.4**	2.3*	2.54**	0.08	0.56*
LSD (p≤0.05)	**55.9**	**0.20**	**1**	**1.95**	**1.28**	**0.58**	**0.53**
LSD (p≤0.01)	**74.6**	**0.27**	**1.4**	**2.61**	**1.71**	**0.77**	**0.71**

* Significant at 5% level & ** Significant at 1% level

Table 4.4 Continued….

Crosses/Traits	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)	No of Branches	TSS (□Brix)	β-carotene (mg/100g)
MS-1 × Kajri	0.13	0.51	4.33**	0.016	0.02	-0.04	3.27**	-0.15**
MS-1 × KP_4HM-15	-0.21	0.80*	3.06**	0.002	-0.99**	0.31	1.03	0.49**
MS-1 × MM Sel-103	-0.05	-0.48	-0.64	0.014	-0.57**	-0.04	0.07	-0.17**
MS-1 × MM-904	0.05	0.007	-0.01	0.017	0.01	0.37	0.50	0.001
MS-1 × MM-625	0.24	0.90*	3.85**	-0.017	0.07	0.55	-0.34	0.21**
MS-1 × MM-610	0.41*	0.24	0.83	-0.010	-0.07	-0.17	0.04	0.10
MS-1 × MM-1831	-0.23	-0.81*	-2.89**	0.027	-1.12**	0.03	-0.25	0.49**
MS-1 × MM 916/ NS-1	0.37*	1.36**	5.61**	0.133**	-0.44*	-0.15	-0.15	-0.25**
MS-1 × Riogold	-0.24	-0.36	-4.82**	-0.043	-0.90**	-0.87 *	-0.99	-0.86**
Kajri × KP_4HM-15	-0.56**	-0.08	-2.39**	-0.143*	-2.30**	-0.24	-4.03**	-0.47**
Kajri × MM Sel-103	0.29	0.63	1.41	0.025	-0.89**	0.06	0.53	0.47**
Kajri × MM-904	0.05	-0.05	0.18	-0.058 *	-0.72**	0.14	2.48**	-0.63**
Kajri × MM-625	0.15	1.02**	3.63**	0.068*	-1.37**	-0.33	-0.83	1.56**
Kajri × MM-610	-0.19	0.35	-2.05**	0.006	0.86**	-0.39	-0.72	-1.16**
Kajri × MM-1831	0.18	0.46	1.60*	0.038	-0.88**	1.14**	1.07	0.68**
Kajri × MM 916/NS-1	-0.15	-0.35	1.08	-0.031	0.38	-0.21	1.56**	0.72**
Kajri × Riogold	-0.008	-1.08**	-2.95**	0.028	1.29**	-0.27	1.85 **	0.15**
KP_4HM-15 × MM Sel-103	0.14	-0.41	-0.21	0.046	1.12**	-0.24	2.21 **	0.62**
KP_4HM-15 × MM-904	-0.07	0.57	1.15	0.058*	1.12**	0.51	-2.00 **	-0.090
KP_4HM-15 × MM-625	0.07	-0.52	-0.2	0.029	0.27	0.35	0.32	0.37**
KP_4HM-15 × MM-610	0.16	-0.68	0.59	0.017	0.17	0.30	0.43	-0.25**
KP_4HM-15 × MM-1831	0.15	-1.74**	-3.95**	-0.006	1.36**	0.84*	1.31*	-0.50**
KP_4HM-15 × MM 916/NS-1	-0.20	0.76*	-1.87*	-0.011	3.29**	0.31	0.64	-0.03
KP_4HM-15 × Riogold	-0.05	0.87*	1.45	-0.026	-1.95**	0.59	1.06	0.23**
MM Sel-103 × MM-904	-0.04	-0.88*	-0.55	-0.049	0.34	0.31	0.50	-0.39**

Crosses/Traits	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)	No of Branches	TSS (□Brix)	β-carotene (mg/100g)
MM Sel-103 × MM-625	0.68**	0.01	3.85**	0.017	2.13**	1.16**	0.75	0.10
MM Sel-103 × MM-610	-0.21	0.18	-0.92	-0.046	-0.47*	-0.06	-1.25*	0.22**
MM Sel-103 × MM-1831	0.18	0.29	1.73*	-0.058*	0.21	-0.35	-1.31 *	-0.78**
MM Sel-103 × MM 916/NS-1	-0.19	-1.02**	-3.58**	0.027	-0.04	-0.37	1.65**	0.69**
MM Sel-103 × Riogold	-0.05	-0.91*	-1.77*	-0.033	-0.67**	-0.27	0.26	-0.71**
MM-904 × MM-625	0.26	1.14**	2.16**	-0.026	1.57**	-0.08	1.98 **	1.31**
MM-904 × MM-610	0.10	-0.66	-0.33	0.012	0.25	-0.30	-0.72	-0.72**
MM-904 × MM-1831	-0.12	-0.04	-2.88**	-0.071*	-0.19	-0.10	-0.12	0.24**
MM-904 × MM 916/NS-1	-0.13	0.13	-0.05	-0.081**	-1.10**	-0.46	1.24*	-0.30**
MM-904 × Riogold	-0.23	-0.09	-1.44	0.064*	0.01	-0.18	-1.98**	0.69**
MM-625 × MM-610	-0.13	-1.08**	-2.53**	0.023	-0.68**	-0.12	1	-0.01
MM-625 × MM-1831	-0.12	-0.31	1.13	-0.005	-1.18**	-0.25	-0.56	-0.11*
MM-625 × MM 916/NS-1	-0.49**	-1.63**	-5.77**	-0.009	-1.35**	-0.28	-0.36	-0.55**
MM-625 × Riogold	-0.33 *	-0.35	-1.94*	0.010	1.28**	0.16	-0.24	-0.93**
MM-610 × MM-1831	-0.04	1.30**	2.65**	0.007	0.22	-0.14	-0.37	0.30**
MM-610 × MM 916/NS-1	0.18	1.20**	3.41**	-0.022	0.38	0.49	1.27*	0.95**
MM-610 × Riogold	0.20	1.31**	5.37**	0.002	0.79**	-0.22	1.05	-0.27**
MM-1831 × MM 916/NS-1	-0.09	-0.02	1.14	0.000	0.94**	0.03	2.28**	-0.68**
MM-1831 × Riogold	-0.01	-0.07	0.55	0.019	0.22	-0.68	1.47**	0.76**
MM 916/NS-1 × Riogold	0.45**	0.26	1.60*	0.000	-0.07	-0.04	0.01	0.60**
LSD (p≤0.05)	**0.31**	**0.75**	**1.49**	**0.054**	**0.41**	**0.72**	**1.09**	**0.1**
LSD (p≤0.01)	**0.42**	**1**	**1.99**	**0.072**	**0.55**	**0.96**	**1.46**	**0.14**

* Significant at 5% level & ** Significant at 1% level

Table 4.4 Continued.

Crosses/Traits	Firmness in (lb/ inch^2)	Ascorbic Acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter %	Reaction to Root-knot nematode (GI)	Reaction to Viral disease (PDI)	Reaction to Fusarium wilt (PDI)
MS-1 × Kajri	-2.77**	-1.42*	-0.0.38 *	-0.15	-1.01	0.33	1.68**	-16.11**
MS-1 × KP$_4$HM-15	-0.48**	-5.52**	-0.0.37 *	0.53**	-4.94**	0.17	1.52**	1.60**
MS-1 × MM Sel-103	0.82**	6.57**	-0.0.36 *	-0.41**	2.15	-0.03	-0.06	-4.09**
MS-1 × MM-904	0.20	1.63**	-0.005	0.42**	0.32	0.83*	2.31**	2.52**
MS-1 × MM-625	-0.50**	-10.63**	0.026	-1.10**	2.95 *	0.33	-6.33**	0.92
MS-1 × MM-610	-1.22**	0.92	0.020	0.62**	3.35**	0.26	0.11	1.14
MS-1 × MM-1831	-1.79**	5.48**	-0.001	-0.32*	1.69	-0.94*	4.74**	4.59**
MS-1 × MM 916/ NS-1	-0.61**	0.52	0.018	-0.43**	-2.03	-0.12	6.23**	-1.84**
MS-1 × Riogold	-1.38**	-6.37**	0.012	-0.73**	-12.52**	-1.28**	-6.77**	0.83
Kajri × KP$_4$HM-15	0.86**	0.45	-0.030	0.33*	2.102	0.87*	-0.43	5.37**
Kajri × MM Sel-103	0.31	1.22*	0.005	-0.26	5.75**	-0.18	6.13**	-5.92**
Kajri × MM-904	0.85**	-6.37**	-0.008	-0.07	2.07	-0.46	-2.92**	-14.80**
Kajri × MM-625	-0.009	-1.30*	-0.023	-0.75**	-0.31	-0.42	-7.91**	5.59**
Kajri × MM-610	0.72**	0.92	-0.039*	1.38**	-0.56	-0.63	-7.54**	2.31**
Kajri × MM-1831	-0.15	0.88	-0.015	0.97**	-3.29**	-0.04	-1.94**	-1.46 *
Kajri × MM 916/NS-1	-0.72**	3.22**	0.019	-0.83**	2.63 *	0.88*	9.43**	-0.17
Kajri × Riogold	-2.63**	0.03	0.083***	-0.83**	6.71**	0.21	-0.33	1.50*
KP$_4$HM-15 × MM Sel-103	-0.03	3.41**	0.071***	-0.12	4.29**	0.4	-14.26**	5.61**
KP$_4$HM-15 × MM-904	1.19**	4.05**	-0.042 *	-0.23	-5.50**	-0.72 *	-7.15**	-3.62**
KP$_4$HM-15 × MM-625	-1.71**	4.19**	0.144***	-0.12	-1.35	0.22	0.63	-1.08
KP$_4$HM-15 × MM-610	-1.18**	-5.63**	0.002	-0.43**	-0.57	-0.34	-9.02**	7.24**
KP$_4$HM-15 × MM-1831	-0.75**	-7.80**	0.012	-0.38**	6.77**	-0.10	5.25**	2.35**
KP$_4$HM-15 × MM 916/NS-1	-0.42*	3.77**	0.020	-0.05	7.41**	0.32	5.21**	2.14**
KP$_4$HM-15 × Riogold	-1.89**	-3.08**	-0.011	-0.25	-0.77	-0.24	6.33**	0.99

Crosses/Traits	Firmness in (lb/ inch^2)	Ascorbic Acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter %	Reaction to Root-knot nematode (GI)	Reaction to Viral disease (PDI)	Reaction to Fusarium wilt (PDI)
MM Sel-103 × MM-904	1.09**	4.14**	0.003	-0.38 **	-9.04**	-0.08	2.37**	-9.78**
MM Sel-103 × MM-625	-2.06**	-4.91**	-0.016	-0.31 *	-13.13**	-0.03	2.02**	-17.38**
MM Sel-103 × MM-610	-0.63**	-1.24*	0.037*	-0.13	3.13 **	-0.55	1.129*	-5.16**
MM Sel-103 × MM-1831	0.59**	-4.85**	-0.013	0.47**	-0.64	-0.26	-8.21**	8.56**
MM Sel-103 × MM 916/NS-1	-1.57**	1.07	-0.024	0.55**	-0.78	0.11	0.36	4.85**
MM Sel-103 × Riogold	-2.84**	-2.01**	-0.040*	-0.44**	2.76 *	0.55	-1.93**	2.27**
MM-904 × MM-625	-1.17**	0.35	-0.019	-0.37 **	4.16**	0.58	5.60**	3.29**
MM-904 × MM-610	-0.29	-6.78**	0.019	-0.68**	2.67 *	0.56	3.61**	7.81**
MM-904 × MM-1831	-1.06**	-4.29**	-0.051**	-0.03	-1.42	0.10	-0.01	2.72**
MM-904 × MM 916/NS-1	-1.63**	-2.75**	0.017	-0.40**	3.07**	-0.56	-6.66**	4.96**
MM-904 × Riogold	-1.35**	0.01	0.016	-0.55**	3.21 **	-0.02	4.72**	2.14**
MM-625 × MM-610	-0.40*	1.26*	0.010	-0.47**	2.69*	-0.68	3.85**	7.35**
MM-625 × MM-1831	-1.53**	3.52**	-0.020	0.27 *	2.21	0.40	-2.91**	-5.42**
MM-625 × MM 916/NS-1	4.39**	-6.50**	-0.037 *	0.657**	3.67 **	0.28	1.20*	3.86**
MM-625 × Riogold	0.68**	1.42*	-0.038*	0.55**	-6.33**	0.16	2.64**	2.29**
MM-610 × MM-1831	-0.57**	5.79**	-0.032	-0.43**	-7.77**	0.63	5.56**	7.79**
MM-610 × MM 916/NS-1	0.68**	-2.96**	-0.003	0.04	-2.54*	0.86*	-1.88**	-9.91**
MM-610 × Riogold	-0.484 **	-0.21	-0.080**	0.64**	3.61**	0.70	-5.29**	-9.73**
MM-1831 × MM 916/NS-1	2.85**	-5.57**	-0.019	-0.60**	-2.83*	0.05	5.00**	-4.68**
MM-1831 × Riogold	6.74**	-1.38*	-0.015	1.14**	-2.91 *	-0.008	-1.32*	2.49**
MM 916/NS-1 × Riogold	3.77**	5.26**	-0.001	-0.47**	-2.30 *	0.31	-7.83**	-2.72**
LSD (p≤0.05)	**0.35**	**1.21**	**0.035**	**0.26**	**2.23**	**0.70**	**1.04**	**1.16**
LSD (p≤0.01)	**0.46**	**1.62**	**0.047**	**0.35**	**2.97**	**0.94**	**1.39**	**1.56**

* Significant at 5% level & ** Significant at 1% level

MM - 904×MM-916/NS-1. These cross combinations regarded as good specific combiners for vine length.

4.2.3.13 Number of branches

The positive and significant SCA effects displayed three cross combinations. The best hybrids with highest SCA values were MM Sel-103 × MM-625 followed by Kajri × MM-1831 and KP_4HM-15 × MM-1831. These cross combinations regarded as good combiners for this trait.

4.2.3.14 TSS

Twelve hybrids gave positive and significant SCA effects. However, the best cross combinations were MS-1 × Kajri followed by Kajri × MM-904, KP_4HM-15 × MM Sel-103, MM-1831 × MM-916/NS-1, and MM-904 × MM-625. These cross combinations regarded as good combiners for higher TSS content.

4.1.3.15 β-carotene

Twenty hybrids combinations showed positive and significant SCA effects for β-carotene. The top hybrids with highest positive SCA values were Kajri × MM-625, Kajri × MM 916/NS-1, MM-904 × Riogold, Kajri × MM-1831, and MM Sel-103 × MM 916/NS-1. These cross combinations were regarded as good specific combiners for higher β-carotene content.

4.1.3.16 Firmness

Twelve crosses exhibited significantly positive SCA effects value and regarded as good specific combiners for this trait. The best combiners for SCA effects were MM-1831 × Riogold, MM-625 × MM 916/NS-1, MM 916/NS-1 × Riogold, MM-1831 × MM 916/NS-1, and MM Sel-103 × MM-904. These cross combinations regarded as good specific combiners for this trait.

4.1.3.17 Ascorbic acid

For this character positive value are desirable. Fifteen hybrids demonstrated significant and positive SCA value for ascorbic acid content**.** The best cross combination *viz.*, MS-1 × MM Sel-103, MM-610 × MM-1831, MS-1 × MM-1831, MM 916/NS-1 × Riogold, and KP_4HM-15 × MM-625. These cross combinations regarded as good specific combiners for this trait.

4.1.3.18 Titrable acidity

The significant and negative SCA value were exhibited by ten cross combinations. The best hybrids with highest SCA values were MM-610 × Riogold, MM-904 × MM-1831, KP_4HM-15 × MM-904, MS-1 × Kajri, and MS-1 × KP_4HM-15. These cross combinations were regarded as good specific combiners for this trait.

4.1.3.19 pH

Twenty-one hybrids exhibited negative and significant SCA effects for this trait. The hybrids with highest negative SCA values were MS-1 × MM-625, Kajri × MM 916/NS-1, Kajri × Riogold, Kajri × MM-625 and MS-1 × Riogold. These cross combinations regarded as good specific combiners for this trait.

4.1.3.20 Dry matter

The highest dry matter content with positive and significant SCA value was displayed by fifteen crosses. Hybrid KP_4HM-15 × MM 916/NS-1 was exhibited highest positive and significant SCA effect values followed by KP_4HM-15 × MM-1831, Kajri × Riogold, Kajri × MM Sel-103, and KP_4HM-15 × MM Sel-103. These cross combinations regarded as good specific combiners for this trait.

4.1.3.21 Reaction to root-knot nematode

Only three hybrids out of 45 hybrids displayed negative and significant SCA value and the desirable hybrids with highest negative SCA values were MS-1 × Riogold, MS-1 × MM-1831 and KP_4HM-15 × MM-904. These hybrids showed lowest incidence to root-knot nematode infestation and regared as best specific combiners.

4.1.3.22 Reaction to viral disease

The SCA effects for reaction to viruses were significant and negative in seventeen crosses and were, thus considered as good combiners for this trait. The best specific combiners were KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-610, MM Sel-103 × MM-1831, Kajri × MM-625, and MM 916/NS-1 × Riogold. These hybrids showed the lowest incidence to virus infestation.

4.1.3.23 Reaction to Fusarium wilt

The Fusarium wilt incidence with negative and significant value was displayed by fifteen cross combinations. The highest lower SCA value was displayed by hybrids *viz.*, MM Sel-103 × MM-625, MS-1 × Kajri, Kajri × MM-904, MM-610 × MM 916/NS-1, and MM-610 × Riogold. These hybrids showed lowest incidence to wilt infestation and were regarded as the best specific combiners.

It was concluded that cross combinations showing positive SCA effects were MS-1 × MM-610, KP_4HM-15 × MM-904, and KP_4HM-15 × MM Sel-103 for Yield (t ha^{-1}). MM Sel-103 × MM-1831 followed by Kajri × MM 916/NS-1, and MM Sel-103 × Riogold for Days taken to 1st fruit harvest. Hybrid Kajri × MM-904 followed by MM-1831 × MM 916/NS-1, and KP_4HM-15 × MM Sel-103 showed the highest SCA value for TSS content. Dry matter (%) with positive and significant value was displayed by two crosse combination KP_4HM-15 × MM 916/NS-1, KP_4HM-15 × MM-1831, and Kajri × Riogold showing desirable SCA effects. The hybrids MM Sel-103 × MM-625, MS-1 × Kajri, and Kajri × MM-904 were the

best specific combination for showing lowest SCA value for reaction to fusarium wilt. Hybrids KP_4HM- 15 × MM Sel-103, KP_4HM-15 5 × MM-610, and MM Sel-103 × MM-1831 identified as specific crosses for virus. In case of Fruit yield, significant SCA effects were recorded by various workers (Gurav *et al* (2000), Moon *et al* (2003), Tomar and Bhalala (2006), Glala *et al* (2011). Higher SCA effects for earliness was suggested by Kumar *et al* (2005). In case of fruit weight some studies have been reported by Munshi and Verma (1997), Gurav *et al* (2000) and Vashisht *et al* (2010). In case of no. of fruits per plant higher SCA effects was detected by Gurav *et al* (2000) and Vashisht *et al* (2010).

Table 4.5: Top cross combinations based on GCA effects and per se performance in the desirable direction for different characters of muskmelon

Traits	Best parent based on GCA performance	Best parent based on *per se* performance
Average fruit weight (g)	MM-610	MM 916/NS-1
No. of fruits per plant	KP_4HM-15	Kajri
Fruit yield (t ha^{-1})	MM-625	MM 916/NS-1
Days to 1st female flower	MM-625	MS-1
Days to 1st fruit harvest	Riogold	MS-1
Polar diameter (cm)	Kajri	MM-1831
Equatorial diameter (cm)	MM-1831	MM-1831
Flesh thickness (cm)	Riogold	Riogold
Rind thickness (mm)	MM-625	MM Sel-103
Fruit cavity area (cm^2)	MM-904	Kajri
Fruit shape index	MM-904	MM-904
Vine length (m)	Riogold	MM-904
No. of branches	-	Riogold
TSS (□Brix)	MM 916/NS-1	KP_4HM-15
β-carotene (mg/100g)	MM-625	Riogold
Firmness in (lb/ $inch^2$)	Riogold	MS-1
Ascorbic Acid (mg/100g)	MM-610	MM-625
Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	Kajri	MM-625
pH	MM-625	MM-1831
Dry matter (%)	MM-610	MS-1
Reaction to root-knot nematode (GI)	Kajri	Kajri
Reaction to viral disease (PDI)	MS-1	MS-1
Reaction to fusarium wilt (PDI)	MM-610	MM-610

Top parents based on GCA and *per se* performance in desirable direction for various parameters are displayd in Table 4.5. Out of top parents for the traits under studied, six characters were exhibited by common parents except average fruit weight, no. of fruits per plant, Days taken to 1st female flower emergence, Days taken to 1st female flower emergence, polar diameter, pulp thickness, rind thickness, fruit cavity area, vine length, no of branches, TSS, ascorbic acid, acidity, beta carotene, firmness, pH, dry matter %, and fruit yield (t ha^{-1}).

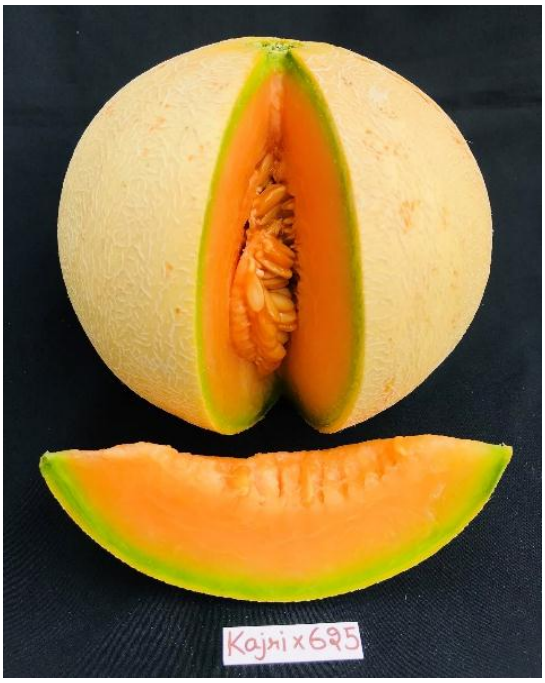
The results of top cross combinations based on GCA effects and *per se* performances in the desirable direction for various parameters are displayed in Table 4.6. Top crosses showing highest SCA effects presented in Plate 4.1 & 4.2. In the cross combinations at least two were common for GCA value and *per se* performance for most of the parameters. This indicated that in general there was a close relationship existed between CA effects and *per se* performance for most of the parameters studied in muskmelon.

Table 4.6: Top cross combinations based on SCA effects and *per se* performance in the desirable direction for different characters of muskmelon

Traits	Top crosses based on SCA performance	Top crosses based on *per se* performance
Average fruit weight (g)	MS-1 × MM-610 MM-610 × MM 916/NS-1 MM 916/NS-1 × Riogold	MM-610 × MM 916/NS-1 MM 916/NS-1 × Riogold MS-1 × MM-610
No. of fruits per plant	MM Sel-103 × MM-904 MM-904 × MM-1831 KP_4HM-15 × Riogold	MM Sel-103 × MM-904 KP_4HM-15 × MM-904 KP_4HM-15 × MM Sel-103
Fruit yyield (t ha^{-1})	MS-1 × MM-610 KP_4HM-15 × MM-904 KP_4HM-15 × MM Sel-103	KP_4HM-15 × MM Sel-103 KP_4HM-15 × MM-625 MS-1 × MM-610
Days taken to 1st female flower emergence	Kajri × Riogold Kajri × MM 916/NS-1 MM Sel-103 × Riogold	MM Sel-103 × Riogold Kajri × Riogold MM Sel-103 × MM-904
Days taken to 1st fruit harvest	MM Sel-103 × MM-1831 MM-625 × MM-1831 MM-904 × MM-610	MM-904 × Riogold MM-625 × MM-1831 Kajri × Riogold
Polar diameter (cm)	MM Sel-103 × MM-904 KP_4HM-15 × Riogold MM Sel-103 × MM-625	Kajri × MM 916/NS-1 KP_4HM-15 × Riogold MM Sel-103 × MM-904
Equatorial diameter (cm)	Kajri × MM-610 MM-625 × Riogold MM-1831 × Riogold	Kajri × MM-1831 MM-904 × MM 916/NS-1 MM-1831 × Riogold
Flesh thickness (cm)	MM Sel-103 × MM-625 MM 916/NS-1 × Riogold MS-1 × MM-610	MM 916/NS-1 × Riogold MM-610 × Riogold MM Sel-103 × MM-1831

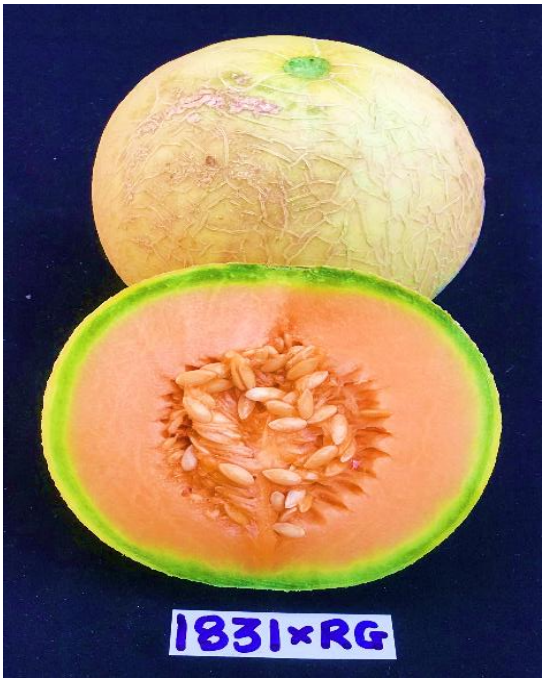
Traits	Top crosses based on SCA performance	Top crosses based on *per se* performance
Rind thickness (mm)	MS-1 × MM 916/ NS-1 MM-610 × Riogold MM-610 × MM-1831	MS-1 × MM-625 MM-610 × MM-1831 MM-610 × Riogold
Fruit cavity area (cm2)	MS-1 × MM 916/ NS-1 MM-610 × Riogold MM Sel-103 × MM-625	Kajri × KP_4HM-15 KP_4HM-15 × MM-1831 KP_4HM-15 × MM 916/NS-1
Fruit shape index	MS-1 × MM 916/ NS-1 Kajri × MM-625 MM-904 × Riogold	KP_4HM-15 × MM-904 MM-904 × Riogold MS-1 × MM 916/ NS-1
Vine length (m)	Kajri × KP_4HM-15 Kajri × MM-625 MM-625 × MM 916/NS-1	Kajri × MM-625 MM-625 × MM 916/NS-1 MS-1 × MM-1831
No. of Branches	MM Sel-103 × MM-625 Kajri × MM-1831 KP_4HM-15 × MM-1831	KP_4HM-15 × MM-1831 MS-1 × MM-625 KP_4HM-15 × Riogold
TSS (° Brix)	MS-1 × Kajri MM-1831 × MM 916/NS-1 KP_4HM-15 × MM Sel-103	MM-1831 × MM 916/NS-1 MM Sel-103 × MM 916/NS-1 KP_4HM-15 × MM Sel-103
β-carotene (mg)	Kajri × MM-625 MM-904 × MM-625 MM-610 × MM 916/NS-1	Kajri × MM-625 MM-610 × MM 916/NS-1 MM-904 × MM-625
Firmness (lb/ inch^2)	MM-1831 × Riogold MM-625 × MM 916/NS-1 MM 916/NS-1 × Riogold	MM-1831 × Riogold MM 916/NS-1 × Riogold MM-625 × MM 916/NS-1
Ascorbic acid (mg)	MS-1 × MM Sel-103 MM-610 × MM-1831 MS-1 × MM-1831	MM-610 × MM-1831 MS-1 × MM Sel-103 MM-625 × MM-1831
Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	MM-610 × Riogold MM-904 × MM-1831 KP_4HM-15 × MM-904	MM-625 × Riogold MM-904 × MM-1831 MM Sel-103 × Riogold
pH	MS-1 × MM-625 Kajri × MM 916/NS-1 Kajri × Riogold	Kajri × MM-610 Kajri × MM-1831 MS-1 × MM-610
Dry matter %	KP_4HM-15 × MM 916/NS-1 KP_4HM-15 × MM-1831 Kajri × Riogold	KP_4HM-15 × MM 916/NS-1 Kajri × Riogold MM-904 × MM-625
Reaction to root-knot nematode	MS-1 × Riogold MS-1 × MM-1831 KP_4HM-15 × MM-904	Kajri × MM-610 Kajri × MM-625 Kajri × MM-904
Reaction to viral disease	KP_4HM-15 × MM Sel-103 KP_4HM-15 × MM-610 MM Sel-103 × MM-1831	KP_4HM-15 × MM Sel-103 MS-1 × Riogold KP_4HM-15 × MM-610
Reaction to fusarium wilt	MM Sel-103 × MM-625 MS-1 × Kajri Kajri × MM-904	MM Sel-103 × MM-625 MS-1 × Kajri Kajri × MM-904

TSS content



β-carotene content

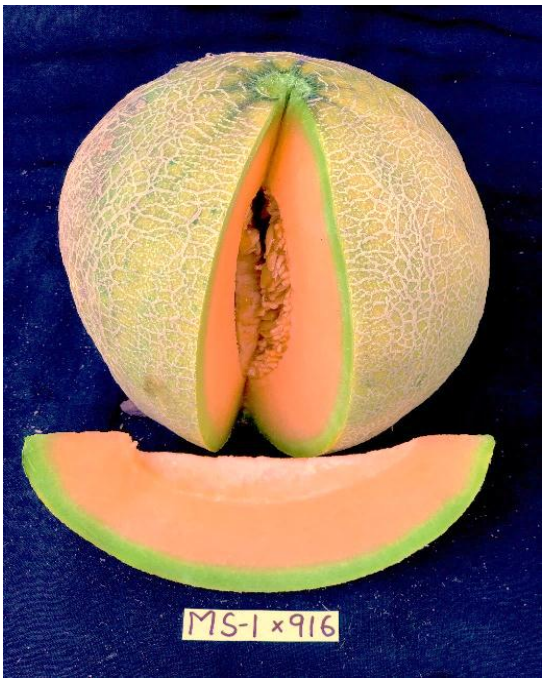
Ascorbic acid content



Firmness

Plate 4.1 Best F_1 Hybrids for Quality traits

Flesh thickness



Rind thickness & Fruit shape index

Small and compact fruit cavity area

Fruit Netting

Plate 4.2 Best F_1 Hybrids for fruit traits

Table 4.7: Top cross combinations with consistent significant SCA effects for different characters along with ranking of parents based on effects of muskmelon

Characters	Top cross combination on SCA basis	Ranking of parents based on GCA basis
Average fruit weight (g)	MS-1 × MM-610	Low × High
No. of fruits per plant	MM Sel-103 × MM-904	High × Low
Fruit yield (t ha^{-1})	MS-1 × MM-610	Low × Low
Days taken to 1st female flower	Kajri × Riogold	Low × Low
Days taken to 1st fruit harvest	MM Sel-103 × MM-1831	Low × High
Polar diameter (cm)	MM Sel-103 × MM-904	Low × Low
Equatorial diameter (cm)	Kajri × MM-610	Low × Low
Flesh thickness (cm)	MM Sel-103 × MM-625	Low × High
Rind thikness (mm)	MS-1 × MM 916/ NS-1	High × Low
Fruit cavity area (cm^2)	MS-1 × MM 916/ NS-1	High × Low
Fruit shape index	MS-1 × MM 916/ NS-1	High × Low
Vine length (m)	Kajri × KP_4HM-15	Low × Low
No. of Branches	MM Sel-103 × MM-625	Low × Low
TSS (□ Brix)	Kajri × MM-904	Low × Low
β-carotene (mg/100g)	Kajri × MM-625	Low × High
Firmness in (lb/ $inch^2$)	MM-1831 × Riogold	High × High
Ascorbic Acid (mg/100g)	MS-1 × MM Sel-103	High × Low
Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	MM-610 × Riogold	Low × High
pH	Kajri × MM-610	High × Low
Dry matter %	KP_4HM-15 × MM 916/NS-1	Low × Low
Reaction to nematode (GI)	MS-1 × Riogold	Low × Low
Reaction to viral disease (PDI)	KP_4HM-15 × MM Sel-103	High × High
Reaction to fusarium wilt (PDI)	MM Sel-103 × MM-625	Low × Low

The grading of parents based on GCA effects exhibited significant and maximum values of SCA effects in desirable direction is presented in Table 4.7. Two characters firmness and reaction to viral disease showed that there was a good tendency of transmitting higher genetic improvement from the parents to the F_1 hybrids involving additive gene action in that particular cross. On the other hand, for remaining characters the best hybrids involved both parents having low GCA effects. This might be due to the presence of complementary

gene action for these characters.

4.3 Estimation of Heterosis

4.3.1 Heterobeltiosis

The results pertaining to heterosis over the better parent for different characters have been presented in the Table 4.8. and had been discussed below character-wise.

4.3.1.1 Average fruit weight (g)

Out of 45 hybrids, 8 hybrids showed significant and positive heterobeltiosis. The highest estimates of positive significant heterobeltiosis were observed in hybrids viz., MS-1 × MM-610, MM Sel-103 × MM-610, KP_4HM-15 × MM Sel-103, MM-610 × MM 916/NS-1, and MM-625 × MM-610. The results are in concord with those of Tomar and Bhalala (2006), Subramanian (2008), Nerson H (2010) and Jagtap and Musmade (2014).

4.3.1.2 Number of fruits per plant

Twelve crosses revealed positive and significant heterotic effects for this trait. The highest estimates of significant positive heterobeltiosis were expressed by hybrids MM Sel-103 × MM-904 followed by KP_4HM-15 × MM-904 (80.00%) and KP_4HM-15 × MM Sel-103, and MM Sel-103 × MM-625. Similarly, Lakshmi *et al* (2016), Hassan *et al* (2018) and Duradundi *et al* (2017) also observed the significant heterosis for no. of fruits per vine.

4.3.1.3 Fruit yield

Twelve hybrids exhibited significant results for fruit yield per ha^{-1}. Maximum significant heterobeltiosis in a positive way was shown by KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-904, MM Sel-103 × MM-610 and KP_4HM-15 × MM-625. Results are in accord with Chaudhary *et al* (2003), Gurav *et al* (2000), Moon *et al* (2003), Kumar *et al* (2005), Tomar and Bhalala (2006b), Herman and Peri Treves (2007) and Pornsuriya P *et al* (2014).

4.3.1.4 Days taken to 1st female flower

Out of forty-five, 40 hybrids revealed significantly results. Among these the cross with maximum negative significant heterobeltiosis was shown Kajri × Riogold followed by Kajri × MM-916/NS-1, MS-1 × Kajri, MM Sel-103 × Riogold and Kajri × KP_4HM-15. The heterosis for earliness had also been documented by Tomar and Bhalala (2006) and Zalapa *et al* (2008), Saha (2017) and Duradundi *et al* (2017).

4.3.1.5 Days taken to 1st fruit harvest

All the hybrids exhibited significantly negative heterosis over the respective better parents except Kajri × KP_4HM-15. Among all the cross, the maximum negative significant heterobeltiosis was shown by hybrids *viz.*, MM-625 × MM-1831 followed by MM-625 × MM-916/NS-1, MM-625 × Riogold, MM Sel-103 × MM-1831, and MM-904 × MM-1831. The heterosis for earliness had also been documented by Tomar and Bhalala (2006), Zalapa *et*

al (2008), Lakshmi *et al* (2016), Saha (2017) and Duradundi *et al* (2017).

4.3.1.6 Polar diameter

Fourteen hybrids had significant positive heterosis for polar diameter. Maximum positive significant heterosis was expressed by hybrids KP_4HM-15 × Riogold, Kajri × MM-625, Kajri × Riogold, Kajri × KP_4HM-15 and Kajri × MM-916/NS-1. Similar results were found by Pornsuriya P *et al* (2014) and Costa *et al* (2019).

4.3.1.7 Equatorial diameter

Six hybrids had significant positive heterosis for this trait. Hybrid Kajri × Riogold exhibited maximum positive significant heterobeltiosis followed by hybrid Kajri × MM-610, MM-625 × Riogold, Kajri × MM-625, Kajri × MM-916/NS-1, and MS-1 × Riogold. Similar results were found by Pornsuriya P *et al* (2014) and Costa *et al* (2019).

4.3.1.8 Flesh thickness

Only two hybrids namely MM Sel-103 × MM-625 and MS-1 × MM-610 out of forty-five hybrids showed significant positive heterosis over the better parents for this character. The heterosis for thick flesh had also been documented by Sedera *et al* (2016), Hassan *et al* (2018) and Costa *et al* (2019).

4.3.1.9 Rind thickness

Only four hybrids viz., MS-1 × MM 916/ NS-1, MM-610 × MM 916/NS-1, MS-1 × MM-610, and MM-610 × Riogold exhibited significant positive heterobeltiosis for rind thickness (mm). The heterosis for thick rind had also been documented by Sedera *et al* (2016).

4.3.1.10 Fruit cavity area

Seventeen hybrids had significant and negative heterosis for this trait over the respective better parent. Hybrid KP_4HM-15 × MM-1831 was exhibited highest negative significant heterobeltiosis followed by hybrid MM-904 × MM-1831, MM-904 × Riogold, Kajri × Riogold, MM-625 × MM 916/NS-1.

4.3.1.11 Fruit shape index

Only one hybrid MS-1 × MM-916/NS-1 out of forty-five crosses showed positive and significant heterosis over the better parents for fruit shape index.

4.3.1.12 Vine length

For vine length, twenty-three hybrids showed significant negative heterobeltiosis. Maximum heterosis was shown by crosses *viz.,* Kajri × MM-625 (-39.36%) followed by MS-1 × Riogold (-37.72), Kajri × KP_4HM-15 (-33.31), MS-1 × MM-1831, and Kajri × MM-904. Similar results were recorded by Chaudhury *et al* (2003), Tomar and Bhalala (2006b), Kamer *et al* (2015) and Duradundi *et al* (2017).

Table 4.8: Estimation of heterosis (%) over the respective better parents for different characters of muskmelon

Crosses/Traits	Average fruit weight (g)	No of fruits per vine	Fruit yield (t ha^{-1})	Days taken to 1st female flower open	Days taken to 1st fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)
MS-1 × Kajri	10.31	-24.72 **	-1.13	-2.52	0.52	1.21	-1.74
MS-1 × KP_4HM-15	6.85	-9.91 *	-3.75	-3.36	0.52	7.05	6.73
MS-1 × MM Sel-103	-8.9	-9.91 *	-17.50 **	-3.36	-1.04	-1.4	-6.86 *
MS-1 × MM-904	-11.39	-11.41 *	-21.50 **	-9.24 **	-3.11 **	-7.62	-10.42 **
MS-1 × MM-625	-0.69	-2.4	19.79 **	-5.04	-1.55	2.57	-3.21
MS-1 × MM-610	40.18 **	8.71	62.52 **	-3.36	-1.55	10.93 **	0.3
MS-1 × MM-1831	-37.54 **	-19.37 **	-49.17 **	-3.36	-1.55	-4.79	-11.02 **
MS-1 × MM 916/ NS-1	-25.15 **	-19.37 **	-36.19 **	-6.72 **	-1.55	-5.06	-1.32
MS-1 × Riogold	-16.67 **	-31.98 **	-35.69 **	-5.88 *	-1.55	9.70 *	7.79 *
Kajri × KP_4HM-15	-10.93	-34.43 **	-32.20 **	-3.36	-0.50	20.14 **	6.6
Kajri × MM Sel-103	21.17 **	-45.78 **	-17.41 **	-6.25 **	-0.50	7.3	-12.81 **
Kajri × MM-904	-23.00 **	-36.95 **	-43.98 **	-4.03	-3.98 **	-1.21	-14.58 **
Kajri × MM-625	-22.35 **	-10.21 *	8.09 *	-1.68	-5.97 **	23.15 **	12.88 **
Kajri × MM-610	-16.08 **	-41.99 **	-34.92 **	-2.46	0.50	10.19 *	13.97 **
Kajri × MM-1831	-22.63 **	-45.40 **	-49.94 **	-2.44	0.50	8.11 *	4.56
Kajri × MM 916/NS-1	-25.96 **	-43.25 **	-47.45 **	-14.17 **	-5.47 **	16.68 **	9.25 *
Kajri × Riogold	10.12	-31.02 **	2.45	-12.90 **	-6.15 **	20.90 **	17.09 **
KP_4HM-15 × MM Sel-103	24.36 **	86.33 **	141.59 **	-5.04	-4.95 **	3.56	-1.53
KP_4HM-15 × MM-904	9.55	98.00 **	117.91 **	-4.20	-5.94 **	0.76	-5
KP_4HM-15 × MM-625	7.9	70.00 **	93.89 **	-5.04	-5.94 **	5.77	-4.37
KP_4HM-15 × MM-610	-3.58	3.47	7.94	-5.04	-6.44 **	-1.67	-7.56 *
KP_4HM-15 × MM-1831	-12.75 *	16.21 **	1.31	-4.20	-6.44 **	10.43 *	-0.29
KP_4HM-15 × MM 916/NS-1	-32.42 **	0.79	-32.05 **	-5.88 *	-8.91 **	10.76 **	1.01
KP_4HM-15 × Riogold	-10.61 *	52.13 **	35.99 **	-5.88 *	-6.15 **	27.84 **	5.8

Crosses/Traits	Average fruit weight (g)	No of fruits per vine	Fruit yield (t ha^{-1})	Days taken to 1st female flower open	Days taken to 1st fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)
MM Sel-103 × MM-904	-18.03 **	104.60 **	78.00 **	-12.10 **	-6.44 **	10.76 **	-5.62
MM Sel-103 × MM-625	4.02	76.60 **	86.06 **	-7.56 **	-4.33 **	9.17 *	-2.64
MM Sel-103 × MM-610	36.07 **	50.21 **	112.25 **	-7.38 **	-6.80 **	-6.94	-10.33 **
MM Sel-103 × MM-1831	15.45 **	-29.39 **	-18.47 **	-7.32 **	-11.59 **	-27.18 **	-18.18 **
MM Sel-103 × MM 916/NS-1	-30.32 **	-15.24 **	-40.94 **	-11.02 **	-7.43 **	-28.44 **	-17.52 **
MM Sel-103 × Riogold	-4.46	2.73	-1.89	-15.32 **	-5.13 **	-29.62 **	-15.83 **
MM-904 × MM-625	-35.99 **	40.00 **	-4.74	-0.84	-4.95 **	-22.74 **	-10.58 **
MM-904 × MM-610	-18.50 **	18.00 **	6.25	-4.10	-9.41 **	-5.96	0
MM-904 × MM-1831	-41.66 **	38.94 **	-18.92 **	-8.13 **	-9.41 **	-6.58	2.78
MM-904 × MM 916/NS-1	-49.68 **	5.71	-46.79 **	-7.26 **	-9.41 **	0.13	5.25
MM-904 × Riogold	-25.07 **	-9.03	-31.84 **	-8.87 **	-6.67 **	-10.31 *	-10.54 **
MM-625 × MM-610	19.91 **	27.43 **	52.80 **	-4.20	-6.80 **	-15.74 **	-13.55 **
MM-625 × MM-1831	-0.8	-12.12 *	-12.96 **	-4.20	-12.08 **	-6.85	-4.81
MM-625 × MM 916/NS-1	-7.93	3.65	-4.59	-10.08 **	-9.41 **	0.59	5.42
MM-625 × Riogold	9.57	-22.83 **	-14.40 **	-9.24 **	-6.15 **	13.57 **	13.16 **
MM-610 × MM-1831	0.16	-31.36 **	-31.27 **	-9.02 **	-5.34 **	-3.54	-4.81
MM-610 × MM 916/NS-1	20.17 **	-26.03 **	-11.12 **	-9.84 **	-4.46 **	-3.69	-4.83
MM-610 × Riogold	5.93	-22.83 **	-18.39 **	-1.64	-1.03	-11.39 **	-10.38 **
MM-1831 × MM 916/NS-1	-1.91	-25.76 **	-24.97 **	-4.88	-3.47 **	-4.93	-6.51
MM-1831 × Riogold	-1.35	-31.36 **	-32.28 **	-6.50 **	-0.51	4.97	3.32
MM 916/NS-1 × Riogold	16.23 **	-6.35	8.85 **	-4.03	-1.03	-1.09	4.14
LSD (p≤0.05)	**85.84**	**0.31**	**1.6**	**3**	**1.97**	**0.89**	**0.82**
LSD (p≤0.01)	**113.72**	**0.41**	**2.1**	**3.98**	**2.61**	**1.10**	**1.08**

* Significant at 5% level & ** Significant at 1% level

Table 4.8 Continued….

Crosses/Traits	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)	Number of Branches	TSS (□Brix)	β-carotene (mg/100g)
MS-1 × Kajri	6.71	14.78	146.1**	0	-19.14**	-3.67	50.7**	-27.89**
MS-1 × KP_4HM-15	-14	14.78	74.55**	-1	-16.40 **	3.93	7.59	0.89
MS-1 × MM Sel-103	7.62	-23.76*	46.90 **	-0.54	-11.73 *	-0.12	16.52	-12.93 **
MS-1 × MM-904	3.81	-3.67	49.18 **	-9.6**	6.97	0.12	18.04	-35.3**
MS-1 × MM-625	7.0	0	113.58 **	-0.54	2.75	11.66	0.48	37.98 **
MS-1 × MM-610	24.34 *	29.67 *	65.19 **	-2.44	3.06	-7.62	2.23	-22.38 **
MS-1 × MM-1831	-18.50 *	-19.98 *	23.06	2.55	-26.97 **	0.12	5.62	27.60 **
MS-1 × MM 916/ NS-1	13.4	44.44 **	98.78 **	16.84 **	1.47	-10.61	28.33 **	-7.42
MS-1 × Riogold	-23.08 **	-6.28	5.88	-1.06	-15.13 **	-34.40 **	2.57	-56.49 **
Kajri × KP_4HM-15	-33.33 **	-0.15	-18.76	-23.88 **	-30.19 **	-11.11	-41.65 **	-22.4
Kajri × MM Sel-103	16.33	-21.07 *	103.17 **	-0.58	-9.09	0	16.68	10.63 *
Kajri × MM-904	-6.04	11	15.91	-23.01 **	2.62	-7.44	35.03 **	-61.47 **
Kajri × MM-625	0.76	-11.93	162.39 **	8.19	-13.16 *	-11.11	-8.5	109.15 **
Kajri × MM-610	-5.7	11.11	50.99 **	-9.27 *	26.69 **	-14.78	-9.53	-82.38 **
Kajri × MM-1831	-6.81	-14.24	107.76 **	-5.1	-16.88 **	22.22	14.11	39.33 **
Kajri × MM 916/NS-1	-11.28	-11.55	72.92 **	-9.47 *	24.37 **	-10.72	42.56 **	58.28 **
Kajri × Riogold	-18.37 *	-37.58 **	41.49 *	-2.65	31.65 **	-21.93 *	28.86 **	-22.94 **
KP_4HM-15 × MM Sel-103	7.33	-42.15 **	33.33 *	-5.47	38.56 **	-7.73	20.54 **	9.77 *
KP_4HM-15 × MM-904	-17.11	10.04	10.02	-6.69	56.41 **	23.86	-21.12 **	-4.8
KP_4HM-15 × MM-625	-6.31	-38.07 **	53.84 **	-3.98	34.89 **	22.62	5.49	26.83 **
KP_4HM-15 × MM-610	5.26	-18.44	46.49 **	-0.49	35.62 **	0.12	3.84	-52.67 **
KP_4HM-15 × MM-1831	-11.52	-57.12 **	-15.16	-3.98	30.89 **	25	18.30 *	-50.33 **
KP_4HM-15 × MM 916/NS-1	-19.15	7.74	-9.82	-4.48	96.27 **	-3.54	16.34 *	-4.83
KP_4HM-15 × Riogold	-23.08 **	-6.28	62.06 **	-5.97	-3.39	-9.37	8.04	-26.19 **

Crosses/Traits	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)	Number of Branches	TSS (□Brix)	β-carotene (mg/100g)
MM Sel-103 × MM-904	-1.35	-50.04 **	43.98 *	-22.59 **	26.42 **	0	19.25 *	-55.46 **
MM Sel-103 × MM-625	28.68 **	-16.71 *	34.88 **	2.35	50.12 **	26.87 *	13.63	31.90 **
MM Sel-103 × MM-610	2.19	-13.18	21.95 *	-14.63 **	9.34	-3.92	-7.74	-14.46 **
MM Sel-103 × MM-1831	0.17	-13.18	10.39	-15.31 **	9.24	-7.73	-1.87	-45.40 **
MM Sel-103 × MM 916/NS-1	-5.74	-39.46 **	-12.15	-3.68	22.03 **	-14.26	48.69 **	49.14 **
MM Sel-103 × Riogold	-13.66	-34.18 **	-11.33	-9.52 *	2.61	-21.93 *	18.87 *	-46.32 **
MM-904 × MM-625	0	-14.79	109.79 **	-17.99 **	38.88 **	4.5	21.12 *	77.13 **
MM-904 × MM-610	1.54	-18.56	49.96 **	-9.21 *	20.31 **	-19.17	-6.92	-75.84 **
MM-904 × MM-1831	-21.99 *	-28.56 **	9.32	-18.83 **	14.21 *	-4.12	5.14	-8.33
MM-904 × MM 916/NS-1	-17.02	-7.62	27.20	-19.67 **	-4.36	-24.97 *	41.45 **	-32.07 **
MM-904 × Riogold	-29.36 **	-25.02 *	37.53 *	-7.53 *	6.36	-28.12 **	-10.19	-11.69 **
MM-625 × MM-610	-3.82	-28.57 **	21.17 *	-4.88	-1.75	-7.62	15.22	-7.13 *
MM-625 × MM-1831	-6.81	-19.07 *	14.12	-6.63	-7.83	0	7.2	24.09 **
MM-625 × MM 916/NS-1	-22.75 *	-42.86 **	-18.69	-4.21	-9.45	-14.26	13.44	7.32
MM-625 × Riogold	-18.84 *	-21.43 *	-5.98	-1.59	27.83 **	-15.65	1.63	-37.66 **
MM-610 × MM-1831	-8.73	16.38	55.65 **	-2.93	18.26 **	-7.62	6.24	-12.87 **
MM-610 × MM 916/NS-1	9.15	40.78 **	58.39 **	-5.85	24.37 **	0	27.38 **	19.41 **
MM-610 × Riogold	-6.44	25.02 *	83.95 **	-3.41	22.96 **	-25.02 *	12.24	-27.13 **
MM-1831 × MM 916/NS-1	-15.01	-14.24	35.42 **	-2.55	36.43 **	-7.07	43.21 **	-21.67 **
MM-1831 × Riogold	-8.48	-11.32	3.15	-0.51	15.39 **	-31.21 **	22.42 **	15.80 **
MM 916/NS-1 × Riogold	-2.67	-3.09	43.63 **	0.53	7.57	-18.74	28.70 **	16.23 **
LSD (p≤0.05)	**0.49**	**1.16**	**2.29**	**0.08**	**0.63**	**1.11**	**1.69**	**0.17**
LSD (p≤0.01)	**0.65**	**1.53**	**3.04**	**0.11**	**0.84**	**1.47**	**2.24**	**0.22**

* Significant at 5% level & ** Significant at 1% level

Table 4.8 Continued….

Crosses/Traits	Firmness in (lb/ inch^2)	Ascorbic Acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter %	Reaction to RNK (GI)	Reaction to VD (PDI)	Reaction to Wilt(PDI)
MS-1 × Kajri	-50.6**	-25.8 **	-31.03	-14.1**	-5.5**	71.4**	57.7 **	-65.2**
MS-1 × KP$_4$HM-15	-54.1**	-51.4**	8.00	-10.1*	-11.5**	25.0	45.8**	44.2**
MS-1 × MM Sel-103	-37.9**	-7.7*	-25.81	-26.2 **	-3.64*	4.00	65.9**	-33.2**
MS-1 × MM-904	-46.9**	-13.4 **	-14.29	-12.6**	-4.2*	31.5*	47.0**	-1.39
MS-1 × MM-625	-34.14 **	-60.49 **	41.67	-44.44 **	-0.96	33.33	-2.87	-1.93
MS-1 × MM-610	-46.9**	-12.76 **	0.00	-4.04	-0.09	35.0	39.7**	46.1**
MS-1 × MM-1831	-46.55 **	-0.3	-17.14	-23.23 **	-3.57 *	-25.00 *	65.39 **	55.33 **
MS-1 × MM 916/ NS-1	-35.86 **	-18.89 **	6.06	-27.27 **	-7.06 **	15.79	82.79 **	-12.50 **
MS-1 × Riogold	-34.83 **	-52.44 **	-6.25	-34.34 **	-18.18 **	-27.50 *	-13.58 *	-2.90
Kajri × KP$_4$HM-15	-33.64 **	-15.90 **	0.00	-6.25	8.41 **	80.95 **	-15.00 **	51.06 **
Kajri × MM Sel-103	-29.09 **	-15.19 **	-3.45	-15.63 **	4.61 *	35.71	28.14 **	-44.34 **
Kajri × MM-904	-30.45 **	-45.62 **	-10.34	-17.48 **	2.06	23.81	0.28	-57.39 **
Kajri × MM-625	-15.00 **	-29.66 **	-12.50	-30.21 **	-3.64 *	21.43	-36.04 **	5.50 *
Kajri × MM-610	-18.64 **	-16.35 **	-31.03	18.75 **	0.53	7.14	-41.00 **	41.03 **
Kajri × MM-1831	-20.91 **	-12.76 **	-20.69	11.46 **	-6.89 **	57.14 *	20.16 **	19.57 **
Kajri × MM 916/NS-1	-22.73 **	6.41	10.34	-28.13 **	6.97 **	114.29 **	108.27 **	-17.66 **
Kajri × Riogold	-31.82 **	-15.12 **	41.38 *	-29.17 **	3.36	66.67 *	-12.50 **	-7.25 **
KP$_4$HM-15 × MM Sel-103	-41.14 **	-1.6	92.00 **	-17.78 **	1.06	25.00	-60.95 **	49.87 **
KP$_4$HM-15 × MM-904	-11.1 *	-14.8 **	4.0	-30.1 **	-8.0**	-9.37	-30.8 **	31.3**
KP$_4$HM-15 × MM-625	-54.46 **	-19.13 **	154.17 **	-20.45 **	-6.62 **	19.05	-6.06	38.30 **
KP$_4$HM-15 × MM-610	-52.25 **	-50.98 **	40.00	-14.81 **	-1.48	3.33	-54.76 **	85.21 **
KP$_4$HM-15 × MM-1831	-15.87 **	-60.58 **	40.00	-13.58 **	1.63	18.75	56.69 **	52.17 **
KP$_4$HM-15 × MM 916/NS-1	2.56	-3.18	56.00 *	-20.21 **	10.21 **	40.63 *	70.83 **	57.45 **
KP$_4$HM-15 × Riogold	-49.3**	-35.88 **	16.00	-18.6**	-6.3**	12.50	3.43	49.6 **

Crosses/Traits	Firmness in (lb/ inch^2)	Ascorbic Acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter %	Reaction to RNK (GI)	Reaction to VD (PDI)	Reaction to Wilt(PDI)
MM Sel-103 × MM-904	-22.15 **	-16.99 **	0.00	-30.10 **	-11.25 **	0.00	45.23 **	-42.94 **
MM Sel-103 × MM-625	-47.89 **	-54.86 **	4.17	-23.33 **	-18.15 **	14.29	17.46 **	-64.34 **
MM Sel-103 × MM-610	-34.27 **	-36.76 **	22.58	-13.33 **	2.82	0.00	0.00	0.00
MM Sel-103 × MM-1831	-2.53	-50.72 **	-16.13	0	-5.50 **	0.00	-1.57	60.87 **
MM Sel-103 × MM 916/NS-1	-25.32 **	-18.48 **	-16.13	-4.26	-2.85	17.33	66.67 **	-1.20
MM Sel-103 × Riogold	-48.37 **	-33.52 **	-38.71 *	-23.33 **	-2.11	20.00	-12.00 **	-6.52 *
MM-904 × MM-625	-46.01 **	-22.85 **	4.17	-33.98 **	0.89	34.92 *	47.99 **	11.62 **
MM-904 × MM-610	-38.20 **	-44.68 **	-7.89	-34.95 **	3.71 *	38.33 *	32.09 **	91.59 **
MM-904 × MM-1831	-15.08 **	-38.25 **	-50.00 **	-22.33 **	-5.02 **	13.70	19.53 **	56.74 **
MM-904 × MM 916/NS-1	-11.97 *	-31.90 **	6.06	-31.07 **	2.65	2.74	-12.60 *	7.86 **
MM-904 × Riogold	-40.93 **	-28.53 **	-3.12	-34.95 **	-0.34	8.22	37.76 **	7.25 **
MM-625 × MM-610	-25.35 **	-15.49 **	29.17	-23.86 **	0.43	-6.67	10.02 **	84.62 **
MM-625 × MM-1831	-30.05 **	-12.70 **	-4.17	-6.82	-1.84	38.10 *	14.65 **	17.39 **
MM-625 × MM 916/NS-1	29.11 **	-49.27 **	-8.33	-6.38	0	42.86 *	54.00 **	14.41 **
MM-625 × Riogold	1.86	-27.16 **	-25.00	-3.41	-10.63 **	28.57	4.57	7.71 **
MM-610 × MM-1831	-17.98 **	1.24	-39.47 **	-5.19	-10.56 **	50.00 **	62.52 **	82.05 **
MM-610 × MM 916/NS-1	0	-31.50 **	-6.06	-13.83 **	-2.06	66.67 **	27.60 **	2.56
MM-610 × Riogold	-19.53 **	-28.36 **	-62.50 **	6.98	1.12	50.00 **	-38.53 **	0.00
MM-1831 × MM 916/NS-1	85.71 **	-40.62 **	-21.21	-27.66 **	-6.88 **	22.37	65.00 **	26.09 **
MM-1831 × Riogold	53.49 **	-31.01 **	-28.13	18.60 **	-7.44 **	6.25	18.58 **	54.35 **
MM 916/NS-1 × Riogold	29.30 **	6.37	-12.50	-27.66 **	-6.47 **	27.63	-12.67 *	-5.80 *
LSD (p≤0.05)	**0.54**	**1.87**	**0.05**	**0.41**	**3.42**	**1.09**	**1.6**	**1.79**
LSD (p≤0.01)	**0.71**	**2.48**	**0.07**	**0.55**	**4.54**	**1.44**	**2.12**	**2.37**

* Significant at 5% level & ** Significant at 1% level

4.3.1.13 Number of branches

Out of 45 hybrid only one hybrid namely MM Sel-103 × MM-625 showed positive and significant heterobeltiosis for no of branches. The heterosis for no. of branches had also been recognized by Lakshmi *et al* (2016) and Duradundi *et al* (2017).

4.3.1.14 TSS

Seventeen crosses had significant and positive heterosis for the TSS compared to the respective better parent. Maximum positive significant heterosis was expressed by hybrid MS-1 × Kajri, MM Sel-103 × MM-916/NS-1, MM-1831 × MM-916/NS-1, Kajri × MM-916/NS-1, and MM-904 × MM-916/NS-1. These results are conformity with those of Moon *at el* (2002), Lal and Kaur (2002), Chaudhury *et al* (2003), Tomar and Bhalala (2006b), Pornsuriya P *et al* (2014) and Hassan *et al* (2018).

4.3.1.15 β-carotene

Fifteen hybrids showed positive and significant heterotic effects. The highest estimates of significant positive heterobeltiosis were expressed by hybrids *viz.*, Kajri × MM-625, MM-904 × MM-625, Kajri × MM 916/NS-1, MM Sel-103 × MM 916/NS-1, and Kajri × MM-1831Meanwhile, Hassan *et al* (2018) observed carotenoids ranged from 35 % to 39.09% over the better parent heterosis in more than 15 hybrids.

4.3.1.16 Firmness

Only four hybrids exhibited the significant positive heterobeltiosis. The maximum estimates of significant positive heterobeltiosis were expressed by hybrids MM-1831 × MM-916/NS-1 followed by MM-1831 × Riogold, MM 916/NS-1 × Riogold, and MM-625 × MM 916/NS-1.

4.3.1.17 Ascorbic acid

Not even a single hybrid displayed heterobeltiosis for this trait. While significant results for ascorbic acid was observed by Burger *et al* (2004), Sharma and Lal (2004) and Hassan *et al* (2018).

4.3.1.18 Titrable acidity

Eighteen hybrids had significant and positive heterosis for acidity as compared to the respective better parent. Hybrid MM-610 × Riogold was exhibited maximum positive significant heterobeltiosis followed by hybrids *viz.*, MM-904 × MM-1831, Kajri × MM-610, MM-625 × MM-1831, and MM-610 × MM-1831.

4.3.1.19 pH

Thirty hybrids revealed significant and negative heterobeltiosis, out of forty-five hybrids for this trait. Hybrid MS-1 × MM-625 was exhibited maximum positive significant heterobeltiosis followed by hybrids *viz.*, MS-1 × Riogold, MM-904 × MM-610, MM-904 × Riogold, and MM-904 × MM-625.

4.3.1.20 Dry matter

Out of forty-five hybrid, only five hybrids namely KP_4HM-15 × MM-916/NS-1, Kajri × KP_4HM-15, Kajri × MM 916/NS-1, Kajri × MM Sel-103, MM-904 × MM-610 were showed positive and significant heterobeltiosis for Dry matter content.

4.3.1.21 Reaction to root-knot nematode (GI)

Only three hybrids viz., MS-1 × Riogold, MS-1 × MM-1831, and Kajri × MM-1831 out of forty-five crosses was shown significant heterobeltiosis for reaction to root-knot nematode infestation.

4.3.1.22 Reaction to fusarium wilt (PDI)

Twenty-seven hybrids exhibited significant and negative heterosis over the better parents out of forty-five hybrids for this trait. The best top crosses *viz.,* MS-1 × Kajri, MM Sel-103 × MM-625, Kajri × MM-904, Kajri × MM Sel-103, and MM Sel-103 × MM-904 exhibiting lowest incidence of fusarium wilt.

4.3.1.23 Reaction to viral disease (PDI)

Thirty hybrids were exhibited significant negative heterosis. The best top crosses *viz.,* MS-1 × Riogold, MM Sel-103 × MM-1831, KP_4HM-15 × MM-610, KP_4HM-15 × MM-904, and MM 916/NS-1 × Riogold exhibiting lowest incidence of viral disease. Similar observations were made by Lal and Kaur (2002).

From the results discussed above, it can be concluded that the highest and significant heterosis over better parent in positive direction as shown by KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-904, MM Sel-103 × MM-610 and KP_4HM-15 × MM-625 for Yield (t ha^{-1}). For Days taken to 1st female flower with maximum negative significant heterosis was recorded in cross *viz.,* Kajri × Riogold, Kajri × MM-916/NS-1, MS-1 × Kajri, MM Sel-103 × Riogold and Kajri × KP_4HM-15. Maximum positive significant heterosis was expressed by hybrid MS-1 × Kajri, MM Sel-103 × MM-916/NS-1, MM-1831 × MM-916/NS-1, Kajri × MM-916/NS-1, and MM-904 × MM-916/NS-1 for TSS content. Negative heterosis is a desirable feature for Virus hybrids *viz.,* MS-1 × Riogold, MM Sel-103 × MM-1831, KP_4HM-15 × MM-610, KP_4HM-15 × MM-904, and MM 916/NS-1 × Riogold exhibiting lowest incidence of viral disease. Cross combination *viz.,* MS-1 × Kajri, MM Sel-103 × MM-625, Kajri × MM-904, Kajri × MM Sel-103, and MM Sel-103 × MM-904 exhibiting lowest incidence of *fusarium* wilt. Similar observations were made by Gurav *et al* (2000), Lal and Kaur (2002), Moon *et al* (2003), Burger *et al* (2004), Sharma and Lal (2004), Moon *et al* (2006), Tomar and Bhalala (2006), Subramanian (2008), Feyzian *et al* (2009), Nerson H (2010), Jag tap and Musmade (2014), Pornsuriya P *et al* (2014), Kamer *et al* (2015), Lakshmi *et al* (2016), Sedera *et al* (2016), Saha (2017), Hassan *et al* (2018), Duradundi *et al* (2017), Costa *et al* (2019).

4.3.2 Heterosis over checks, MH-27, MH-51 and Farmer Glory

Estimation of heterosis over checks *viz.,* MH-27, MH-51 and Farmer Glory for different characters has been presented in Table 4.9 and had been discussed below character-wise.

4.3.2.1 Average fruit weight

Twenty-four cross combinations exhibited desirable heterosis over MH-27**.** The promising hybrids were MM-610 × MM-916/NS-1, MS-1 × MM-610, MM-916/NS-1 × Riogold, MM Sel-103 × MM-610, MM Sel-103 × MM-1831 and MM-625 × MM-610. Similarly, twenty cross combinations showed positive significant heterosis over MH-51. Hybrids with maximum heterosis were MM-610 × MM-916/NS-1 followed by MS-1 × MM-610, MM-916/NS-1 × Riogold, and MM Sel-103 × MM-1831. Standard heterosis over the Farmer Glory, seventeen hybrids expressed positive and significant heterosis. The maximum heterosis shown by hybrids viz., MM-610 × MM 916/NS-1 followed by MM 916/NS-1 × Riogold, MS-1 × MM-610, MM-625 × MM-610, and MM Sel-103 × MM-1831.

4.3.2.2 Number of fruits per plant

Heterosis for no. of fruits per plant over MH-27, eight cross combinations *viz.,* MM Sel-103 × MM-904 followed by KP_4HM-15 × MM-904, MM-904 × MM-1831, KP_4HM-15 × Riogold, and KP_4HM-15 × MM Sel-103 showing significantly higher heterosis. The magnitude of heterosis over MH-51 nine cross combinations were showing significant higher heterosis. Maximum positive and significant heterosis was recorded in case of MM Sel-103 × MM-904, KP_4HM-15 × MM-904, MM-904 × MM-1831, KP_4HM-15 × MM Sel-103, and KP_4HM-15 × Riogold. Standard heterosis over the Farmer Glory shown by sixteen cross combinations. The crosses *viz.,* MM Sel-103 × MM-904, KP_4HM-15 × MM-904, MM-904 × MM-1831, KP_4HM-15 × MM Sel-103, and KP_4HM-15 × Riogold revealed significant results over the standard check Farmer Glory.

4.3.2.3 Fruit yield

Maximum heterosis over MH-27 was observed in sixteen crosses. The top five crosses showing significant higher positive heterosis over MH-27 were KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-625, MS-1 × MM-610, MM Sel-103 × MM-625, and MM 916/NS-1 × Riogold. The heterosis over MH-51 shown by sixteen crosses exhibiting positive economic heterosis over this check and among them the notable crosses were MM-610 × MM 916/NS-1, MM 916/NS-1 × Riogold, MS-1 × MM-610, MM-625 × MM-610, and MM Sel-103 × MM-1831. Twenty cross combinations showed positive significant economic heterosis over Farmer Glory. Hybrids with maximum standard heterosis were KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-625, MS-1 × MM-610, MM Sel-103 × MM-625, and MM 916/NS-1 × Riogold.

4.3.2.4 Days taken to 1st female flower

The negative heterosis was observed in twenty-five cross combinations over the MH-27. The highest magnitude of standard heterosis was observed in the cross *viz.*, MM Sel-103 × Riogold, MM-625 × MM 916/NS-1, MS-1 × MM-904, Kajri × Riogold, and MM-625 × Riogold Thirty-five cross combinations were showing significantly higher heterosis over the MH-51. Maximum negative heterosis was expressed in case of MM Sel-103 × Riogold, MM-625 × MM 916/NS-1, MS-1 × MM-904, Kajri × Riogold, and MM-625 × Riogold. The negative heterosis over the Farmer Glory shown by thirty-five cross combinations. The highest magnitude of economic heterosis was observed in hybrids *viz.*, MM Sel-103 × Riogold, MM-625 × MM 916/NS-1, MM-625 × Riogold, MS-1 × MM-904, and Kajri × Riogold.

4.3.2.5 Days taken to 1st fruit harvest

Highest standard heterosis over MH-27 was observed in fourteen cross combinations. Maximum negative heterosis was expressed in hybrids *viz.*, MM-904 × Riogold, MM-625 × MM-1831, Kajri × Riogold, KP_4HM-15 × Riogold, and MM Sel-103 × MM-1831. Highest standard heterosis over MH-51 was observed in forty-one cross combinations. Maximum negative heterosis was expressed in hybrids *viz.*, MM-904 × Riogold, MM-625 × MM-1831, Kajri × Riogold, KP_4HM-15 × Riogold, and MM-904 × MM-610. The negative heterosis over the Farmer Glory was observed in all the Forty-five cross combinations. All the hybrids showing significantly and negatively higher heterosis over the Farmer Glory. The top five crosses were MM-625 × MM-1831, KP_4HM-15 × Riogold, MM Sel-103 × MM-1831, MM-904 × MM-1831, and MM-625 × Riogold.

4.3.2.6 Polar diameter

The magnitude of standard heterosis over MH-27 was observed in twenty-three hybrids combination. Maximum positive and significant standard heterosis was expressed in hybrid Kajri × MM-916/NS-1 followed by KP_4HM-15 × Riogold, MM Sel-103 × MM-904, KP_4HM-15 × MM-1831, and KP_4HM-15 × MM 916/NS-1. Two hybrids viz., Kajri × MM-916/NS-1 and KP_4HM-15 × Riogold, out of forty-five were exhibited highly significant and positive standard heterosis over MH-51 for this trait. Economic heterosis over Farmer Glory for polar diameter observed in Twelve hybrids that had significant positive heterosis Farmer Glory were Kajri × MM-916/NS-1 followed by KP_4HM-15 × Riogold, MM Sel-103 × MM-904, KP_4HM-15 × MM-1831 and KP_4HM-15 × MM-916/NS-1.

4.3.2.7 Equatorial diameter

Expression of standard heterosis over MH-27 was in positive direction in thirty-six crosses. The top five crosses displayed maximum significant result over MH-27 were MM-904 × MM 916/NS-1, Kajri × MM-1831, MM-1831 × Riogold, Kajri × MM 916/NS-1, and MM-904 × MM-1831. Fifteen hybrids positive heterosis over the MH-51. The top five

crosses showing significant higher positive heterosis over MH-51 were MM Sel-103 × MM-1831, MM Sel-103 × MM 916/NS-1, MM-625 × MM-610, MM Sel-103 × Riogold,and Kajri × MM-904. Sixteen cross combinations showed positive significant economic heterosis over Farmer Glory. Hybrids with maximum economic heterosis were Kajri × MM-610 followed by MM-904 × MM-916/NS-1, Kajri × MM-1831, MM-1831 × Riogold, Kajri × MM-916/NS-1 and MM-904 × MM-1831.

4.3.2.8 Flesh thickness

Standard heterosis for flesh thickness over MH-27 observed in twenty-four crosses combinations. The highest significant heterosis were shown by crosses *viz.*, MM Sel-103 × MM-625 followed by MM-916/NS-1 × Riogold, MM-610 × Riogold, MM-1831 × Riogold, MM Sel-103 × MM-1831 over the check. The magnitude of heterosis for flesh thickness over MH-51 observed in five crosses. Maximum positive and significant economic heterosis was noted in case of five crosses viz., MM Sel-103 × MM-625, MM-916/NS-1 × Riogold, MM-610 × Riogold, and MM-1831 × Riogold than the MH-51. Standard heterosis over Farmer Glory ranged observed in three cross combinations MM Sel-103×MM – 625, MM-916/NS-1×Riogold and MM-610×Riogold showing positive and significant heterosis over the standard check Farmer Glory.

4.3.2.9 Rind thickness

Standard heterosis for rind thickness over MH-27 observed in nine cross combinations Maximum positive and significant heterosis was noted in hybrids viz., MS-1 × MM-625, MM-610 × MM-1831, MM-610 × Riogold, MS-1 × MM 916/ NS-1, and MM-610 × MM 916/NS-1. The magnitude of heterosis for rind thickness over MH-51 observed in twenty-five cross combinations. Maximum positive and significant standard heterosis exhibited by MS-1 × MM-625, MM-610 × MM-1831, MM-610 × Riogold, MS-1 × MM 916/ NS-1, and MM-610 × MM 916/NS-1. No hybrids exhibited positive and significant result over the Farmer Glory for rind thickness.

4.3.2.10 Fruit cavity area

Standard heterosis for fruit cavity area cm^2 over MH-27 observed in only two hybrids viz., Kajri × KP_4HM-15, and KP_4HM-15 × MM-1831 were exhibited significantly negative higher heterosis. Maximum negative and significant standard heterosis was recorded over MH-51 in eight hybrids combination. The hybrids showing highest heterosis were Kajri × KP_4HM-15, KP_4HM-15 × MM-1831, KP_4HM-15 × MM 916/NS-1, MM-904 × MM-1831, and KP_4HM-15 × MM-904. Only one hybrid showed negative and significant results over the Farmer Glory was Kajri × KP_4HM-15.

4.3.2.11 Fruit shape index

Standard heterosis for fruit shape index was noted in fifteen hybrids over MH-27**.** The top five crosses showing positive and significant maximum heterosis over MH-27 were

KP_4HM-15 × MM-904 followed by MS-1 × MM-916/NS-1, MM-904 × Riogold, MM-904 × MM-610 and MS-1 × MM-904. The range of heterosis over MH-27 observed in thirty-three cross combination. The maximum positive standard heterosis over this check exhibited by hybrids *viz.*, KP_4HM-15 × MM-904, MS-1 × MM 916/ NS-1, MM-904 × Riogold, MM-904 × MM-610, KP_4HM-15 × MM-610. Three hybrids namely MS-1 × Kajri, MM-610 × Riogold and MM Sel-103 × MM-625 were showed positive significant economic heterosis over Farmer Glory.

4.3.2.12 Vine length

Standard heterosis for vine length over MH-27 observed in twelve cross combinations. Maximum negative and significnat heterosis was expressed in case of MS-1 × Riogold, Kajri × MM-625, MM-625 × MM-916/NS-1, and MS-1 × MM-1831. The negative heterosis over the MH-51 observed in twenty-one cross combinations. The highest magnitude of economic heterosis was observed in MS-1 × Riogold cross followed by Kajri × MM-625, MM-625 × MM-916/NS-1, MS-1 × MM-1831, MM-904 × MM-916/NS-1, MM-625 × MM-1831 and KP_4HM-15 × Riogold. No hybrids exhibited negative and significant result over the Farmer Glory for vine length.

4.3.2.13 Number of branches

Out of forty-five, three hybrids *viz.*, Kajri × MM-1831, MM Sel-103 × MM-625 and KP_4HM-15 × MM-1831 exhibited positive and highly significant standard heterosis over the 'MH-27'. Similarly, only six cross combinations showed significant positive heterosis over the check 'Farmer Glory'. The highest estimates of positive and significant heterosis expressed by hybrids Kajri × MM-1831, MM Sel-103 × MM-625, KP_4HM-15 × MM-1831 and MS-1 × MM-625. No hybrids exhibited positive and significant standard heterosis over the MH-51.

4.3.2.14 TSS

Standard heterosis for TSS over MH-27 observed in fourteen cross combinations showing significantly higher heterosis. Maximum positive and significant standard heterosis was documented in MM-1831 × MM-916/NS-1, MM Sel-103 × MM-916/NS-1, KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-1831 and MS-1 × Kajri. The estimates of significant positive standard check over MH-51 observed in twelve cross combinations showing positive and significant higher heterosis. Maximum positive and significant standard heterosis exhibited by MM-1831 × MM-916/NS-1 followed by MM Sel-103 × MM-916/NS-1, KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-1831 and MS-1 × Kajri. Standard heterosis over the Farmer Glory observed in thirteen cross combinations showing significantly higher heterosis. Cross combinations *viz.*, MM-1831 × MM-916/NS-1 followed by MM Sel-103 × MM-916/NS-1, KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-1831 and MS-1 × Kajri showed best results over Farmer Glory.

Table 4.9: Estimation of heterosis (%) over commercials checks, MH-27, MH-51 and Farmer Glory for the different characters of muskmelon

Traits	Average fruit weight (g)			No of fruits per vine			Fruit yield (t ha^{-1})		
Crosses/ Checks	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**
MS-1 × Kajri	18.70 **	7.82	0.45	-12.59 **	-8.15	8.55	3.81	-0.95	9.05 *
MS-1 × KP$_4$HM-15	14.98 *	4.44	-2.7	-12.15 **	-7.69	9.09	1.07	-3.57	6.17
MS-1 × MM Sel-103	-1.45	-10.48	-16.60 **	-12.15 **	-7.69	9.09	-13.38 **	-17.35 **	0
MS-1 × MM-904	-4.65	-13.39 *	-19.31 **	-13.62 **	-9.23	7.27	-17.58 **	-21.36 **	-13.41 **
MS-1 × MM-625	32.08 **	19.97 **	11.77 *	-4.83	0	18.18 **	25.78 **	20.01 **	32.13 **
MS-1 × MM-610	60.90 **	46.15 **	36.16 **	6	11.38 *	31.64 **	70.65 **	62.82 **	79.27 **
MS-1 × MM-1831	-15.27 *	-23.04 **	-28.30 **	-21.38 **	-17.38 **	-2.36	-33.33 **	-36.39 **	-29.97 **
MS-1 × MM 916/ NS-1	4.61	-4.98	-11.48 *	-21.38 **	-17.38 **	-2.36	-17.70 **	-21.47 **	-13.54 **
MS-1 × Riogold	9.48	-0.55	-7.35	-33.67 **	-30.31 **	-17.64 **	-27.34 **	-30.67 **	-23.67 **
Kajri × KP$_4$HM-15	-11.23	-19.37 **	-24.88 **	-23.87 **	-20.00 **	-5.45	-32.41 **	-35.51 **	-29.00 **
Kajri × MM Sel-103	31.09 **	19.07 **	10.93	-37.04 **	-33.85 **	-21.82 **	-17.67 **	-21.45 **	-13.52 **
Kajri × MM-904	-23.47 **	-30.49 **	-35.24 **	-26.79 **	-23.08 **	-9.09	-44.16 **	-46.72 **	-41.34**
Kajri × MM-625	3.27	-6.19	-12.61 *	4.25	9.54	29.45 **	7.74	2.8	13.19 **
Kajri × MM-610	-3.68	-12.51 *	-18.49 **	-32.65 **	-29.23 **	-16.36 **	-35.13 **	-38.11 **	-31.85 **
Kajri × MM-1831	4.96	-4.66	-11.18	-36.60 **	-33.38 **	-21.27 **	-34.35 **	-37.36 **	-31.04 **
Kajri × MM 916/NS-1	3.48	-6	-12.43 *	-34.11 **	-30.77 **	-18.18 **	-32.22 **	-35.33 **	-28.79 **
Kajri × Riogold	44.68 **	31.41 **	22.43 **	-19.91 **	-15.85 **	-0.55	15.76 **	10.45 **	21.60 **
KP$_4$HM-15 × MM Sel-103	34.53 **	22.20 **	13.84 *	33.67 **	40.46 **	66.00 **	79.95 **	71.69 **	89.03 **
KP$_4$HM-15 × MM-904	9.17	-0.83	-7.62	44.95 **	52.31 **	80.00 **	58.34 **	51.08 **	66.34 **
KP$_4$HM-15 × MM-625	43.50 **	30.35 **	21.43 **	21.96 **	28.15 **	51.45 **	74.92 **	66.90 **	83.75 **
KP$_4$HM-15 × MM-610	10.68	0.53	-6.34	-25.77 **	-22.00 **	-7.82	-17.84 **	-21.61 **	-13.70 **
KP$_4$HM-15 × MM-1831	18.36 **	7.51	0.16	12.30 **	18.00 **	39.45 **	32.87 **	26.78 **	39.58 **
KP$_4$HM-15 × MM 916/NS-1	-5.55	-14.21 *	-20.07 **	-7.03	-2.31	15.45 **	-12.36 **	-16.38 **	-7.93
KP$_4$HM-15 × Riogold	17.45 *	6.68	-0.62	30.75 **	37.38 **	62.36 **	53.65 **	46.61 **	61.41 **

Traits	Average fruit weight (g)			No of fruits per vine			Fruit yield (t ha^{-1})		
MM Sel-103 × MM-904	-11.32	-19.45 **	-24.96 **	49.78 **	57.38 **	86.00 **	32.58 **	26.50 **	39.28 **
MM Sel-103 × MM-625	38.35 **	25.67 **	17.07 **	21.52 **	27.69 **	50.91 **	67.86 **	60.16 **	76.33 **
MM Sel-103 × MM-610	56.19 **	41.87 **	32.17 **	3.37	8.62	28.36 **	61.54 **	54.13 **	69.70 **
MM Sel-103 × MM-1831	56.62 **	42.26 **	32.53 **	-31.77 **	-28.31 **	-15.27 **	6.92	2.02	12.32 **
MM Sel-103 × MM 916/NS-1	-2.61	-11.54	-17.59 **	-21.82 **	-17.85 **	-2.91	-23.82 **	-27.31 **	-19.97 **
MM Sel-103 × Riogold	25.52 **	14.01 *	6.21	-11.71 *	-7.23	9.64	10.85 **	5.77	16.45 **
MM-904 × MM-625	-14.87 *	-22.67 **	-27.96 **	2.49	7.69	27.27 **	-14.06 **	-18.00 **	-9.72 *
MM-904 × MM-610	-6.46	-15.03 *	-20.84 **	-13.62 **	-9.23	7.27	-19.13 **	-22.84 **	-15.05 **
MM-904 × MM-1831	-20.86 **	-28.11 **	-33.03 **	34.26 **	41.08 **	66.73 **	6.34	1.46	11.71 **
MM-904 × MM 916/NS-1	-29.66 **	-36.11 **	-40.48 **	-2.49	2.46	21.09 **	-31.37 **	-34.51 **	-27.90 **
MM-904 × Riogold	-1.56	-10.58	-16.70 **	-21.82 **	-17.85 **	-2.91	-22.99 **	-26.52 **	-19.10 **
MM-625 × MM-610	59.48 **	44.86 **	34.95 **	-13.62 **	-9.23	7.27	37.85 **	31.53 **	44.81 **
MM-625 × MM-1831	34.58 **	22.24 **	13.88 *	-15.08 **	-10.77 *	5.45	14.15 **	8.92 *	19.92 **
MM-625 × MM 916/NS-1	28.69 **	16.89 **	8.9	-4.39	0.46	18.73 **	23.06 **	17.42 **	29.28 **
MM-625 × Riogold	45.73 **	32.37 **	23.32 **	-33.67 **	-30.31 **	-17.64 **	-3.28	-7.71 *	1.61
MM-610 × MM-1831	35.88 **	23.42 **	14.98 *	-33.67 **	-30.31 **	-17.64 **	-9.86 *	-13.99 **	-5.3
MM-610 × MM 916/NS-1	67.96 **	52.56 **	42.13 **	-31.77 **	-28.31 **	-15.27 **	14.64 **	9.38 *	20.43 **
MM-610 × Riogold	39.18 **	26.42 **	17.77 **	-33.67 **	-30.31 **	-17.64 **	-7.79	-12.02 **	-3.14
MM-1831 × MM 916/NS-1	37.10 **	24.53 **	16.02 **	-28.26 **	-24.62 **	-10.91	-1.6	-6.12	3.37
MM-1831 × Riogold	33.83 **	21.56 **	13.25 *	-33.67 **	-30.31 **	-17.64 **	-11.19 **	-15.27 **	-6.71
MM 916/NS-1 × Riogold	62.45 **	47.56 **	37.46 **	-13.62 **	-9.23	7.27	40.40 **	33.96 **	47.49 **
LSD (p≤0.05)	**85.8**			**0.31**			**1.6**		
LSD (p≤0.01)	**113.7**			**0.41**			**2.1**		

* Significant at 5% level & ** Significant at 1% level

Table 4.9: Continued….

Traits	Days taken to 1st female flower emerge			Days taken to 1st fruit harvest			Polar diameter (cm)		
Crosses/ Checks	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**
MS-1 × Kajri	-3.33	-5.69 *	-5.69 *	1.57	-3.96 **	-5.83 **	2.39	-12.87 **	-6.34
MS-1 × KP_4HM-15	-4.17	-6.50 **	-6.50 **	1.57	-3.96 **	-5.83 **	8.3	-7.85 *	-0.93
MS-1 × MM Sel-103	-4.17	-6.50 **	-6.50 **	0	-5.45 **	-7.28 **	7.34	-8.67 *	-1.82
MS-1 × MM-904	-10.00 **	-12.20 **	-12.20 **	-2.09 *	-7.43 **	-9.22 **	4.94	-10.71 **	-4.01
MS-1 × MM-625	-5.83 *	-8.13 **	-8.13 **	-0.52	-5.94 **	-7.77 **	3.77	-11.70 **	-5.08
MS-1 × MM-610	-4.17	-6.50 **	-6.50 **	-0.52	-5.94 **	-7.77 **	22.06 **	3.86	11.65 **
MS-1 × MM-1831	-4.17	-6.50 **	-6.50 **	-0.52	-5.94 **	-7.77 **	8.3	-7.85 *	-0.93
MS-1 × MM 916/ NS-1	-7.50 **	-9.76 **	-9.76 **	-0.52	-5.94 **	-7.77 **	6.11	-9.71 *	-2.94
MS-1 × Riogold	-6.67 **	-8.94 **	-8.94 **	-0.52	-5.94 **	-7.77 **	11.21 *	-5.37	1.72
Kajri × KP_4HM-15	-4.17	-6.50 **	-6.50 **	4.71 **	-0.99	-2.91 **	12.43 **	-4.33	2.84
Kajri × MM Sel-103	0	-2.44	-2.44	4.71 **	-0.99	-2.91 **	16.81 **	-0.61	6.85
Kajri × MM-904	-0.83	-3.25	-3.25	1.05	-4.46 **	-6.31 **	12.23 **	-4.51	2.66
Kajri × MM-625	-2.5	-4.88	-4.88	-1.05	-6.44 **	-8.25 **	22.77 **	4.46	12.30 **
Kajri × MM-610	-0.83	-3.25	-3.25	5.76 **	0	-1.94 *	21.24 **	3.16	10.90 *
Kajri × MM-1831	0	-2.44	-2.44	5.76 **	0	-1.94 *	22.98 **	4.64	12.49 **
Kajri × MM 916/NS-1	-9.17 **	-11.38 **	-11.38 **	-0.52	-5.94 **	-7.77 **	30.41 **	10.97 **	19.29 **
Kajri × Riogold	-10.00 **	-12.20 **	-12.20 **	-4.19 **	-9.41 **	-11.17 **	22.57 **	4.29	12.12 **
KP_4HM-15 × MM Sel-103	-5.83 *	-8.13 **	-8.13 **	0.52	-4.95 **	-6.80 **	12.74 **	-4.07	3.12
KP_4HM-15 × MM-904	-5	-7.32 **	-7.32 **	-0.52	-5.94 **	-7.77 **	14.47 **	-2.6	4.71
KP_4HM-15 × MM-625	-5.83 *	-8.13 **	-8.13 **	-0.52	-5.94 **	-7.77 **	5.45	-10.27 **	-3.54
KP_4HM-15 × MM-610	-5.83 *	-8.13 **	-8.13 **	-1.05	-6.44 **	-8.25 **	8.2	-7.93 *	-1.03
KP_4HM-15 × MM-1831	-5	-7.32 **	-7.32 **	-1.05	-6.44 **	-8.25 **	25.62 **	6.89	14.91 **
KP_4HM-15 × MM 916/NS-1	-6.67 **	-8.94 **	-8.94 **	-3.66 **	-8.91 **	-10.68 **	23.79 **	5.33	13.23 **
KP_4HM-15 × Riogold	-6.67 **	-8.94 **	-8.94 **	-4.19 **	-9.41 **	-11.17 **	29.60 **	10.27 **	18.55 **
MM Sel-103 × MM-904	-9.17 **	-11.38 **	-11.38 **	-1.05	-6.44 **	-8.25 **	25.83 **	7.07	15.10 **

Traits	Days taken to 1st female flower emerge			Days taken to 1st fruit harvest			Polar diameter (cm)		
MM Sel-103 × MM-625	-8.33 **	-10.57 **	-10.57 **	4.19 **	-1.49	-3.40 **	18.85 **	1.13	8.71 *
MM Sel-103 × MM-610	-5.83 *	-8.13 **	-8.13 **	0.52	-4.95 **	-6.80 **	2.39	-12.87 **	-6.34
MM Sel-103 × MM-1831	-5	-7.32 **	-7.32 **	-4.19 **	-9.41 **	-11.17 **	-17.17 **	-29.52 **	-24.23 **
MM Sel-103 × MM 916/NS-1	-5.83 *	-8.13 **	-8.13 **	-2.09 *	-7.43 **	-9.22 **	-20.02 **	-31.95 **	-26.84 **
MM Sel-103 × Riogold	-12.50 **	-14.63 **	-14.63 **	-3.14 **	-8.42 **	-10.19 **	-23.38 **	-34.81 **	-29.92 **
MM-904 × MM-625	-1.67	-4.07	-4.07	0.52	-4.95 **	-6.80 **	-12.23 **	-25.31 **	-19.71 **
MM-904 × MM-610	-2.5	-4.88	-4.88	-4.19 **	-9.41 **	-11.17 **	6.83	-9.10 *	-2.28
MM-904 × MM-1831	-5.83 *	-8.13 **	-8.13 **	-4.19 **	-9.41 **	-11.17 **	6.27	-9.58 *	-2.8
MM-904 × MM 916/NS-1	-4.17	-6.50 **	-6.50 **	-4.19 **	-9.41 **	-11.17 **	13.75 **	-3.21	4.05
MM-904 × Riogold	-5.83 *	-8.13 **	-8.13 **	-4.71 **	-9.90 **	-11.65 **	1.88	-13.31 **	-6.8
MM-625 × MM-610	-5	-7.32 **	-7.32 **	0.52	-4.95 **	-6.80 **	-7.28	-21.11 **	-15.19 **
MM-625 × MM-1831	-5	-7.32 **	-7.32 **	-4.71 **	-9.90 **	-11.65 **	5.96	-9.84 *	-3.08
MM-625 × MM 916/NS-1	-10.83 **	-13.01 **	-13.01 **	-4.19 **	-9.41 **	-11.17 **	12.43 **	-4.33	2.84
MM-625 × Riogold	-10.00 **	-12.20 **	-12.20 **	-4.19 **	-9.41 **	-11.17 **	15.13 **	-2.04	5.31
MM-610 × MM-1831	-7.50 **	-9.76 **	-9.76 **	2.09 *	-3.47 **	-5.34 **	9.73 *	-6.63	0.37
MM-610 × MM 916/NS-1	-8.33 **	-10.57 **	-10.57 **	1.05	-4.46 **	-6.31 **	7.64	-8.41 *	-1.54
MM-610 × Riogold	0	-2.44	-2.44	1.05	-4.46 **	-6.31 **	-2.5	-17.04 **	-10.81 *
MM-1831 × MM 916/NS-1	-2.5	-4.88	-4.88	2.09 *	-3.47 **	-5.34 **	8.15	-7.98 *	-1.07
MM-1831 × Riogold	-4.17	-6.50 **	-6.50 **	1.57	-3.96 **	-5.83 **	19.41 **	1.6	9.23 *
MM 916/NS-1 × Riogold	-0.83	-3.25	-3.25	1.05	-4.46 **	-6.31 **	10.55 *	-5.94	1.12
LSD (p≤0.05)	**3.0**			**1.9**			**0.89**		
LSD (p≤0.01)	**3.9**			**2.6**			**1.2**		

* Significant at 5% level & ** Significant at 1% level

Table 4.9: Continued…..

Traits	Equatorial diameter (cm)			Flesh thickness (cm)			Rind thickness (mm)		
Crosses/ Checks	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**
MS-1 × Kajri	10.00 *	-10.14 **	-1.33	23.58	0.21	-4.02	10.72	40.74 *	-13.92
MS-1 × KP_4HM-15	19.49 **	-2.39	7.18	0.26	-18.7	-22.13 *	10.72	40.74 *	-13.92
MS-1 × MM Sel-103	15.59 **	-5.57	3.68	24.35	0.84	-3.42	3.54	31.61 *	-19.50 *
MS-1 × MM-904	10.26 *	-9.93 **	-1.1	12.95	-8.4	-12.27	-7.07	18.12	-27.75 **
MS-1 × MM-625	8.36	-11.48 **	-2.81	45.08 **	17.65	12.68	50.05 **	90.74 **	16.67
MS-1 × MM-610	20.36 **	-1.68	7.96 *	46.89 **	19.12	14.08	25.08 *	58.99 **	-2.75
MS-1 × MM-1831	10.10 *	-10.05 **	-1.24	20.98	-1.89	-6.04	0	27.11	-22.25 *
MS-1 × MM 916/ NS-1	14.87 **	-6.16	3.04	38.08 **	11.97	7.24	39.34 **	77.11 **	8.33
MS-1 × Riogold	20.67 **	-1.42	8.23 *	26.94 *	2.94	-1.41	7.18	36.24 *	-16.67
Kajri × KP_4HM-15	15.90 **	-5.32	3.96	-22.28	-36.97 **	-39.64 **	-28.62 *	-9.26	-44.50 **
Kajri × MM Sel-103	8.21	-11.60 **	-2.94	34.72 **	9.24	4.63	7.18	36.24 *	-16.67
Kajri × MM-904	5.13	-14.12 **	-5.7	8.81	-11.76	-15.49	-28.62 *	-9.26	-44.50 **
Kajri × MM-625	24.46 **	1.68	11.64 **	36.53 **	10.71	6.04	32.15 *	67.98 **	2.75
Kajri × MM-610	36.77 **	11.73 **	22.68 **	11.4	-9.66	-13.48	7.18	36.24 *	-16.67
Kajri × MM-1831	29.38 **	5.7	16.05 **	38.34 **	12.18	7.44	7.18	36.24 *	-16.67
Kajri × MM 916/NS-1	27.18 **	3.9	14.08 **	8.03	-12.39	-16.1	-17.9	4.36	-36.17 **
Kajri × Riogold	19.49 **	-2.39	7.18	34.72 **	9.24	4.63	-28.62 *	-9.26	-44.50 **
KP_4HM-15 × MM Sel-103	22.21 **	-0.17	9.61 *	25.13	1.47	-2.82	-21.44	-0.14	-38.92 **
KP_4HM-15 × MM-904	16.92 **	-4.48	4.88	-3.37	-21.64 *	-24.95 *	-21.33	0	-38.83 **
KP_4HM-15 × MM-625	5.44	-13.87 **	-5.43	26.94 *	2.94	-1.41	-7.07	18.12	-27.75 **
KP_4HM-15 × MM-610	10.92 *	-9.38 **	-0.51	24.35	0.84	-3.42	-21.33	0	-38.83 **
KP_4HM-15 × MM-1831	23.38 **	0.8	10.67 **	31.35 *	6.51	2.01	-46.41 **	-31.88 *	-58.33 **
KP_4HM-15 × MM 916/NS-1	17.59 **	-3.94	5.47	-1.55	-20.17	-23.54 *	0	27.11	-22.25 *
KP_4HM-15 × Riogold	15.03 **	-6.03	3.17	26.94 *	2.94	-1.41	7.18	36.24 *	-16.67
MM Sel-103 × MM-904	17.13 **	-4.32	5.06	13.99	-7.56	-11.47	-32.15 *	-13.76	-47.25 **

Traits	Equatorial diameter (cm)			Flesh thickness (cm)			Rind thickness (mm)		
MM Sel-103 × MM-625	20.82 **	-1.3	8.37 *	74.35 **	41.39 **	35.41 **	24.97 *	58.86 **	-2.83
MM Sel-103 × MM-610	11.28 **	-9.09 **	-0.18	20.73	-2.1	-6.24	17.9	49.86 **	-8.33
MM Sel-103 × MM-1831	1.54	-17.05 **	-8.92 *	48.70 **	20.59 *	15.49	17.9	49.86 **	-8.33
MM Sel-103 × MM 916/NS-1	2.36	-16.38 **	-8.19 *	14.77	-6.93	-10.87	-17.79	4.5	-36.08 **
MM Sel-103 × Riogold	4.46	-14.66 **	-6.3	42.49 **	15.55	10.66	-10.61	13.62	-30.50 **
MM-904 × MM-625	10.05 *	-10.10 **	-1.29	35.49 **	9.87	5.23	27.87 *	62.53 **	-0.58
MM-904 × MM-610	23.08 **	0.54	10.40 **	19.95	-2.73	-6.84	-21.44	-0.14	-38.92 **
MM-904 × MM-1831	27.18 **	3.9	14.08 **	15.8	-6.09	-10.06	-10.72	13.49	-30.58 **
MM-904 × MM 916/NS-1	29.54 **	5.82	16.19 **	1.04	-18.07	-21.53 *	-14.26	8.99	-33.33 **
MM-904 × Riogold	10.10 *	-10.05 **	-1.24	16.58	-5.46	-9.46	-14.26	8.99	-33.33 **
MM-625 × MM-610	3.74	-15.25 **	-6.95	30.31 *	5.67	1.21	7.18	36.24 *	-16.67
MM-625 × MM-1831	17.79 **	-3.77	5.66	38.34 **	12.18	7.44	21.44	54.36 **	-5.58
MM-625 × MM 916/NS-1	22.72 **	0.25	10.07 **	4.66	-15.13	-18.71	-14.26	8.99	-33.33 **
MM-625 × Riogold	24.77 **	1.93	11.91 **	33.94 **	8.61	4.02	17.9	49.86 **	-8.33
MM-610 × MM-1831	17.79 **	-3.77	5.66	35.49 **	9.87	5.23	45.44 **	84.88 **	13.08
MM-610 × MM 916/NS-1	14.21 **	-6.7	2.44	32.90 *	7.77	3.22	35.80 **	72.62 **	5.58
MM-610 × Riogold	7.54	-12.15 **	-3.54	54.40 **	25.21 *	19.92 *	42.98 **	81.74 **	11.17
MM-1831 × MM 916/NS-1	15.69 **	-5.49	3.77	26.17 *	2.31	-2.01	7.18	36.24 *	-16.67
MM-1831 × Riogold	27.85 **	4.44	14.67 **	51.04 **	22.48 *	17.3	10.83	40.87 *	-13.83
MM 916/NS-1 × Riogold	21.23 **	-0.96	8.74 *	60.62 **	30.25 **	24.75 *	10.83	40.87 *	-13.83
LSD (p≤0.05)	**0.82**			**0.49**			**1.2**		
LSD (p≤0.01)	**1.1**			**0.65**			**1.5**		

* Significant at 5% level & ** Significant at 1% level

Table 4.9: Continued.

Traits	Fruit cavity area (cm^2)			Fruit shape index			Vine length (m)		
Crosses/ Checks	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**
MS-1 × Kajri	61.26 **	77.86 **	43.47 **	5.08	10.71 *	-8.82 *	-3.5	-10.40 *	17.31 **
MS-1 × KP_4HM-15	35.53 **	49.49 **	20.58	12.43 *	18.45 **	-2.45	-0.23	-7.36	21.30 **
MS-1 × MM Sel-103	37.45 **	51.60 **	22.29 *	4.52	10.12 *	-9.31 *	-8.3	-14.85 **	11.48
MS-1 × MM-904	-0.41	9.84	-11.4	22.03 **	28.57 **	5.88	-6.55	-13.22 **	13.61 *
MS-1 × MM-625	99.84 **	120.42 **	77.80 **	4.52	10.12 *	-9.31 *	-6.02	-12.73 **	14.26 *
MS-1 × MM-610	54.56 **	70.48 **	37.52 **	12.99 **	19.05 **	-1.96	-5.03	-11.81 *	15.46 *
MS-1 × MM-1831	15.15	27.00 *	2.45	13.56 **	19.64 **	-1.47	-18.96 **	-24.75 **	-1.48
MS-1 × MM 916/ NS-1	86.00 **	105.15 **	65.48 **	25.42 **	32.14 **	8.82 *	-10.89 *	-17.26 **	8.33
MS-1 × Riogold	-0.93	9.27	-11.86	5.65	11.31 *	-8.33 *	-25.67 **	-30.98 **	-9.63
Kajri × KP_4HM-15	-46.78 **	-41.30 **	-52.65 **	-13.56 **	-8.93	-25.00 **	-12.64 *	-18.88 **	6.2
Kajri × MM Sel-103	33.09 **	46.80 **	18.41	-3.95	1.19	-16.67 **	-5.56	-12.31 **	14.81 *
Kajri × MM-904	-24.07 *	-16.25	-32.44 **	3.95	9.52	-9.80 *	-10.36 *	-16.76 **	8.98
Kajri × MM-625	71.89 **	89.59 **	52.93 **	4.52	10.12 *	-9.31 *	-20.56 **	-26.24 **	-3.43
Kajri × MM-610	-1.09	9.1	-12	5.08	10.71 *	-8.82 *	16.76 **	8.42	41.94 **
Kajri × MM-1831	36.10 **	50.11 **	21.09	5.08	10.71 *	-8.82 *	-7.77	-14.36 **	12.13 *
Kajri × MM 916/NS-1	13.28	24.94	0.78	-2.82	2.38	-15.69 **	9.22	1.41	32.78 **
Kajri × Riogold	-7.31	2.23	-17.54	3.95	9.52	-9.80 *	15.31 **	7.07	40.19 **
KP_4HM-15 × MM Sel-103	3.53	14.19	-7.89	7.34	13.10 *	-6.86	43.95 **	33.66 **	75.00 **
KP_4HM-15 × MM-904	-26.56 *	-18.99	-34.66 **	25.99 **	32.74 **	9.31 *	36.63 **	26.87 **	66.11 **
KP_4HM-15 × MM-625	19.45	31.75 *	6.28	9.04	14.88 **	-5.39	23.38 **	14.57 **	50.00 **
KP_4HM-15 × MM-610	13.74	25.46	1.2	15.25 **	21.43 **	0	24.98 **	16.05 **	51.94 **
KP_4HM-15 × MM-1831	-34.13 **	-27.35 *	-41.39 **	9.04	14.88 **	-5.39	45.24 **	34.87 **	76.57 **
KP_4HM-15 × MM 916/NS-1	-29.98 *	-22.77	-37.70 **	8.47	14.29 **	-5.88	72.35 **	60.04 **	109.54 **
KP_4HM-15 × Riogold	25.83 *	38.79 **	11.95	6.78	12.50 *	-7.35	-15.38 **	-21.43 **	2.87
MM Sel-103 × MM-904	-3.89	6.01	-14.49	4.52	10.12 *	-9.31 *	10.43 *	2.55	34.26 **

Traits	Fruit cavity area (cm^2)			Fruit shape index			Vine length (m)		
MM Sel-103 × MM-625	101.97 **	122.77 **	79.70 **	-1.69	3.57	-14.71 **	37.32 **	27.51 **	66.94 **
MM Sel-103 × MM-610	38.33 **	52.57 **	23.07 *	-1.13	4.17	-14.22 **	0.76	-6.44	22.50 **
MM Sel-103 × MM-1831	65.30 **	82.32 **	47.07 **	-6.21	-1.19	-18.63 **	13.48 **	5.37	37.96 **
MM Sel-103 × MM 916/NS-1	-7.37	2.17	-17.58	3.39	8.93	-10.29 *	7.16	-0.5	30.28 **
MM Sel-103 × Riogold	32.78 **	46.45 **	18.14	-3.39	1.79	-16.18 **	-10.13 *	-16.55 **	9.26
MM-904 × MM-625	40.04 **	54.46 **	24.60 *	10.73 *	16.67 **	-3.92	21.33 **	12.66 **	47.50 **
MM-904 × MM-610	0.1	10.41	-10.94	22.60 **	29.17 **	6.37	5.1	-2.4	27.78 **
MM-904 × MM-1831	-27.02 *	-19.51	-35.07 **	9.60 *	15.48 **	-4.9	-0.23	-7.36	21.30 **
MM-904 × MM 916/NS-1	-15.09	-6.35	-24.46 *	8.47	14.29 **	-5.88	-16.45 **	-22.42 **	1.57
MM-904 × Riogold	-8.2	1.26	-18.32	24.86 **	31.55 **	8.33 *	-7.08	-13.72 **	12.96 *
MM-625 × MM-610	37.45 **	51.60 **	22.29 *	10.17 *	16.07 **	-4.41	-10.13 *	-16.55 **	9.26
MM-625 × MM-1831	74.79 **	92.79 **	55.51 **	3.39	8.93	-10.29 *	-15.69 **	-21.71 **	2.5
MM-625 × MM 916/NS-1	-14.26	-5.43	-23.72 *	2.82	8.33	-10.78 *	-20.49 **	-26.17 **	-3.33
MM-625 × Riogold	46.78 **	61.90 **	30.60 **	5.08	10.71 *	-8.82 *	11.96 *	3.96	36.11 **
MM-610 × MM-1831	76.56 **	94.74 **	57.08 **	12.43 *	18.45 **	-2.45	8.99	1.2	32.50 **
MM-610 × MM 916/NS-1	67.01 **	84.21 **	48.59 **	9.04	14.88 **	-5.39	9.22	1.41	32.78 **
MM-610 × Riogold	108.66 **	130.15 **	85.65 **	11.86 *	17.86 **	-2.94	7.69	0	30.93 **
MM-1831 × MM 916/NS-1	42.79 **	57.49 **	27.04 *	7.91	13.69 **	-6.37	19.80 **	11.24 *	45.65 **
MM-1831 × Riogold	57.99 **	74.26 **	40.56 **	10.17 *	16.07 **	-4.41	1.07	-6.15	22.87 **
MM 916/NS-1 × Riogold	51.45 **	67.05 **	34.75 **	7.91	13.69 **	-6.37	-5.79	-12.52 **	14.54 *
LSD (p≤0.05)	**2.2**			**0.08**			**0.63**		
LSD (p≤0.01)	**3.0**			**0.11**			**0.84**		

* Significant at 5% level & ** Significant at 1% level

Table 4.9: Continued….

Traits	No of Branches			TSS (□Brix)			β-carotene (mg/100g)		
Crosses/ Checks	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**
MS-1 × Kajri	13.04	-7.07	23.86	27.38 **	25.38 **	27.01 **	-20.72 **	-22.60 **	-17.60 **
MS-1 × KP_4HM-15	17.34	-3.54	28.57	16.59 *	14.76	16.26	-48.10 **	-49.34 **	-46.06 **
MS-1 × MM Sel-103	12.91	-7.18	23.71	3.39	1.76	3.09	-1.4	-3.75	2.47
MS-1 × MM-904	13.04	-7.07	23.86	3.19	1.57	2.89	-7.5	-9.70 *	-3.87
MS-1 × MM-625	26.08	3.64	38.14 *	1.26	-0.33	0.96	-56.29 **	-57.33 **	-54.57 **
MS-1 × MM-610	4.3	-14.26	14.29	2.23	0.62	1.93	-5.94	-8.18 *	-2.24
MS-1 × MM-1831	13.04	-7.07	23.86	6.43	4.76	6.13	6.53	3.99	10.71 **
MS-1 × MM 916/ NS-1	8.74	-10.61	19.14	11.76	10	11.43	-13.34 **	-15.40 **	-9.93 *
MS-1 × Riogold	-8.74	-24.97 *	0	-9.39	-10.81	-9.65	-49.18 **	-50.39 **	-47.18 **
Kajri × KP_4HM-15	4.3	-14.26	14.29	-36.77 **	-37.76 **	-36.95 **	-27.63 **	-29.35 **	-24.78 **
Kajri × MM Sel-103	17.34	-3.54	28.57	3.53	1.9	3.23	-27.02 **	-28.76 **	-24.15 **
Kajri × MM-904	8.6	-10.72	19	18.05 *	16.19 *	17.70 *	-43.89 **	-45.23 **	-41.69 **
Kajri × MM-625	4.3	-14.26	14.29	-7.79	-9.24	-8.06	-22.20 **	-24.05 **	-19.14 **
Kajri × MM-610	0	-17.79	9.57	-9.53	-10.95	-9.79	-9.80 *	-11.95 **	-6.25
Kajri × MM-1831	43.42 **	17.9	57.14 **	15	13.19	14.66	-16.04 **	-18.04 **	-12.74 **
Kajri × MM 916/NS-1	8.6	-10.72	19	24.14 **	22.19 **	23.78 **	-6.22	-8.45 *	-2.54
Kajri × Riogold	8.6	-10.72	19	13.84	12.05	13.51	-26.96 **	-28.70 **	-24.09 **
KP_4HM-15 × MM Sel-103	4.3	-14.26	14.29	30.62 **	28.57 **	30.25 **	-28.79 **	-30.48 **	-25.99 **
KP_4HM-15 × MM-904	13.04	-7.07	23.86	-14.51	-15.86	-14.76	-12.18 **	-14.27 **	-8.73 *
KP_4HM-15 × MM-625	17.34	-3.54	28.57	14.32	12.52	13.99	-10.55 **	-12.68 **	-7.04
KP_4HM-15 × MM-610	13.04	-7.07	23.86	12.53	10.76	12.2	-47.14 **	-48.40 **	-45.07 **
KP_4HM-15 × MM-1831	30.38 *	7.18	42.86 **	28.21 **	26.19 **	27.83 **	-62.07 **	-62.97 **	-60.57 **
KP_4HM-15 × MM 916/NS-1	17.34	-3.54	28.57	26.08 **	24.10 **	25.71 **	-14.68 **	-16.71 **	-11.32 **
KP_4HM-15 × Riogold	26.08	3.64	38.14 *	17.08 *	15.24	16.74 *	-50.34 **	-51.52 **	-48.38 **
MM Sel-103 × MM-904	13.04	-7.07	23.86	5.81	4.14	5.5	-14.35 **	-16.39 **	-10.99 **

Traits	No of Branches			TSS (□Brix)			β-carotene (mg/100g)		
MM Sel-103 × MM-625	43.42 **	17.9	57.14 **	14.51	12.71	14.18	-50.07 **	-51.26 **	-48.11 **
MM Sel-103 × MM-610	8.6	-10.72	19	-7.74	-9.19	-8.01	-31.82 **	-33.44 **	-29.14 **
MM Sel-103 × MM-1831	4.3	-14.26	14.29	-1.11	-2.67	-1.4	-52.57 **	-53.70 **	-50.71 **
MM Sel-103 × MM 916/NS-1	4.3	-14.26	14.29	31.93 **	29.86 **	31.55 **	-28.16 **	-29.87 **	-25.33 **
MM Sel-103 × Riogold	8.6	-10.72	19	5.47	3.81	5.16	-48.51 **	-49.73 **	-46.48 **
MM-904 × MM-625	0	-17.79	9.57	22.06 **	20.14 *	21.71 **	-14.66 **	-16.69 **	-11.30 **
MM-904 × MM-610	-8.74	-24.97 *	0	-6.92	-8.38	-7.19	-40.35 **	-41.77 **	-38.01 **
MM-904 × MM-1831	0	-17.79	9.57	5.95	4.29	5.64	-36.29 **	-37.81 **	-33.78 **
MM-904 × MM 916/NS-1	-8.74	-24.97 *	0	23.66 **	21.71 **	23.30 **	-29.74 **	-31.41 **	-26.98 **
MM-904 × Riogold	0	-17.79	9.57	-20.66 *	-21.90 **	-20.89 *	-26.27 **	-28.02 **	-23.37 **
MM-625 × MM-610	4.3	-14.26	14.29	16.11	14.29	15.77	-6.53	-8.75 *	-2.85
MM-625 × MM-1831	4.3	-14.26	14.29	8.03	6.33	7.72	-3.44	-5.74	0.36
MM-625 × MM 916/NS-1	4.3	-14.26	14.29	14.32	12.52	13.99	-43.89 **	-45.23 **	-41.69 **
MM-625 × Riogold	17.34	-3.54	28.57	2.42	0.81	2.12	-19.43 **	-21.35 **	-16.27 **
MM-610 × MM-1831	4.3	-14.26	14.29	7.06	5.38	6.75	9.17 *	6.57	13.46 **
MM-610 × MM 916/NS-1	21.64	0	33.29 *	27.38 **	25.38 **	27.01 **	-26.14 **	-27.90 **	-23.24 **
MM-610 × Riogold	4.3	-14.26	14.29	12.24	10.48	11.92	-22.75 **	-24.59 **	-19.71 **
MM-1831 × MM 916/NS-1	13.04	-7.07	23.86	44.32 **	42.05 **	43.90 **	-42.85 **	-44.22 **	-40.61 **
MM-1831 × Riogold	-4.3	-21.33	4.86	23.37 **	21.43 **	23.01 **	-33.60 **	-35.19 **	-31.00 **
MM 916/NS-1 × Riogold	13.04	-7.07	23.86	13.69	11.9	13.36	-6.26	-8.49 *	-2.58
LSD (p≤0.05)	**1.1**			**1.7**			**1.8**		
LSD (p≤0.01)	**1.5**			**2.2**			**2.4**		

* Significant at 5% level & ** Significant at 1% level

Table 4.9: Continued…..

Traits	Firmness in (lb/ inch^2)			Ascorbic Acid (mg/100g)			Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)		
Crosses/ Checks	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**
MS-1 × Kajri	-52.38 **	-59.18 **	-42.86 **	-42.14 **	-48.19 **	-51.01 **	24.35 **	28.83 **	-45.83 **
MS-1 × KP$_4$HM-15	-35.71 **	-44.90 **	-22.86	-19.05 **	-27.51 **	-31.45 **	15.65 **	19.82 **	-49.62 **
MS-1 × MM Sel-103	-45.24 **	-53.06 **	-34.29 *	-27.86 **	-35.39 **	-38.91 **	56.52 **	62.16 **	-31.82 **
MS-1 × MM-904	-28.57 *	-38.78 **	-14.29	-48.10 **	-53.52 **	-56.05 **	33.91 **	38.74 **	-41.67 **
MS-1 × MM-625	-19.05	-30.61 **	-2.86	10.71 **	-0.85	-6.25	66.09 **	72.07 **	-27.65 **
MS-1 × MM-610	-16.67	-28.57 *	0	-6.67	-16.42 **	-20.97 **	33.91 **	38.74 **	-41.67 **
MS-1 × MM-1831	-30.95 *	-40.82 **	-17.14	2.38	-8.32 *	-13.31 **	34.78 **	39.64 **	-41.29 **
MS-1 × MM 916/ NS-1	-16.67	-28.57 *	0	-25.71 **	-33.48 **	-37.10 **	61.74 **	67.57 **	-29.55 **
MS-1 × Riogold	-28.57 *	-38.78 **	-14.29	-52.14 **	-57.14 **	-59.48 **	64.35 **	70.27 **	-28.41 **
Kajri × KP$_4$HM-15	-40.48 **	-48.98 **	-28.57	-76.90 **	-79.32 **	-80.44 **	26.96 **	31.53 **	-44.70 **
Kajri × MM Sel-103	-33.33 *	-42.86 **	-20	-8.33 *	-17.91 **	-22.38 **	35.65 **	40.54 **	-40.91 **
Kajri × MM-904	-38.10 **	-46.94 **	-25.71	-90.00 **	-91.04 **	-91.53 **	33.04 **	37.84 **	-42.05 **
Kajri × MM-625	-50.00 **	-57.14 **	-40.00 *	63.33 **	46.27 **	38.31 **	62.61 **	68.47 **	-29.17 **
Kajri × MM-610	-52.38 **	-59.18 **	-42.86 **	-78.81 **	-81.02 **	-82.06 **	55.65 **	61.26 **	-32.20 **
Kajri × MM-1831	-45.24 **	-53.06 **	-34.29 *	-0.48	-10.87 **	-15.73 **	51.30 **	56.76 **	-34.09 **
Kajri × MM 916/NS-1	-23.81	-34.69 **	-8.57	9.29 *	-2.13	-7.46 *	47.83 **	53.15 **	-35.61 **
Kajri × Riogold	-2.38	-16.33	17.14	-15.24 **	-24.09 **	-28.23 **	30.43 **	35.14 **	-43.18 **
KP$_4$HM-15 × MM Sel-103	14.29	-2.04	37.14 *	-9.05 *	-18.55 **	-22.98 **	-19.13 **	-16.22 **	-64.77 **
KP$_4$HM-15 × MM-904	-38.10 **	-46.94 **	-25.71	-71.67 **	-74.63 **	-76.01 **	-9.57 *	-6.31	-60.61 **
KP$_4$HM-15 × MM-625	45.24 **	24.49 *	74.29 **	-0.95	-11.30 **	-16.13 **	-15.65 **	-12.61 *	-63.26 **
KP$_4$HM-15 × MM-610	-16.67	-28.57 *	0	-43.10 **	-49.04 **	-51.81 **	-26.09 **	-23.42 **	-67.80 **
KP$_4$HM-15 × MM-1831	-16.67	-28.57 *	0	-64.52 **	-68.23 **	-69.96 **	-7.83	-4.5	-59.85 **
KP$_4$HM-15 × MM 916/NS-1	-7.14	-20.41	11.43	-34.29 **	-41.15 **	-44.35 **	4.35	8.11	-54.55 **
KP$_4$HM-15 × Riogold	-30.95 *	-40.82 **	-17.14	-18.81 **	-27.29 **	-31.25 **	-5.22	-1.8	-58.71 **
MM Sel-103 × MM-904	-26.19 *	-36.73 **	-11.43	-63.10 **	-66.95 **	-68.75 **	6.96	10.81 *	-53.41 **

Traits	Firmness in (lb/ inch^2)			Ascorbic Acid (mg/100g)			Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)		
MM Sel-103 × MM-625	-40.48 **	-48.98 **	-28.57	9.29 *	-2.13	-7.46 *	-3.48	0	-57.95 **
MM Sel-103 × MM-610	-9.52	-22.45 *	8.57	2.86	-7.89 *	-12.90 **	1.74	5.41	-55.68 **
MM Sel-103 × MM-1831	-38.10 **	-46.94 **	-25.71	-54.76 **	-59.49 **	-61.69 **	33.91 **	38.74 **	-41.67 **
MM Sel-103 × MM 916/NS-1	-38.10 **	-46.94 **	-25.71	23.57 **	10.66 **	4.64	2.61	6.31	-55.30 **
MM Sel-103 × Riogold	-54.76 **	-61.22 **	-45.71 **	-40.95 **	-47.12 **	-50.00 **	-3.48	0	-57.95 **
MM-904 × MM-625	-40.48 **	-48.98 **	-28.57	38.33 **	23.88 **	17.14 **	0	3.6	-56.44 **
MM-904 × MM-610	-16.67	-28.57 *	0	-70.95 **	-73.99 **	-75.40 **	-4.35	-0.9	-58.33 **
MM-904 × MM-1831	-54.76 **	-61.22 **	-45.71 **	-34.52 **	-41.36 **	-44.56 **	-6.96	-3.6	-59.47 **
MM-904 × MM 916/NS-1	-16.67	-28.57 *	0	-53.10 **	-58.00 **	-60.28 **	-10.43 *	-7.21	-60.98 **
MM-904 × Riogold	-26.19 *	-36.73 **	-11.43	-2.86	-13.01 **	-17.74 **	10.43 *	14.41 **	-51.89 **
MM-625 × MM-610	-26.19 *	-36.73 **	-11.43	11.67 **	0	-5.44	38.26 **	43.24 **	-39.77 **
MM-625 × MM-1831	-45.24 **	-53.06 **	-34.29 *	-3.1	-13.22 **	-17.94 **	29.57 **	34.23 **	-43.56 **
MM-625 × MM 916/NS-1	-47.62 **	-55.10 **	-37.14 *	-16.19 **	-24.95 **	-29.03 **	139.13 **	147.75 **	4.17 *
MM-625 × Riogold	-57.14 **	-63.27 **	-48.57 **	-31.43 **	-38.59 **	-41.94 **	90.43 **	97.30 **	-17.05 **
MM-610 × MM-1831	-45.24 **	-53.06 **	-34.29 *	4.76	-6.18	-11.29 **	26.96 **	31.53 **	-44.70 **
MM-610 × MM 916/NS-1	-26.19 *	-36.73 **	-11.43	43.57 **	28.57 **	21.57 **	54.78 **	60.36 **	-32.58 **
MM-610 × Riogold	-71.43 **	-75.51 **	-65.71 **	-12.38 **	-21.54 **	-25.81 **	50.43 **	55.86 **	-34.47 **
MM-1831 × MM 916/NS-1	-38.10 **	-46.94 **	-25.71	-44.05 **	-49.89 **	-52.62 **	103.48 **	110.81 **	-11.36 **
MM-1831 × Riogold	-45.24 **	-53.06 **	-34.29 *	27.38 **	14.07 **	7.86 *	186.96 **	197.30 **	25.00 **
MM 916/NS-1 × Riogold	-33.33 *	-42.86 **	-20	27.86 **	14.50 **	8.27 *	141.74 **	150.45 **	5.30 *
LSD (p≤0.05)	**0.05**			**0.16**			**0.54**		
LSD (p≤0.01)	**0.07**			**0.22**			**0.71**		

* Significant at 5% level & ** Significant at 1% level

Table 4.9: Continued…

Traits	pH			Dry matter %		
Crosses/ Checks	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**
MS-1 × Kajri	66.67 **	37.10 **	-4.49	-3.70 *	-5.17 **	-5.78 **
MS-1 × KP_4HM-15	74.51 **	43.55 **	0	-9.77 **	-11.15 **	-11.72 **
MS-1 × MM Sel-103	43.14 **	17.74 **	-17.98 **	-1.75	-3.26	-3.87 *
MS-1 × MM-904	76.47 **	45.16 **	1.12	-2.37	-3.87 *	-4.48 *
MS-1 × MM-625	7.84	-11.29	-38.20 **	0.98	-0.57	-1.2
MS-1 × MM-610	86.27 **	53.23 **	6.74	1.87	0.31	-0.33
MS-1 × MM-1831	49.02 **	22.58 **	-14.61 **	-1.67	-3.18	-3.80 *
MS-1 × MM 916/ NS-1	41.18 **	16.13 *	-19.10 **	-5.23 **	-6.69 **	-7.28 **
MS-1 × Riogold	27.45 **	4.84	-26.97 **	-16.57 **	-17.85 **	-18.37 **
Kajri × KP_4HM-15	76.47 **	45.16 **	1.12	-1.73	-3.24	-3.85 *
Kajri × MM Sel-103	58.82 **	30.65 **	-8.99	2.68	1.1	0.46
Kajri × MM-904	66.67 **	37.10 **	-4.49	0.13	-1.41	-2.04
Kajri × MM-625	31.37 **	8.06	-24.72 **	-1.78	-3.29	-3.90 *
Kajri × MM-610	123.53 **	83.87 **	28.09 **	-1.57	-3.08	-3.70 *
Kajri × MM-1831	109.80 **	72.58 **	20.22 **	-6.24 **	-7.68 **	-8.27 **
Kajri × MM 916/NS-1	35.29 **	11.29	-22.47 **	0.31	-1.23	-1.85
Kajri × Riogold	33.33 **	9.68	-23.60 **	4.23 *	2.63	1.98
KP_4HM-15 × MM Sel-103	45.10 **	19.35 **	-16.85 **	-0.81	-2.33	-2.95
KP_4HM-15 × MM-904	41.18 **	16.13 *	-19.10 **	-9.77 **	-11.15 **	-11.72 **
KP_4HM-15 × MM-625	37.25 **	12.9	-21.35 **	-4.83 **	-6.29 **	-6.88 **
KP_4HM-15 × MM-610	35.29 **	11.29	-22.47 **	-3.54	-5.02 **	-5.62 **
KP_4HM-15 × MM-1831	37.25 **	12.9	-21.35 **	2.34	0.77	0.13
KP_4HM-15 × MM 916/NS-1	47.06 **	20.97 **	-15.73 **	3.36	1.77	1.13
KP_4HM-15 × Riogold	37.25 **	12.9	-21.35 **	-5.57 **	-7.02 **	-7.61 **
MM Sel-103 × MM-904	41.18 **	16.13 *	-19.10 **	-12.89 **	-14.22 **	-14.77 **
MM Sel-103 × MM-625	35.29 **	11.29	-22.47 **	-16.57 **	-17.85 **	-18.37 **

Traits	pH			Dry matter %		
MM Sel-103 × MM-610	52.94 **	25.81 **	-12.36 **	0.92	-0.63	-1.26
MM Sel-103 × MM-1831	76.47 **	45.16 **	1.12	-4.84 **	-6.30 **	-6.89 **
MM Sel-103 × MM 916/NS-1	76.47 **	45.16 **	1.12	-4.64 *	-6.10 **	-6.70 **
MM Sel-103 × Riogold	35.29 **	11.29	-22.47 **	-1.29	-2.8	-3.42
MM-904 × MM-625	33.33 **	9.68	-23.60 **	2.84	1.26	0.61
MM-904 × MM-610	31.37 **	8.06	-24.72 **	1.75	0.19	-0.45
MM-904 × MM-1831	56.86 **	29.03 **	-10.11 *	-4.35 *	-5.82 **	-6.42 **
MM-904 × MM 916/NS-1	39.22 **	14.52 *	-20.22 **	0.7	-0.85	-1.47
MM-904 × Riogold	31.37 **	8.06	-24.72 **	0.49	-1.05	-1.68
MM-625 × MM-610	31.37 **	8.06	-24.72 **	2.37	0.79	0.15
MM-625 × MM-1831	60.78 **	32.26 **	-7.87	0.05	-1.48	-2.11
MM-625 × MM 916/NS-1	72.55 **	41.94 **	-1.12	1.93	0.36	-0.28
MM-625 × Riogold	66.67 **	37.10 **	-4.49	-8.91 **	-10.31 **	-10.88 **
MM-610 × MM-1831	43.14 **	17.74 **	-17.98 **	-9.93 **	-11.32 **	-11.88 **
MM-610 × MM 916/NS-1	58.82 **	30.65 **	-8.99	-4.11 *	-5.59 **	-6.19 **
MM-610 × Riogold	80.39 **	48.39 **	3.37	1.97	0.4	-0.24
MM-1831 × MM 916/NS-1	33.33 **	9.68	-23.60 **	-6.23 **	-7.67 **	-8.25 **
MM-1831 × Riogold	100.00 **	64.52 **	14.61 **	-6.67 **	-8.10 **	-8.68 **
MM 916/NS-1 × Riogold	33.33 **	9.68	-23.60 **	-5.68 **	-7.13 **	-7.72 **
LSD (p≤0.05)	**0.41**			**3.4**		
LSD (p≤0.01)	**0.55**			**4.5**		

* Significant at 5% level & ** Significant at 1% level

Table 4.9: Continued….

Traits	Reaction to RKN (GI)			Reaction to Viral disease (PDI)			Reaction to Fusarium wilt (PDI)		
Crosses/ Checks	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**	**MH-27**	**MH-51**	**FG**
MS-1 × Kajri	-1.37	-1.37	16.13	-38.89 **	-14.51 **	-10.13 **	-63.24 **	-63.77 **	-48.98 **
MS-1 × KP_4HM-15	9.59	9.59	29.03	-43.48 **	-20.93 **	-16.88 **	-0.29	-1.74	38.37 **
MS-1 × MM Sel-103	6.85	6.85	25.81	-35.70 **	-10.05 **	-5.45	-29.41 **	-30.43 **	-2.04
MS-1 × MM-904	31.51 *	31.51 *	54.84 **	-43.04 **	-20.31 **	-16.23 **	4.41	2.9	44.90 **
MS-1 × MM-625	15.07	15.07	35.48 *	-62.37 **	-47.36 **	-44.66 **	-2.94	-4.35	34.69 **
MS-1 × MM-610	10.96	10.96	30.65	-45.85 **	-24.25 **	-20.37 **	-16.18 **	-17.39 **	16.33 **
MS-1 × MM-1831	-9.59	-9.59	6.45	-35.93 **	-10.36 **	-5.77	5.07	3.55	45.82 **
MS-1 × MM 916/ NS-1	20.55	20.55	41.94 *	-29.19 **	-0.93	4.14	-7.35 **	-8.70 **	28.57 **
MS-1 × Riogold	-20.55	-20.55	-6.45	-66.52 **	-53.16 **	-50.76 **	-1.47	-2.9	36.73 **
Kajri × KP_4HM-15	4.11	4.11	22.58	-37.04 **	-11.92 **	-7.41 *	4.41	2.9	44.90 **
Kajri × MM Sel-103	-21.92	-21.92	-8.06	-5.08 *	32.79 **	39.59 **	-41.18 **	-42.03 **	-18.37 **
Kajri × MM-904	-28.77	-28.77	-16.13	-46.30 **	-24.87 **	-21.02 **	-52.94 **	-53.62 **	-34.69 **
Kajri × MM-625	-30.14 *	-30.14 *	-17.74	-54.79 **	-36.75 **	-33.51 **	4.41	2.9	44.90 **
Kajri × MM-610	-38.36 *	-38.36 *	-27.42	-56.30 **	-38.86 **	-35.73 **	-19.12 **	-20.29 **	12.24 **
Kajri × MM-1831	-9.59	-9.59	6.45	-43.48 **	-20.93 **	-16.88 **	-19.12 **	-20.29 **	12.24 **
Kajri × MM 916/NS-1	23.29	23.29	45.16 *	-7.44 **	29.49 **	36.12 **	-8.82 **	-10.14 **	26.53 **
Kajri × Riogold	-4.11	-4.11	12.9	-35.19 **	-9.33 **	-4.68	-5.88 *	-7.25 **	30.61 **
KP_4HM-15 × MM Sel-103	9.59	9.59	29.03	-69.63 **	-57.51 **	-55.34 **	3.59	2.09	43.76 **
KP_4HM-15 × MM-904	-20.55	-20.55	-6.45	-62.96 **	-48.19 **	-45.53 **	-9.21 **	-10.52 **	26.00 **
KP_4HM-15 × MM-625	2.74	2.74	20.97	-33.59 **	-7.09 *	-2.33	-4.41	-5.80 *	32.65 **
KP_4HM-15 × MM-610	-15.07	-15.07	0	-64.81 **	-50.78 **	-48.26 **	6.22 *	4.68	47.41 **
KP_4HM-15 × MM-1831	4.11	4.11	22.58	-26.30 **	3.11	8.39 *	2.94	1.45	42.86 **
KP_4HM-15 × MM 916/NS-1	23.29	23.29	45.16 *	-24.07 **	6.22	11.66 **	8.82 **	7.25 **	51.02 **
KP_4HM-15 × Riogold	-1.37	-1.37	16.13	-19.56 **	12.54 **	18.30 **	3.46	1.96	43.57 **
MM Sel-103 × MM-904	0	0	17.74	-22.22 **	8.81 **	14.38 **	-39.71 **	-40.58 **	-16.33 **
MM Sel-103 × MM-625	-1.37	-1.37	16.13	-16.96 **	16.17 **	22.11 **	-64.71 **	-65.22 **	-51.02 **

Traits	Reaction to RKN (GI)			Reaction to Viral disease (PDI)			Reaction to Fusarium wilt (PDI)		
MM Sel-103 × MM-610	-17.81	-17.81	-3.23	-22.22 **	8.81 **	14.38 **	-42.65 **	-43.48 **	-20.41 **
MM Sel-103 × MM-1831	2.74	2.74	20.97	-53.70 **	-35.23 **	-31.92 **	8.82 **	7.25 **	51.02 **
MM Sel-103 × MM 916/NS-1	20.55	20.55	41.94 *	-25.93 **	3.63	8.93 *	4.41	2.9	44.90 **
MM Sel-103 × Riogold	23.29	23.29	45.16 *	-31.56 **	-4.25	0.65	-5.15	-6.52 *	31.63 **
MM-904 × MM-625	16.44	16.44	37.10 *	-20.74 **	10.88 **	16.56 **	10.47 **	8.87 **	53.31 **
MM-904 × MM-610	13.7	13.7	33.87	-29.26 **	-1.04	4.03	9.88 **	8.29 **	52.49 **
MM-904 × MM-1831	13.7	13.7	33.87	-43.78 **	-21.35 **	-17.32 **	6.03 *	4.49	47.14 **
MM-904 × MM 916/NS-1	2.74	2.74	20.97	-61.16 **	-45.66 **	-42.88 **	19.12 **	17.39 **	65.31 **
MM-904 × Riogold	8.22	8.22	27.42	-26.22 **	3.21	8.50 *	8.82 **	7.25 **	51.02 **
MM-625 × MM-610	-23.29	-23.29	-9.68	-22.22 **	8.81 **	14.38 **	5.88 *	4.35	46.94 **
MM-625 × MM-1831	19.18	19.18	40.32 *	-46.07 **	-24.56 **	-20.70 **	-20.59 **	-21.74 **	10.20 **
MM-625 × MM 916/NS-1	23.29	23.29	45.16 *	-31.56 **	-4.25	0.65	13.24 **	11.59 **	57.14 **
MM-625 × Riogold	10.96	10.96	30.65	-26.07 **	3.42	8.71 *	6.60 *	5.06	47.94 **
MM-610 × MM-1831	23.29	23.29	45.16 *	-23.56 **	6.94 *	12.42 **	4.41	2.9	44.90 **
MM-610 × MM 916/NS-1	36.99 *	36.99 *	61.29 **	-43.29 **	-20.66 **	-16.60 **	-41.18 **	-42.03 **	-18.37 **
MM-610 × Riogold	23.29	23.29	45.16 *	-52.19 **	-33.12 **	-29.69 **	-42.65 **	-43.48 **	-20.41 **
MM-1831 × MM 916/NS-1	27.4	27.4	50.00 **	-26.67 **	2.59	7.84 *	-14.71 **	-15.94 **	18.37 **
MM-1831 × Riogold	16.44	16.44	37.10 *	-44.22 **	-21.97 **	-17.97 **	4.41	2.9	44.90 **
MM 916/NS-1 × Riogold	32.88 *	32.88 *	56.45 **	-61.19 **	-45.70 **	-42.92 **	-4.41	-5.80 *	32.65 **
LSD (p≤0.05)	**1.0**			**1.6**			**1.8**		
LSD (p≤0.01)	**1.4**			**2.1**			**2.3**		

* Significant at 5% level & ** Significant at 1% level

4.3.2.15 β-carotene (mg/100g)

Only one hybrid MM-610 × MM-1831 exhibiting positive and significant standard heterosis over the standard check MH-27. Two hybrids *viz.*, MM-610 × MM-1831 and MS-1 × MM-1831, out of forty-five were exhibited positive and highly significant standard heterosis over the Farmer Glory. No hybrids showed significant results over the MH-51.

4.3.2.16 Firmness (lb/ inch2)

Only one hybrid KP_4HM-15 × MM-625 exhibiting positive and significant standard heterosis over the standard check MH-27 and MH-51. Two hybrids exhibited positive and highly significant standard heterosis over the Farmer Glory were KP_4HM-15 × MM Sel-103 and KP_4HM-15 × MM-625 for this trait.

4.3.2.17 Ascorbic acid

Standard heterosis for ascorbic acid over MH-27 observed in nine cross combinations showing significantly higher heterosis. Maximum positive and significant standard heterosis was recorded in case of Kajri × MM-625, MM-904 × MM-625, MM 916/NS-1 × Riogold, MM-1831 × Riogold, and MM Sel-103 × MM 916/NS-1 hybrid combination. Five crosses *viz.*, Kajri × MM-625, MM-904 × MM-625, MM 916/NS-1 × Riogold, MM-1831 × Riogold, MM Sel-103 × MM 916/NS-1 showing positive and significant higher standard heterosis than the MH-51. Four hybrids *viz.*, Kajri × MM-625, MM-904 × MM-625, MM-1831 × Riogold, MM 916/NS-1 × Riogold exhibited positive and significant standard heterosis over the Farmer Glory.

4.3.2.18 Titrable acidity

Out of forty-five, only four hybrids viz., KP_4HM-15 × MM-610, KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-625, and MM-904 × MM 916/NS-1 was exhibited positive and highly significant standard heterosis over the 'MH-27'. Similarly, the estimates of significant and positive standard heterosis were exhibited by only three hybrids viz., KP_4HM-15 × MM-610, KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-625, over the best check 'MH-51'. The highest estimates of positive and significant standard heterosis expressed by forty-two hybrids over the Farmer Glory. Maximum positive and significant standard heterosis was recorded in case of KP_4HM-15 × MM-610, KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-625, MM-904 × MM 916/NS-1 and KP_4HM-15 × MM-904 cross combination.

4.3.2.19 pH

Standard heterosis for pH over Farmer Glory were observed in 28 cross combinations showing significantly higher heterosis. Maximum positive and significant standard heterosis was recorded in case of MS-1 × MM-625, MS-1 × Riogold, MM-904 × MM-610, Kajri × MM-625, and Kajri × Riogold cross combinations. No hybrids showed significant results over the MH-27 and MH-51 for pH.

4.3.2.20 Dry matter

No hybrids exhibited positive and significant results over the all three checks namely MH-51, MH-27 and Farmer Glory.

4.3.2.21 Reaction to root knot nematode incidence

Only two hybrids *viz.*, Kajri × MM-625 and Kajri × MM-610 were exhibited positive and significant economic heterosis over MH-27 and MH-51. No hybrids exhibited positive and significant standard heterosis over the Farmer Glory.

4.3.2.22 Reaction to viral disease

Negative heterosis is a desirable feature for the virus, all the hybrids were exhibited negative and significant economic heterosis over the MH-27. Maximum positive and significant standard heterosis was recorded in case of KP_4HM-15 × MM Sel-103, MS-1 × MM-625, KP_4HM-15 × MM-610, KP_4HM-15 × MM-904, and MM 916/NS-1 × Riogold cross combination. Thirty-four hybrids out of forty-five were exhibited negative and significant standard heterosis over the MH-51. Maximum negative and significant standard heterosis exhibited by KP_4HM-15 × MM Sel-103, MS-1 × Riogold, KP_4HM-15 × MM-610, KP_4HM-15 × MM-904, MM 916/NS-1 × Riogold cross combination. Twenty-two hybrids exhibited negative and significant standard heterosis over the Farmer Glory. Maximum negative and significant standard heterosis exhibited by KP_4HM-15 × MM Sel-103, MS-1 × Riogold, KP_4HM-15 × MM-610, KP_4HM-15 × MM-904, and MS-1 × MM-625 cross combinations.

4.3.2.23 Reaction to Fusarium wilt

Negative heterosis is a desirable feature for the fusarium wilt, 18, 12 and 8 hybrids were exhibited negative and significant standard heterosis over the three checks MH-27, MH-51 and Farmer Glory respectively. Maximum positive and significant standard heterosis was recorded in case of MM Sel-103 × MM-625, MS-1 × Kajri, Kajri × MM-904, MM Sel-103 × MM-610, and MM-610 × Riogold cross combination over all the three checks.

4.4 Study of inheritance of characters

The estimates of variation in genetic components of for inheritance of various parameters were displayed in Table 4.10 and discussed as follows. This present study showed that the values of dominance variance (H_1), non- additive variance (H_2) were greater than the additive genetic variance (D) for every traits except fruit shape index. This showed the presence of 'non-additive' gene action (dominance) involved in the 'inheritance' of these parameters. The estimates of the mean degree of dominance $(H_1/D_1)^{1/2}$ were much higher for all the traits except fruit shape index depicting over-dominance. The positive values of 'F' for number of fruit per plant, fruit yield (t ha^{-1}), Days taken to 1st female flower, Days taken to 1st fruit harvest, polar diameter, equatorial diameter, rind thickness, fruit cavity area, fruit shape index, vine length, number of branches, TSS, ascorbic acid, acidity, pH, β-carotene,

Table 4.10: Estimates of genetic components of variation and various statistical parameters for yield related traits

Traits	Additive (D)	Dominance (H_1)	Non-additive (H_2)	F	E	$(H_1/D)^{1/2}$	$H_2/4H_1$	$(4DH1)^{1/2}+F/(4DH1)^{1/2}-F$	h^2/H_2
Average fruit weight (g)	12909.0*	68628.5*	52496.7*	-344.4	904.2	2.3	0.19	0.98	0.015
No. of fruits per plant	0.31	2.8*	1.7*	1.05	0.01	3	0.14	3.49	0.083
Fruit yield (t ha^{-1})	22	212.8*	144.2*	62.9	0.32	3.1	0.17	2.7	0.08
Days taken to 1st female flower	6.4*	24.2*	21.1*	7.8	1.1	1.9	0.21	1.9	4.26
Days to 1st fruit harvest	6.2	43.4	36.4	8.3	0.46	2.6	0.21	1.6	3.3
Polar diameter (cm)	0.68	6.7*	4.9*	2	0.09	3.1	0.18	2.7	0.19
Equatorial diameter (cm)	0.73*	3.1*	2.3*	1.3	0.08	2	0.18	2.6	0.076
Flesh thickness (cm)	0.10*	0.22*	0.18*	-0.001	0.02	1.4	0.2	0.99	-0.04
Rind thickness (mm)	1.7*	2.9*	2.2*	1.1	0.16	1.2	0.19	1.6	-0.015
Fruit cavity area (cm^2)	14.7*	35.0*	28.5*	4.6	0.63	1.5	0.2	1.2	0.11
Fruit shape index	0.01*	0.008*	0.006*	0.003	0.0008	0.89	0.2	1.5	-0.03
Vine length (m)	1.1	6.5*	4.8*	1.6	0.05	2.3	0.18	1.8	-0.002
No. of branches	0.37*	0.93*	0.53*	0.75	0.14	1.57	0.14	4.4	-0.04
TSS (□ Brix)	1.1	9.7*	8.2*	1.2	0.35	2.8	0.21	1.4	1.4
β-carotene (mg/100g)	0.49*	1.7*	1.5*	0.3	0.003	1.8	0.21	1.3	0.11
Firmness (lb/ $inch^2$)	8.8*	21.8*	15.1*	8.3	0.03	1.5	0.17	1.8	0.21
Ascorbic acid (mg/100g)	23.0*	81.5*	74.6*	22.0*	0.43	1.8	0.22	1.6	0.64
Acidity (mg/ 100 ml)	0.0005	0.007*	0.005*	0.001	0.0003	3.6	0.19	2.4	0.2
pH	0.23	1.7*	1.3*	0.48	0.02	2.7	0.19	2.2	0.64
Dry matter %	16.3	110.8*	87.7*	35.9	1.43	2.6	0.19	2.4	0
Reaction to RKN (GI)	0.34*	0.82*	0.75*	-0.03	0.15	1.5	0.23	0.93	0.29
Reaction to Viral disease	45.6*	138.2*	114.2*	59.3*	0.33*	1.7	0.2	2.2	0.07
Reaction to Fusarium wilt	49.8	250.2*	174.2*	100.6	0.38	2.2	0.17	2.6	0.02

firmness, reaction to *fusarium* wilt infestation and reaction to viral disease except average fruit weight, Flesh thickness, and reaction to root-knot nematode indicated the presence of more rate of dominant alleles than 'recessive' alleles in the inbred lines. The percentage of genes with positive and negative effects ($H_2/4H_1$) in the inbred lines was detected less than 0.25 for all the traits considering genes are to be asymmetrically distributed at the loci depicting dominance. The ratio of 'dominant' and recessive genes $[(4DH_1)^{1/2}+F/(4DH1)^{1/2} -F]$ in the inbred lines were greater than unity for traits *viz.*, average fruit weight, no. of fruit per plant, fruit yield (t ha^{-1}), Days taken to 1st female flower, polar diameter, equatorial diameter, rind thickness, fruit cavity area, fruit shape index, vine length, number of branches, TSS, ascorbic acid, acidity, β-carotene, firmness, pH, dry matter %, reaction to Fusarium wilt, reaction to viral disease and values lower than unity in traits *viz.*, flesh thickness and reaction to root-knot nematode indicated the asymmetrical distribution of genes among the parents. Number of blocks of dominant genes ($h^2/H2$) showed that one group of genes display 'dominance' for all the parameters, except days taken to 1st female flower emergence, days taken to 1st fruit harvest, and TSS content. The results of the analysis of components of variance in conformity with findings of Moon *et al* (2004), Munshi *et al* (2006), Kamer *et al* (2015) and Saha (2018).

In plant breeding, the variance of genetic components or variance of combining ability and effects measured the gene action. Since most of the parameters showing heterosis are controlled by polygenes, so the knowledge of gene action (inheritance pattern) of these parameters is of valuable importance in determining the genetic 'basis' of heterosis. In the present study, the predominance of dominance gene action in the inheritance or all the characters suggested that heterosis breeding may be beneficial to obtain greater profit in muskmelon.

4.5 Estimation of correlation coefficients

The relationship between different parameters is usefully defined by studying the correlation existing between these characters. In the present study, the genotypic and phenotypic correlation coefficients have been worked out for various parameters which are displayed in Table 4.11a & 4.11b and had been discussed below character-wise.

4.5.1 Average fruit weight

The genotypic correlation coefficients among different characters showed that average fruit weight (g) had a positive and significant association with flesh thickness, rind thickness, fruit cavity area, number of branches, TSS, β-carotene, firmness, and fruit yield (t ha^{-1}).

While the phenotypic correlation coefficient indicated that average fruit weight had a significant positive association with flesh thickness, rind thickness, fruit cavity area, number of branches, β-carotene, firmness, and fruit yield (t ha^{-1}).

Table 4. 11a: Genotypic correlation coefficient analysis between different characters of muskmelon

Traits	FNPP	DFFE	DFFH	PD	ED	FT	RT	FCA	FSI	VL	NBP	TSS
AVFW (g)	-0.100	-0.174	0.041	-0.034	-0.108	0.728**	0.512**	0.614**	-0.143	0.021	0.327**	0.205*
FNPP		-0.113	-0.267**	0.151	0.004	-0.101	-0.299**	-0.232*	0.038	0.323**	0.365**	-0.024
DFFE			0.717**	-0.164	-0.126	-0.047	-0.047	-0.131	-0.050	-0.041	0.013	-0.483**
DFFH				0.034	0.071	0.050	0.192*	0.062	-0.152	-0.027	0.048	-0.286**
Polar dia					0.697**	-0.090	-0.111	-0.122	0.070	0.078	0.427**	0.135
ED						-0.100	-0.049	-0.110	0.117	0.049	-0.046	0.082
FT							0.605**	0.890**	-0.114	-0.045	0.508**	0.267**
RT								0.898**	-0.100	-0.243**	0.244**	0.058
FCA									-0.088	-0.190*	0.454**	0.202*
FSI										0.000	-0.405**	0.100
VL											0.265**	0.269**
NBP												0.207*

* Significant at 5% & ** Significant 1%

Abbreviations: AVFW: Average fruit weight (g), FNPP: Number of fruits per plant, DFFE: Days taken to 1st female flower emergence, DFFH: Days taken to 1st fruit harvest, PD: Polar diameter (cm), ED: Equatorial diameter(cm), FT: Flesh thickness(cm), RT: Rind thickness(cm), FCA: Fruit cavity area(cm^2), FSI: Fruit shape index, VL: Vine length(m), NBP: Number of branches, β- caro: β- carotene content (mg/100g), F: Firmness (lb/inch^2), AA: Ascorbic acid (mg/100g), TA: Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice), DM: Dry matter (%), RNK: Reaction to root-knot nematode (GI), VD: Reaction to viral disease (PDI), FW: Reaction to Fusarium wilt (PDI)

Table 4.11a: Contd.....

Traits	β-caro	F	AA	TA	pH	DM	RKN	VD	FW	Yield
AVFW	0.405**	0.239**	-0.041	0.111	-0.025	0.005	0.304**	-0.073	-0.205*	0.610**
FNPP	-0.075	-0.367**	-0.086	0.303**	-0.315**	-0.149	-0.066	-0.086	0.053	0.713**
DFFE	-0.086	0.161	0.289**	0.189*	0.355**	0.102	-0.558**	0.061	0.015	-0.206*
DFFH	0.027	0.171	0.328**	0.106	0.360**	-0.080	-0.423**	0.135	-0.320**	-0.155
Polar dia	-0.017	0.022	0.034	0.191*	-0.015	-0.040	-0.151	-0.036	-0.122	0.117
ED	-0.058	0.070	0.005	-0.083	0.171	-0.107	0.028	-0.236*	0.076	-0.065
FT	0.523**	0.271**	-0.122	-0.226*	-0.105	-0.101	0.290**	-0.065	-0.292**	0.401**
RT	0.573**	0.346**	0.116	-0.294**	0.002	0.016	0.230*	0.008	-0.211*	0.096
FCA	0.550**	0.258**	-0.036	-0.295**	-0.095	-0.079	0.310**	0.002	-0.328**	0.227*
FSI	-0.093	-0.120	0.214*	0.165	0.021	-0.047	0.158	-0.267**	0.117	-0.056
VL	-0.187*	-0.269**	-0.105	0.269**	-0.089	-0.098	0.104	0.061	-0.012	0.265**
NBPP	0.362**	-0.027	-0.232*	0.061	-0.034	-0.213*	0.144	0.200*	-0.232*	0.530**
TSS	0.278**	-0.071	-0.231*	-0.004	-0.259**	0.043	0.507**	0.060	-0.202*	0.119
β-carotene		0.260**	0.218*	0.102	-0.227*	0.178	0.303**	0.169	-0.032	0.217*
F			0.151	-0.336**	0.353**	0.009	0.136	-0.089	0.026	-0.155
AA				0.200*	0.150	0.188*	-0.006	0.043	-0.027	-0.099
TA					-0.389**	0.279**	0.039	0.042	0.171	0.381**
pH						-0.025	-0.147	-0.181	-0.035	-0.264**
DM (%)							0.193*	0.090	0.144	-0.087
RNK								-0.010	0.187*	0.133
VD									-0.111	-0.126
FW										-0.111

* Significant at 5% & ** Significant 1%

Abbreviations: AVFW: Average fruit weight (g), FNPP: Number of fruits per plant, DFFE: Days taken to 1st female flower emergence, DFFH: Days taken to 1st fruit harvest, Polar dia (cm): Polar diameter, ED(cm): Equatorial diameter, FT: Flesh thickness (cm), RT: Rind thickness (cm), FCA: Fruit cavity area (cm^2), FSI: Fruit shape index, VL: Vine length (m), NBP: Number of branches, β- caro: β- carotene content (mg/100g), F: Firmness ($lb/inch^2$), AA: Ascorbic acid (mg/100g), TA: Titrable acidity (mg/100 ml of fruit juice), DM: Dry matter (%), RNK: Reaction to root-knot nematode (GI), VD: Reaction to viral disease (PDI), FW: Reaction to Fusarium wilt (PDI), FY: Fruit yield (t ha-1)

Table 4.11b: Phenotypic correlation coefficient analysis between different characters of muskmelon

Traits	FNPP	DFFE	DFFH	PD	ED	FT	RT	FCA	FSI	VL	NBP	TSS
AVFW	-0.128	-0.150	0.029	-0.038	-0.104	0.529**	0.401**	0.550**	-0.129	0.030	0.188*	0.157
FNPP		-0.104	-0.252**	0.143	0.014	-0.082	-0.246**	-0.205*	0.035	0.300**	0.141	-0.007
DFFE			0.675**	-0.108	-0.085	-0.006	0.030	-0.063	-0.039	-0.040	-0.016	-0.382**
DFFH				0.039	0.063	0.046	0.170	0.069	-0.105	-0.022	0.032	-0.248**
PD					0.708**	-0.087	-0.102	-0.111	0.064	0.055	0.201*	0.106
ED						-0.097	-0.045	-0.110	0.105	0.029	-0.048	0.102
FT							0.517**	0.700**	-0.036	-0.044	0.237*	0.153
RT								0.828**	-0.061	-0.228*	0.030	0.073
FCA									-0.093	-0.189*	0.202*	0.200*
FSI										-0.013	-0.174	0.006
VL											0.150	0.228*
NBPP												0.061

* Significant at 5% & ** Significant 1%

Abbreviations: AVFW: Average fruit weight (g), FNPP: Number of fruits per plant, DFFE: Days taken to 1st female flower emergence, DFFH: Days taken to 1st fruit harvest, PD: Polar diameter (cm), ED: Equatorial diameter(cm), FT: Flesh thickness(cm), RT: Rind thickness(cm), FCA: Fruit cavity area(cm^2), FSI: Fruit shape index, VL: Vine length(m), NBP: Number of branches, β- caro: β- carotene content (mg/100g), F: Firmness ($lb/inch^2$), AA: Ascorbic acid (mg/100g), TA: Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice), DM: Dry matter (%), RNK: Reaction to root-knot nematode (GI), VD: Reaction to viral disease (PDI), FW: Reaction to Fusarium wilt (PDI), FY: Fruit yield ($t\ ha^{-1}$)

Table 4.11b: Contd.....

Traits	β-caro	F	AA	TA	pH	DM	RKN	VD	FW	FY
AVFW	0.390**	0.230*	-0.043	0.067	-0.023	0.015	0.194*	-0.075	-0.191*	0.601**
FNPP	-0.076	-0.356**	-0.077	0.251**	-0.291**	-0.144	-0.047	-0.076	0.043	0.699**
DFFE	-0.061	0.139	0.249**	0.064	0.318**	0.099	-0.295**	0.040	0.004	-0.185*
DFFH	0.024	0.165	0.316**	0.071	0.341**	-0.057	-0.286**	0.131	-0.312**	-0.155
PD	-0.002	0.011	0.024	0.161	-0.016	-0.041	-0.032	-0.040	-0.109	0.107
ED	-0.040	0.057	-0.013	-0.033	0.155	-0.105	0.077	-0.213*	0.067	-0.058
FT	0.411**	0.224*	-0.086	-0.078	-0.084	-0.061	0.113	-0.058	-0.234*	0.303**
RT	0.502**	0.303**	0.088	-0.226*	0.018	0.016	0.183*	0.006	-0.187*	0.072
FCA	0.525**	0.246**	-0.031	-0.234*	-0.057	-0.074	0.243**	0.001	-0.316**	0.212*
FSI	-0.085	-0.111	0.178	0.107	-0.015	-0.032	0.112	-0.219*	0.099	-0.051
VL	-0.178	-0.263**	-0.103	0.218*	-0.083	-0.081	0.048	0.059	-0.013	0.257**
NBPP	0.151	-0.011	-0.131	0.075	-0.031	-0.091	0.053	0.085	-0.135	0.247**
TSS	0.237*	-0.055	-0.192*	0.012	-0.184*	0.032	0.319**	0.048	-0.168	0.100
β-caro		0.257**	0.211*	0.082	-0.217*	0.175	0.207*	0.166	-0.031	0.214*
F			0.147	-0.268**	0.335**	0.017	0.088	-0.089	0.027	-0.152
AA				0.167	0.140	0.176	-0.042	0.046	-0.026	-0.096
TA					-0.307**	0.213*	-0.038	0.027	0.130	0.302**
pH						-0.040	-0.098	-0.172	-0.038	-0.247**
DM							0.050	0.081	0.132	-0.081
RNK								-0.004	0.148	0.077
VD									-0.110	-0.123
FW										-0.111

* Significant at 5% & ** Significant 1%

Abbreviations: AVFW: Average fruit weight (g), FNPP: Number of fruits per plant, DFFE: Days taken to 1st female flower emergence, DFFH: Days taken to 1st fruit harvest, PD: Polar diameter(cm), ED: Equatorial diameter(cm), FT: Flesh thickness(cm), RT: Rind thickness(cm), FCA: Fruit cavity area (cm^2), FSI: Fruit shape index, VL: Vine length(m), NBP: Number of branches, β- caro: β- carotene content (mg/100g), F: Firmness ($lb/inch^2$), AA: Ascorbic acid (mg/100g), TA: Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice), DM: Dry matter (%), RNK: Reaction to root-knot nematode (GI), VD: Reaction to viral disease (PDI), FW: Reaction to Fusarium wilt (PDI), FY: Fruit yield ($t\ ha^{-1}$)

4.5.2 Number of fruits per plant

The estimates regarding genotypic and phenotypic correlation coefficients revealed that no. of fruits per plant had highly significant and positively correlated with vine length, no. of branches, titrable acidity, and fruit yield (t ha^{-1}). However, it depicted significant negative correlation with days taken to 1st fruit harvest, rind thickness, fruit cavity area, firmness, and pH. Number of fruits per plants had not any association with number of branches at phenotypic level.

4.5.3 Days taken to 1st female flower

The genotypic correlation coefficients among different characters revealed that days taken to 1st female flower had significantly associated with days taken to 1st fruit harvest, while significant negative correlation with TSS content, and fruit yield (t ha^{-1}).

Phenotypic correlation of days taken to 1st female flower positive and highly significant values with Days taken to 1st fruit harvest, ascorbic acid content, and pH. While significant negative correlation with TSS content, and fruit yield (t ha^{-1}).

4.5.4 Days taken to 1st fruit harvest

The estimates of genotypic correlation coefficients revealed that days taken to 1st fruit harvest had a positive and significant correlation with ascorbic acid content and pH. While it had negatively and significantly associated with TSS content.

Days taken to 1st fruit harvest had a positive and highly significant phenotypic correlation with ascorbic acid content and pH. While it had negatively and significantly associated with TSS content. Results discussed above supported the findings of Taha *et al* (2003), Choudhary *et al* (2004), Singh and Lal (2005), Mehta *et al* (2009), Rad *et al* (2010) and Malik and Vashisht (2012)

4.5.5 Polar diameter

Polar diameter of fruit had a positive and significant correlation with an equatorial diameter of fruit, no. of branches, and titrable acidity both at the genotypic and phenotypic level.

4.5.6 Equatorial diameter of fruit

Equatorial diameter of fruit did not exhibit any correlation with other traits.

4.5.7 Flesh thickness

The estimates of genotypic and phenotypic correlation coefficients revealed that that flesh thickness had a positive and significant correlation with rind thickness, fruit cavity area, number of branches, TSS, β-carotene, firmness, and fruit yield (t ha-1). It had negative correlation with titrable acidity. But flesh thickness did not have any association with TSS at phenotypic level. These results are similar to the finding of various workers like Taha *et al* (2003), Choudhary *et al* (2004), Pandey et 01(200)) and Rad *et al* (2010).

4.5.8 Rind thickness

The estimates of genotypic and phenotypic correlation coefficients revealed that rind thickness had a negative and significant correlation with vine length, titrable acidity and reaction to fusarium wilt infestation. However, it had a positive and highly significant association with Fruit cavity area, no. of branches, β-carotene, firmness, and reaction to root-knot nematode. But it had no correlation with no. of branches at phenotypic level. These results were also documented by Choudhary *et al* (2004) and Pandey *et al* (2005), Choudhary *et al* (2010), Malik and Vashisht (2012) and Reddy *et al* (2013).

4.5.9 Fruit cavity area

Fruit cavity area exhibited positive and significant genotypic and phenotypic correlation with no. of branches, TSS, β-carotene, firmness, and fruit yield (t ha^{-1}), while it had negative and significant correlation with titrable acidity.

4.5.10 Fruit shape index

Fruit shape index exhibited positive and significant correlation with ascorbic acid while, it had negative correlation with number of branches, and reaction to viral disease at genotypic level. Fruit shape index exhibited negative and significant correlation with reaction to viral disease at phenotypic level.

4.5.11 Vine length

The estimates of genotypic correlation coefficients revealed that vine length exhibited positive and significant correlation with number of branches, TSS, titrable acidity, and fruit yield (t ha^{-1}) at both genotypic and phenotypic level. But vine length did not have any association with number of branches at phenotypic level. The vine length had negative and highly significant association with firmness at both genotypic and phenotypic level, while it had negative association with β-carotene at the genotypic level only.

4.5.12 Number of branches

The estimates of both genotypic and phenotypic correlation coefficients revealed that number of branches exhibited positive and highly significant correlation with fruit yield (t ha^{-1}).

4.5.13 TSS

TSS content had a positive and highly significant genotypic and phenotypic correlation with β-carotene. However, it had exhibited negative and significant association with ascorbic acid, and pH both at genotypic and phenotypic level. But TSS had negative and significant association with reaction to fusarium wilt at genotypic level only.

4.5.14 β-carotene

β-carotene exhibited positive and significant correlation with firmness, ascorbic acid and fruit yield (t ha^{-1}) at both genotypic and phenotypic level. However, it also exhibited

negative and significant association with pH.

4.5.15 Firmness

Firmness exhibited positive and significant correlation with pH at both genotypic and phenotypic level. However, it also exhibited negative and significant association with titrable acidity.

4.5.16 Ascorbic acid

The estimates of genotypic correlation coefficients revealed that ascorbic acid exhibited a positive and highly significant correlation with titrable acidity, and dry matter. None of the other traits exhibited significant association with this trait.

4.5.17 Titrable acidity

The estimates of genotypic and phenotypic correlation coefficients revealed that acidity exhibited positive and significant correlation with dry matter, and fruit yield (t ha^{-1}). However, it had exhibited a negative and significant correlation with pH at both genotypic and phenotypic level.

4.5.18 pH

The estimates of genotypic correlation coefficients revealed that pH exhibited negative and highly significant correlation with fruit yield (t ha^{-1}). None of the other traits exhibited positive and significant association with this trait at both genotypic and phenotypic level.

4.5.19 Dry matter

None of traits exhibited positive and significant association with this trait at both genotypic and phenotypic level.

4.5.20 Reaction to root-knot nematode

The estimates of genotypic correlation coefficients revealed that significant and positive correlation with reaction to fusarium wilt.

4.5.21 Reaction to fusarium wilt

None of the traits exhibited significant association with this trait.

4.5.22 Reaction to viral disease

None of the traits exhibited significant association with this trait.

From the present result it was concluded that the extent of genotypic correlation higher than the phenotypic correlation coefficient for all the studied parameters. This may be due to low 'environmental' effect on these parameters and demonstrating that there is sturdy correlation between various inherent traits (Choudhary *et al* 2004). Tomar *et al* (2008), Mehta *et al* (2009), Choudhary *et al* (2010) and Cheema *et al* (2011) also reported that the higher values of genotypic correlations than those of the respective phenotypic correlation coefficients in most of the cases. It was suggesting that genotypic correlations were more

reliable and unrestricted from the environmental factors.

4.6 Path coefficient analysis

Path coefficient analysis is useful for finding out direct and indirect effect 'of relationship between the two variables. In the present investigation, path coefficient analysis was carried out taking total fruit yield (t ha^{-1}) as a dependent variable and rest components parameter as independent variables. Correlation coefficient obtained among the component traits and fruit yield was portioned into direct and indirect effects at both genotypic and phenotypic level. In present studies, twenty-three traits and one dependent trait had been worked out which are presented in Table 4.12a and 4.12b.

4.6.1 Average fruit weight (g)

In case of average fruit weight, positive direct effect (0.46) was low at genotypic level but high (0.685) at phenotypic level on the fruit yield (t ha^{-1}). Average fruit weight also exhibited indirect and positive effects on fruit yield per ha^{-1} via fruit cavity area, flesh thickness, days taken to 1st female flower emergence, and titrable acidity. However, it had comparatively high negative indirect effects on fruit yield per ha^{-1} via no. of fruits per vine, rind thickness, no. of branches, and reaction to root-knot nematode at genotypic and phenotypic level. It was observed that average fruit weight had positive direct effect on fruit yield (t ha^{-1}). Thus, fruit weight is an important component of total fruit yield and selection should be made according to this trait suggested by Choudhary *et al* (2004) and Singh and Lal (2005).

4.6.2 Number of fruits per plant

` No. of fruits per plant had the highest positive direct effect (0.83 and 0.77) on fruit yield (t ha^{-1}). The characters showed maximum positive indirect effects on fruit yield (t ha^{-1}) via days taken to first female flower, rind thickness, polar diameter, titrable acidity, ascorbic acid, and reaction to root-knot nematode. However, it had comparatively high negative indirect effects on fruit yield per ha-1 via number of branches, pH, fruit cavity area, flesh thickness and days taken to 1st fruit harvest at both genotypic and phenotypic level. Similar results were reported by Choudhary *et al* (2004), Mehta *et al* (2009), Ibrahim and Ramadan (2013). Singh and Lal (2005) also detected the negative indirect effect of no. of fruits per wine via fruit weight on total fruit yield.

4.6.3 Days taken to 1st female flower emergence

Days taken to 1st female flower had negative direct effect (-0.20 and -0.04) on fruit yield (t ha^{-1}) whereas, Days taken to 1st female flower exhibited a positive indirect effect on fruit yield (t ha^{-1}) via days taken to 1st fruit harvest, titrable acidity, and pH. However, it showed negative indirect effects on fruit yield (t ha^{-1}) via average fruit weight, no of fruits per vine, fruit cavity area, ascorbic acid, and polar diameter at genotypic and phenotypic level.

Table 4. 12a: Path-coefficient analysis showing direct (diagonal) and indirect effects of different characters on fruit yield (t ha^{-1}) at genotypic level

Traits	AVFW	FNPP	DFFE	DFFH	PD	ED	FT	RT	FCA	FSI	VL	NBP	TSS
AVFW	**0.462**	-0.083	0.035	0.002	-0.002	0.006	0.126	-0.024	0.135	0.013	0.000	-0.058	0.004
FNPP	-0.046	**0.834**	0.023	-0.011	0.010	0.000	-0.018	0.014	-0.051	-0.003	-0.002	-0.065	-0.001
DFFE	-0.081	-0.094	**-0.202**	0.029	-0.011	0.008	-0.008	0.002	-0.029	0.005	0.000	-0.002	-0.010
DFFH	0.019	-0.223	-0.145	**0.041**	0.002	-0.004	0.009	-0.009	0.014	0.014	0.000	-0.009	-0.006
PD	-0.016	0.126	0.033	0.001	**0.065**	-0.042	-0.016	0.005	-0.027	-0.006	0.000	-0.076	0.003
ED	-0.050	0.004	0.025	0.003	0.045	**-0.060**	-0.017	0.002	-0.024	-0.011	0.000	0.008	0.002
FT	0.337	-0.084	0.010	0.002	-0.006	0.006	**0.173**	-0.029	0.196	0.010	0.000	-0.091	0.006
RT	0.236	-0.249	0.010	0.008	-0.007	0.003	0.105	**-0.048**	0.197	0.009	0.001	-0.044	0.001
FCA	0.284	-0.194	0.026	0.003	-0.008	0.007	0.154	-0.043	**0.220**	0.008	0.001	-0.081	0.004
FSI	-0.066	0.032	0.010	-0.006	0.005	-0.007	-0.020	0.005	-0.019	**-0.091**	0.000	0.072	0.002
VL	0.010	0.270	0.008	-0.001	0.005	-0.003	-0.008	0.012	-0.042	0.000	**-0.005**	-0.047	0.006
NBPP	0.151	0.305	-0.003	0.002	0.028	0.003	0.088	-0.012	0.100	0.037	-0.001	**-0.179**	0.005
TSS	0.095	-0.020	0.097	-0.012	0.009	-0.005	0.046	-0.003	0.045	-0.009	-0.001	-0.037	**0.022**
β-caro	0.187	-0.063	0.017	0.001	-0.001	0.004	0.091	-0.027	0.121	0.008	0.001	-0.065	0.006
F	0.110	-0.306	-0.033	0.007	0.001	-0.004	0.047	-0.017	0.057	0.011	0.001	0.005	-0.002
AA	-0.019	-0.072	-0.058	0.013	0.002	0.000	-0.021	-0.006	-0.008	-0.020	0.001	0.041	-0.005
TA	0.051	0.253	-0.038	0.004	0.012	0.005	-0.039	0.014	-0.065	-0.015	-0.001	-0.011	0.000
pH	-0.012	-0.263	-0.072	0.015	-0.001	-0.010	-0.018	0.000	-0.021	-0.002	0.000	0.006	-0.006
Dry matter	0.002	-0.124	-0.021	-0.003	-0.003	0.006	-0.018	-0.001	-0.017	0.004	0.001	0.038	0.001
RNK	0.140	-0.055	0.113	-0.017	-0.010	-0.002	0.050	-0.011	0.068	-0.014	-0.001	-0.026	0.011
VD	-0.034	-0.071	-0.012	0.006	-0.002	0.014	-0.011	0.000	0.000	0.024	0.000	-0.036	0.001
FW	-0.095	0.045	-0.003	-0.013	-0.008	-0.005	-0.051	0.010	-0.072	-0.011	0.000	0.041	-0.004

R Square = 0.9906 & Residual Effect = 0.0970

Abbreviations: AVFW: Average fruit weight (g), FNPP: Number of fruits per plant, DFFE: Days taken to first female flower, DFFH: Days taken to 1st fruit harvest, PD : Polar diameter (cm), ED: Equatorial diameter(cm), FT (cm): Flesh thickness, RT: Rind thickness(cm), FCA: Fruit cavity area (cm^2), FSI: Fruit shape index, VL : Vine length (m), NBP: Number of branches, β- caro: β- carotene content (mg/100g), F: Firmness (lb/inch^2), AA: Ascorbic acid (mg/100g), TA: Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice), DM: Dry matter (%), RNK: Reaction to root-knot nematode (GI), VD: Reaction to viral disease (PDI), FW: Reaction to Fusarium wilt (PDI), FY: Fruit yield (t ha^{-1})

Table 4.12a: Contd.....

Traits	β-caro	F	AA	TA	pH	DM	RNK	VD	FW	FY
AVFW	-0.004	0.004	0.002	0.036	-0.006	0.000	-0.029	-0.002	-0.006	0.610**
FNPP	0.001	-0.006	0.004	0.097	-0.074	0.002	0.006	-0.003	0.002	0.713**
DFFE	0.001	0.003	-0.013	0.060	0.083	-0.002	0.052	0.002	0.000	-0.206*
DFFH	0.000	0.003	-0.015	0.034	0.085	0.001	0.040	0.005	-0.009	-0.155
PD	0.000	0.000	-0.002	0.061	-0.004	0.001	0.014	-0.001	-0.004	0.117
ED	0.001	0.001	0.000	-0.027	0.040	0.002	-0.003	-0.008	0.002	-0.065
FT	-0.006	0.004	0.006	-0.072	-0.025	0.002	-0.027	-0.002	-0.009	0.401**
RT	-0.006	0.006	-0.005	-0.094	0.001	0.000	-0.022	0.000	-0.006	0.096
FCA	-0.006	0.004	0.002	-0.095	-0.022	0.001	-0.029	0.000	-0.010	0.227*
FSI	0.001	-0.002	-0.010	0.053	0.005	0.001	-0.015	-0.009	0.003	-0.056
VL	0.002	-0.004	0.005	0.086	-0.021	0.002	-0.010	0.002	0.000	0.265**
NBPP	-0.004	0.000	0.011	0.019	-0.008	0.003	-0.014	0.007	-0.007	0.530**
TSS	-0.003	-0.001	0.011	-0.001	-0.061	-0.001	-0.048	0.002	-0.006	0.119
β-caro	**-0.011**	0.004	-0.010	0.033	-0.053	-0.003	-0.028	0.006	-0.001	0.217*
F	-0.003	**0.016**	-0.007	-0.108	0.083	0.000	-0.013	-0.003	0.001	-0.155
AA	-0.002	0.002	**-0.046**	0.064	0.035	-0.003	0.001	0.001	-0.001	-0.099
TA	-0.001	-0.005	-0.009	**0.320**	-0.091	-0.004	-0.004	0.001	0.005	0.381**
pH	0.003	0.006	-0.007	-0.124	**0.235**	0.000	0.014	-0.006	-0.001	-0.264**
Dry matter	-0.002	0.000	-0.009	0.089	-0.006	**-0.015**	-0.018	0.003	0.004	-0.087
RNK	-0.003	0.002	0.000	0.013	-0.035	-0.003	**-0.094**	0.000	0.005	0.133
VD	-0.002	-0.001	-0.002	0.013	-0.043	-0.001	0.001	**0.034**	-0.003	-0.126
FW	0.000	0.000	0.001	0.055	-0.008	-0.002	-0.018	-0.004	**0.029**	-0.111

R Square = 0.9906 & Residual Effect = 0.0970

Abbreviations: AVFW: Average fruit weight (g), FNPP: Number of fruits per plant, DFFE: Days taken to 1st female flower emergence, DFFH: Days taken to 1st fruit harvest, PD : Polar diameter(cm), ED: Equatorial diameter(cm), FT: Flesh thickness(cm), RT: Rind thickness(cm), FCA: Fruit cavity area(cm^2), FSI: Fruit shape index, VL : Vine length(m), NBP: Number of branches, β- caro: β- carotene content (mg/100g), F: Firmness ($lb/inch^2$), AA: Ascorbic acid (mg/100g), TA: Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice), DM: Dry matter (%), RNK: Reaction to root-knot nematode (GI), VD: Reaction to viral disease (PDI), FW: Reaction to Fusarium wilt (PDI), FY: Fruit yield ($t\ ha^{-1}$)

Table 4.12b: Path-coefficient analysis showing direct (diagonal) and indirect effects of different characters on fruit yield (t ha^{-1}) at phenotypic level

Traits	AVFW	N_PP	DFFE	DFFH	PD	ED	FT	RT	FCA	FSI	VL	NBP	TSS
AVFW	**0.685**	-0.099	0.006	0.001	-0.001	0.002	0.004	-0.009	0.011	-0.001	0.000	-0.001	-0.002
FNPP	-0.088	**0.777**	0.004	-0.013	0.004	0.000	-0.001	0.005	-0.004	0.000	-0.003	-0.001	0.000
DFFE	-0.103	-0.081	**-0.040**	0.034	-0.003	0.002	0.000	-0.001	-0.001	0.000	0.000	0.000	0.004
DFFH	0.020	-0.196	-0.027	**0.050**	0.001	-0.001	0.000	-0.004	0.001	-0.001	0.000	0.000	0.002
PD	-0.026	0.111	0.004	0.002	**0.026**	-0.015	-0.001	0.002	-0.002	0.001	-0.001	-0.002	-0.001
ED	-0.071	0.011	0.003	0.003	0.019	**-0.022**	-0.001	0.001	-0.002	0.001	0.000	0.000	-0.001
FT	0.362	-0.064	0.000	0.002	-0.002	0.002	**0.007**	-0.011	0.013	0.000	0.001	-0.002	-0.002
RT	0.275	-0.192	-0.001	0.009	-0.003	0.001	0.004	**-0.021**	0.016	-0.001	0.002	0.000	-0.001
FCA	0.377	-0.160	0.003	0.004	-0.003	0.002	0.005	-0.018	**0.019**	-0.001	0.002	-0.002	-0.002
FSI	-0.089	0.028	0.002	-0.005	0.002	-0.002	0.000	0.001	-0.002	**0.009**	0.000	0.001	0.000
VL	0.021	0.233	0.002	-0.001	0.001	-0.001	0.000	0.005	-0.004	0.000	**-0.011**	-0.001	-0.002
NBPP	0.129	0.110	0.001	0.002	0.005	0.001	0.002	-0.001	0.004	-0.002	-0.002	**-0.008**	-0.001
TSS	0.107	-0.006	0.015	-0.013	0.003	-0.002	0.001	-0.002	0.004	0.000	-0.002	-0.001	**-0.010**
β-caro	0.267	-0.059	0.003	0.001	0.000	0.001	0.003	-0.011	0.010	-0.001	0.002	-0.001	-0.002
F	0.158	-0.277	-0.006	0.008	0.000	-0.001	0.002	-0.007	0.005	-0.001	0.003	0.000	0.001
AA	-0.030	-0.060	-0.010	0.016	0.001	0.000	-0.001	-0.002	-0.001	0.002	0.001	0.001	0.002
TA	0.046	0.195	-0.003	0.004	0.004	0.001	-0.001	0.005	-0.005	0.001	-0.002	-0.001	0.000
pH	-0.016	-0.227	-0.013	0.017	0.000	-0.003	-0.001	0.000	-0.001	0.000	0.001	0.000	0.002
DM	0.011	-0.112	-0.004	-0.003	-0.001	0.002	0.000	0.000	-0.001	0.000	0.001	0.001	0.000
RNK	0.133	-0.036	0.012	-0.014	-0.001	-0.002	0.001	-0.004	0.005	0.001	-0.001	0.000	-0.003
VD	-0.052	-0.059	-0.002	0.007	-0.001	0.005	0.000	0.000	0.000	-0.002	-0.001	-0.001	-0.001
FW	-0.131	0.034	0.000	-0.016	-0.003	-0.002	-0.002	0.004	-0.006	0.001	0.000	0.001	0.002

R Square =0.9798 & Residual Effect =0.1420

Abbreviations: AVFW: Average fruit weight (g), FNPP: Number of fruits per plant, DFFE: Days taken to 1st female flower emergence, DFFH: Days taken to 1st fruit harvest, PD : Polar diameter(cm), ED: Equatorial diameter(cm), FT: Flesh thickness(cm), RT: Rind thickness(cm), FCA: Fruit cavity area(cm^2), FSI: Fruit shape index, VL : Vine length(m), NBP: Number of branches, β- caro: β- carotene content (mg/100g), F: Firmness (lb/inch^2), AA: Ascorbic acid (mg/100g), TA: Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice), DM: Dry matter (%), RNK: Reaction to root-knot nematode (GI), VD: Reaction to viral disease (PDI), FW: Reaction to Fusarium wilt (PDI), FY: Fruit yield (t ha^{-1})

Table 4.12b: Contd.....

Traits	β-caro	F	AA	TA	pH	DM	RNK	VD	FW	FY
AVFW	0.008	-0.007	0.001	0.004	-0.001	0.000	-0.002	0.002	0.001	0.601**
FNPP	-0.002	0.012	0.002	0.014	-0.008	-0.003	0.001	0.002	0.000	0.699**
DFFE	-0.001	-0.005	-0.008	0.004	0.009	0.002	0.004	-0.001	0.000	-0.185*
DFFH	0.001	-0.005	-0.010	0.004	0.009	-0.001	0.004	-0.003	0.001	-0.155
PD	0.000	0.000	-0.001	0.009	0.000	-0.001	0.000	0.001	0.000	0.107
ED	-0.001	-0.002	0.000	-0.002	0.004	-0.002	-0.001	0.004	0.000	-0.058
FT	0.008	-0.007	0.003	-0.004	-0.002	-0.001	-0.001	0.001	0.001	0.303**
RT	0.010	-0.010	-0.003	-0.013	0.001	0.000	-0.002	0.000	0.001	0.072
FCA	0.011	-0.008	0.001	-0.013	-0.002	-0.002	-0.003	0.000	0.001	0.212*
FSI	-0.002	0.004	-0.006	0.006	0.000	-0.001	-0.001	0.004	0.000	-0.051
VL	-0.004	0.009	0.003	0.012	-0.002	-0.002	-0.001	-0.001	0.000	0.257**
NBPP	0.003	0.000	0.004	0.004	-0.001	-0.002	-0.001	-0.002	0.000	0.247**
TSS	0.005	0.002	0.006	0.001	-0.005	0.001	-0.004	-0.001	0.001	0.100
β-caro	**0.020**	-0.008	-0.007	0.005	-0.006	0.004	-0.003	-0.003	0.000	0.214*
F	0.005	**-0.032**	-0.005	-0.015	0.009	0.000	-0.001	0.002	0.000	-0.152
AA	0.004	-0.005	**-0.031**	0.009	0.004	0.004	0.001	-0.001	0.000	-0.096
TA	0.002	0.009	-0.005	**0.056**	-0.008	0.005	0.001	-0.001	0.000	0.302**
pH	-0.004	-0.011	-0.004	-0.017	**0.027**	-0.001	0.001	0.003	0.000	-0.247**
DM	0.004	-0.001	-0.006	0.012	-0.001	**0.021**	-0.001	-0.002	0.000	-0.081
RNK	0.004	-0.003	0.001	-0.002	-0.003	0.001	**-0.012**	0.000	0.000	0.077
VD	0.003	0.003	-0.001	0.002	-0.005	0.002	0.000	**-0.020**	0.000	-0.123
FW	-0.001	-0.001	0.001	0.007	-0.001	0.003	-0.002	0.002	**-0.003**	-0.111

R Square =0.9798 & Residual Effect =0.1420

Abbreviations: AVFW: Average fruit weight (g), FNPP: Number of fruits per plant, DFFE: Days taken to 1st female flower emergence, DFFH: Days taken to 1st fruit harvest, PD : Polar diameter(cm), ED: Equatorial diameter(cm), FT: Flesh thickness(cm), RT: Rind thickness(cm), FCA: Fruit cavity area(cm^2), FSI: Fruit shape index, VL : Vine length(m), NBP: Number of branches, β- caro: β- carotene content (mg/100g), F: Firmness ($lb/inch^2$), AA: Ascorbic acid (mg/100g), TA: Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice), DM: Dry matter (%), RNK: Reaction to root-knot nematode (GI), VD: Reaction to viral disease (PDI), FW: Reaction to Fusarium wilt (PDI), FY: Fruit yield ($t\ ha^{-1}$)

4.6.4 Days taken to 1st fruit harvest

Days taken to 1st fruit harvest had positive direct effect (0.041 and 0.05) on fruit yield (t ha^{-1}). The traits exhibited a positive indirect effect on fruit yield (t ha^{-1}) were average fruit weight, titrable acidity, pH, fruit cavity area, polar diameter, and reaction to root-knot nematode. However, it showed negative indirect effects on fruit yield (t ha^{-1}) via number of fruits per vine, days taken to 1st female flower emergence, ascorbic acid at both genotypic and phenotypic level.

4.6.5 Polar diameter (cm)

A positive direct effect (0.065 and 0.026) of polar diameter on fruit yield (t ha^{-1}) was observed. However, it exerted positive indirect effects by number of fruits per vine, days taken to 1st female flower emergence, and titrable acidity. The negative indirect effects were observed through equatorial diameter fruit cavity area, number of branches, average fruit weight, flesh thickness at genotypic and phenotypic level.

4.6.6 Equatorial diameter (cm)

Negative direct effect (-0.06 and -0.022) of equatorial diameter on fruit yield (t ha^{-1}) was observed. It exerted positive indirect effects by polar diameter, days taken to 1st female flower emergence and pH while, negative indirect effects through average fruit weight, titrable acidity, fruit cavity area, and flesh thickness were recorded at both genotypic and phenotypic level.

4.6.7 Flesh thickness (cm)

The positive direct effect of flesh thickness (0.173 and 0.007) on fruit yield (t ha^{-1}) was observed. Flesh thickness exerted positive indirect effects on fruit yield (t ha^{-1}) via average fruit weight, and fruit cavity area. Whereas negative indirect effects through number of fruits per vine, number of branches, and rind thickness were recorded at both genotypic and phenotypic level. Similar results were reported by Choudhary *et al* (2004) for this trait that flesh thickness showed direct effect on total fruit yield per vine.

4.6.8 Rind thickness (cm)

The negative direct effect of rind thickness (-0.048 and -0.021) on fruit yield (t ha^{-1}) was observed. Rind thickness exerted positive indirect effects by average fruit weight, fruit cavity area and flesh thickness. Whereas negative indirect effects via number of fruit per vine, polar diameter, ascorbic acid and titrable acidity were recorded at both genotypic and phenotypic level.

4.6.9 Fruit cavity area

Fruit cavity area showed positive direct effects (0.220 and 0.019) on fruit yield (t ha^{-1}). Though, it also exhibited positive and indirect effect on fruit yield (t ha^{-1}) through average fruit weight, flesh thickness, and days to first fruit emergence. The negative indirect effects via no. of fruits per vine, no. of branches, rind thickness, titrable acidity, pH, reaction

to root-knot nematode, and polar diameter were recorded at the genotypic and phenotypic level.

4.6.10 Fruit shape index

Fruit shape index showed highest negative direct effects (-0.091) at genotypic level and low positive direct effect (0.009) at phenotypic level on fruit yield (t ha^{-1}). However, it also exhibited positive and indirect influence fruit yield (t ha^{-1}) via number of branches, titrable acidity, number of fruits per vine and days taken to 1st fruit harvest. The negative indirect effects exhibited via average fruit weight, fruit cavity area, reaction to root-knot nematode, and ascorbic acid both at the genotypic and phenotypic level.

4.6.11 Vine length

Vine length showed negative direct effects (-0.005 and -0.011) at genotypic level and phenotypic level on fruit yield (t ha^{-1}). Whereas it also exhibited positive and indirect influence on fruit yield (t ha^{-1}) via number of fruits per vine, titrable acidity, rind thickness and average fruit weight. The negative indirect effects via number of branches, fruit cavity area, pH and reaction to root-knot nematode were recorded both at the genotypic and phenotypic level.

4.6.12 Number of branches

The negative direct effect of number of branches (-0.179 and -0.008) at genotypic level and phenotypic level on fruit yield (t ha^{-1}) was observed. However, it exerted positive indirect effects via number of fruits per vine, average fruit weight, fruit cavity area, flesh thickness, and polar diameter. Whereas, it exhibited negative indirect effects via rind thickness, pH and reaction to root-knot nematode at both genotypic and phenotypic level.

4.6.13 TSS

The positive and negative direct effect of TSS (0.02 and -0.010) on fruit yield (t ha^{-1}) was observed. However, it exerted positive indirect effects via average fruit weight, days taken to 1st female flower emergence, flesh thickness, fruit cavity area, and ascorbic acid. It exhibited negative indirect effects via pH, reaction to root-knot nematode, number of branches, number of fruits per vine and days taken to 1st fruit harvest at both genotypic and phenotypic level. A similar finding was reported by Pandey *et al* (2005), Singh and Lal (2005, (Reddy *et al* 2007) and Subramanian (2008).

4.6.14 β-carotene

β-carotene showed positive and negative direct effects (0.1988 and -0.0185) on fruit yield (t ha^{-1}). Whereas it also exhibited maximum positive and indirect influence on fruit yield (t ha^{-1}) via average fruit weight, fruit cavity area, flesh thickness, titrable acidity, and days taken to 1st female flower emergence. It exhibited negative indirect effects via no. of branches, number of fruits per vine, pH, reaction to root-knot nematode and rind thickness at both genotypic and phenotypic level.

4.6.15 Firmness

Firmness showed positive and negative direct effects (0.016 and -0.032) respectively on fruit yield (t ha^{-1}). However, it also exhibited positive and indirect influence on fruit yield (t ha^{-1}) via average fruit weight, pH, fruit cavity area, and flesh thickness at genotypic and phenotypic level. The negative considerable indirect effects via number of fruits per vine, titrable acidity, days taken to 1st female flower emergence both at genotypic and phenotypic level.

4.6.16 Ascorbic acid

The negative direct effect of ascorbic acid (-0.46 and -0.031) on fruit yield (t ha^{-1}) was observed. However, it exerted positive indirect effects via titrable acidity, pH, number of branches, Days taken to 1st fruit harvest and negative indirect effects via number of fruits per vine, days taken to 1st fruit harvest, flesh thickness, average fruit weight at both genotypic and phenotypic level.

4.6.17 Titrable acidity

The positive direct effect of acidity (0.32 and 0.056) on fruit yield (t ha^{-1}) was observed. However, it exerted positive indirect effects via average fruit weight and number of fruits per vine. The negative indirect effects were observed via fruit cavity area, pH, flesh thickness, days taken to 1st female flower emergence, rind thickness, and number of branches at both genotypic and phenotypic level.

4.6.18 pH

pH showed positive direct effects (0.235 and 0.027) on fruit yield (t ha^{-1}) at genotypic and phenotypic level. While it also exhibited positive and indirect influence on fruit yield (t ha^{-1}) via days taken to 1st fruit harvest and reaction to root-knot nematode. The negative indirect effects via number of fruits per plant, days taken to 1st female flower emergence, fruit cavity area, flesh thickness, average fruit weight were recorded at genotypic and phenotypic level.

4.6.19 Dry matter

Dry matter % showed negative and positive direct effects (-0.015 and 0.021) on fruit yield (t ha^{-1}) at genotypic and phenotypic level whereas it also exhibited positive and indirect influence on fruit yield (t ha^{-1}) via titrable acidity, and number of branches. It exhibited negative indirect effects via average fruit weight, Days taken to 1st female flower emergence, reaction to root-knot nematode, and fruit cavity area at genotypic and phenotypic level.

4.6.20 Reaction to root-knot nematode

Resistance reaction to root-knot nematode exhibited negative direct effect of nematode (-0.094 and -0.012) on fruit yield (t ha^{-1}) was observed at genotypic and phenotypic level. However, it exerted positive indirect effects via Days taken to 1st female flower emergence, average fruit weight, fruit cavity area, flesh thickness. It exhibited negative

indirect effects via number of fruits per vine, Days taken to 1st fruit harvest and pH at both genotypic and phenotypic level.

4.6.21 Reaction to viral disease

A positive and negative direct effect (0.034 and -0.02) on fruit yield (t ha^{-1}). The positive and indirect effect of reaction to virus on fruit yield (t ha^{-1}) via titrable acidity, equatorial diameter, and Days taken to 1st fruit harvest. while negative indirect effects exhibited via number of fruits per vine, pH, average fruit weight and Days taken to 1st female flower open.

4.6.22 Reaction to Fusarium wilt

Resistance reaction to Fusarium wilt exhibited positive and negative direct effect of wilt (0.029 and -0.003) on fruit yield (t ha^{-1}) was observed at genotypic and phenotypic level. However, positive but indirect influence of reaction to Fusarium wilt on fruit yield (t ha^{-1}) via titrable acidity, number of fruit per vine, and number of branches. The negative indirect effects of reaction to Fusarium wilt on total yield per vine via average fruit weight, fruit cavity area, flesh thickness, days taken to 1st fruit harvest, reaction to root-knot nematode were recorded at genotypic and phenotypic level.

The above characters which had maximum positive direct effects on no. of fruits per vine were also positively correlated with fruit yield (t ha^{-1}). Therefore, selection for high yield per vine will based on no. of fruits per vine, average fruit weight, days taken to 1st female flower emergence, days taken to 1st fruit harvest, polar diameter, equatorial diameter, flesh thickness, rind thickness, fruit cavity area, fruit shape index, vine length, TSS, firmness, ascorbic acid, reaction to root-knot nematode, reaction to Fusarium wilt infestation and reaction to virus infestation. All these traits are taken into consideration while selection as these are yield components contributing to higher yield and quality fruit development. Major emphasis should be given number of fruits per vine and average fruit weight with the due consideration to flesh thickness, fruit cavity area and TSS content while making selecting in breeding programme in muskmelon.

4.7 Reaction of genotypes to disease incidence

4.7.1 Reaction to Fusarium wilt

All the F_1 hybrids showed resistance against fusarium wilt infestation expect one hybrid (Table 4.13). Out of which eight hybrids highly exhibited resistance to this disease. The best F1 hybrids showing highly resistance were MM Sel-103 × MM-625, MS-1 × MM Sel-103, Kajri × MM Sel-103, Kajri × MM-904, MM-625 × Riogold while, MS-1 × MM-1831 hybrid showed poor performance to this disease. Rest hybrids were presented in Table 4.13 (Plate 4.3a & b).

4.7.2 Reaction to Viral disease

Ten F_1 hybrids exhibited mild symptoms to viral disease. The best crosses showing

Table 4.13: Reaction to Fusarium wilt of F_1 hybrids

Genotypes	Score	Symptoms
MS-1 × Kajri	1	Resistant
MS-1 × KP_4HM-15	2.3	Moderately resistant
MS-1 × MM Sel-103	0.8	Highly resistant
MS-1 × MM-904	1.7	Resistant
MS-1 × MM-625	2.2	Moderately resistant
MS-1 × MM-610	1.5	Resistant
MS-1 × MM-1831	3	Moderately susceptible
MS-1 × MM 916/ NS-1	2	Moderately resistant
MS-1 × Riogold	2.4	Moderately resistant
Kajri × KP_4HM-15	2	Moderately resistant
Kajri × MM Sel-103	0.7	Highly resistant
Kajri × MM-904	0.8	Highly resistant
Kajri × MM-625	1.6	Resistant
Kajri × MM-610	1.1	Resistant
Kajri × MM-1831	1.2	Resistant
Kajri × MM 916/NS-1	1	Resistant
Kajri × Riogold	1.7	Resistant
KP_4HM-15 × MM Sel-103	2.7	Moderately resistant
KP_4HM-15 × MM-904	2.4	Moderately resistant
KP_4HM-15 × MM-625	2.4	Moderately resistant
KP_4HM-15 × MM-610	1.7	Resistant
KP_4HM-15 × MM-1831	2.6	Moderately resistant
KP_4HM-15 × MM 916/NS-1	2	Moderately resistant

Genotypes	Score	Symptoms
KP_4HM-15 × Riogold	2.9	Moderately resistant
MM Sel-103 × MM-904	2.6	Moderately resistant
MM Sel-103 × MM-625	0.5	Highly resistant
MM Sel-103 × MM-610	1.2	Resistant
MM Sel-103 × MM-1831	0.9	Highly resistant
MM Sel-103 × MM 916/NS-1	0.8	Highly resistant
MM Sel-103 × Riogold	2.1	Moderately resistant
MM-904 × MM-625	2.2	Moderately resistant
MM-904 × MM-610	2.7	Moderately resistant
MM-904 × MM-1831	2.3	Moderately resistant
MM-904 × MM 916/NS-1	2	Moderately resistant
MM-904 × Riogold	2.6	Moderately resistant
MM-625 × MM-610	1.8	Resistant
MM-625 × MM-1831	1.7	Resistant
MM-625 × MM 916/NS-1	1.8	Resistant
MM-625 × Riogold	0.9	Highly resistant
MM-610 × MM-1831	2.1	Moderately resistant
MM-610 × MM 916/NS-1	2.2	Moderately resistant
MM-610 × Riogold	1.5	Resistant
MM-1831 × MM 916/NS-1	1	Resistant
MM-1831 × Riogold	0.8	Highly resistant
MM 916/NS-1 × Riogold	1.6	Resistant

Plate 4.3a: Highly Resistance F_1 hybrid to fusarium wilt

Plate 4.3b: Moderately susceptible F_1 hybrid to fusarium wilt

Table 4.14: Reaction to viral disease of F_1 hybrids

Genotypes	Score	Symptoms
MS-1 × Kajri	4.5	Very severe
MS-1 × KP_4HM-15	3.5	Severe
MS-1 × MM Sel-103	4.5	Very severe
MS-1 × MM-904	1.75	Mild
MS-1 × MM-625	3	Severe
MS-1 × MM-610	3.5	Severe
MS-1 × MM-1831	2.75	Moderate
MS-1 × MM 916/ NS-1	2.75	Moderate
MS-1 × Riogold	1.5	Mild
Kajri × KP_4HM-15	1.75	Mild
Kajri × MM Sel-103	2.75	Moderate
Kajri × MM-904	3.5	Severe
Kajri × MM-625	2.75	Moderate
Kajri × MM-610	3	Severe
Kajri × MM-1831	3.5	Severe
Kajri × MM 916/NS-1	2.75	Moderate
Kajri × Riogold	2	Moderate
KP_4HM-15 × MM Sel-103	1	Mild
KP_4HM-15 × MM-904	2	Moderate
KP_4HM-15 × MM-625	1.5	Mild
KP_4HM-15 × MM-610	1.5	Mild
KP_4HM-15 × MM-1831	2.5	Moderate
KP_4HM-15 × MM 916/NS-1	3	Severe
KP_4HM-15 × Riogold	4	Very severe
MM Sel-103 × MM-904	3.5	Severe
MM Sel-103 × MM-625	2.5	Moderate
MM Sel-103 × MM-610	2	Moderate
MM Sel-103 × MM-1831	2.5	Moderate
MM Sel-103 × MM 916/NS-1	4	Very severe
MM Sel-103 × Riogold	2	Moderate
MM-904 × MM-625	1.5	Mild
MM-904 × MM-610	3	Severe
MM-904 × MM-1831	3.5	Severe
MM-904 × MM 916/NS-1	2	Moderate
MM-904 × Riogold	2.5	Moderate
MM-625 × MM-610	2.5	Moderate
MM-625 × MM-1831	2.25	Moderate
MM-625 × MM 916/NS-1	3.5	Severe
MM-625 × Riogold	3.5	Severe
MM-610 × MM-1831	3	Severe
MM-610 × MM 916/NS-1	1.5	Mild
MM-610 × Riogold	2.5	Moderate
MM-1831 × MM 916/NS-1	2.25	Moderate
MM-1831 × Riogold	1.5	Mild
MM 916/NS-1 × Riogold	1.5	Mild

Table 4.15: Reaction to root-knot nematode of F_1 hybrids

Genotypes	Score	Symptoms
MS-1 × Kajri	3.6	Susceptible
MS-1 × KP4HM-15	4	Susceptible
MS-1 × MM Sel-103	3.9	Susceptible
MS-1 × MM-904	4.8	Highly susceptible
MS-1 × MM-625	4.2	Highly susceptible
MS-1 × MM-610	4.05	Highly susceptible
MS-1 × MM-1831	3.3	Susceptible
MS-1 × MM 916/ NS-1	4.4	Highly susceptible
MS-1 × Riogold	2.9	Moderately susceptible
Kajri × KP4HM-15	3.8	Susceptible
Kajri × MM Sel-103	2.85	Moderately susceptible
Kajri × MM-904	2.6	Moderately susceptible
Kajri × MM-625	2.55	Moderately susceptible
Kajri × MM-610	2.25	Moderately susceptible
Kajri × MM-1831	3.3	Susceptible
Kajri × MM 916/NS-1	4.5	Highly susceptible
Kajri × Riogold	3.5	Susceptible
KP4HM-15 × MM Sel-103	4	Susceptible
KP4HM-15 × MM-904	2.9	Moderately susceptible
KP4HM-15 × MM-625	3.75	Susceptible
KP4HM-15 × MM-610	3.1	Susceptible
KP4HM-15 × MM-1831	3.8	Susceptible
KP4HM-15 × MM 916/NS-1	4.5	Highly susceptible
KP4HM-15 × Riogold	3.6	Susceptible

Genotypes	Score	Symptoms
KP4HM-15 × MM 916/NS-1	4.5	Highly susceptible
KP4HM-15 × Riogold	3.6	Susceptible
MM Sel-103 × MM-904	3.65	Susceptible
MM Sel-103 × MM-625	3.6	Susceptible
MM Sel-103 × MM-610	3	Moderately susceptible
MM Sel-103 × MM-1831	3.75	Susceptible
MM Sel-103 × MM 916/NS-1	4.4	Highly susceptible
MM Sel-103 × Riogold	4.5	Highly susceptible
MM-904 × MM-625	4.25	Highly susceptible
MM-904 × MM-610	4.1	Highly susceptible
MM-904 × MM-1831	4.1	Highly susceptible
MM-904 × MM 916/NS-1	3.75	Susceptible
MM-904 × Riogold	3.8	Susceptible
MM-625 × MM-610	2.8	Moderately susceptible
MM-625 × MM-1831	4.3	Highly susceptible
MM-625 × MM 916/NS-1	4.5	Highly susceptible
MM-625 × Riogold	4	Susceptible
MM-610 × MM-1831	4.5	Highly susceptible
MM-610 × MM 916/NS-1	5	Highly susceptible
MM-610 × Riogold	4.5	Highly susceptible
MM-1831 × MM 916/NS-1	4.6	Highly susceptible
MM-1831 × Riogold	4.25	Highly susceptible
MM 916/NS-1 × Riogold	4.8	Highly susceptible

Plate 4.4a: Moderately susceptible F_1 hybrid to virus

Plate 4.4b: Highly susceptible F_1 hybrid to virus

Plate 4.5a: Moderately susceptible F_1 hybrid to root-knot nematode

Plate 4.5b: Highly susceptible F_1 hybrid to root-knot nematode

mild resistance were KP_4HM-15 × MM Sel-103, MS-1 × MM-904, Kajri × KP_4HM-15, MM-904 × MM-625, and MM-610 × MM 916/NS-1. while eighteen hybrids exhibiting moderate resistance to viral disease. Rest hybrids were showing susceptible symptoms to viral disease presented in Table 4.14 (Plate 4.4a & b).

4.7.3 Reaction to root-knot nematode

Out of 45 F_1 hybrids, eight cross combination exhibiting moderately susceptible symptoms to root-knot nematode infestation. Five hybrids showing lowest score were Kajri × MM-610, Kajri × MM-904, Kajri × MM-625, MS-1 × Riogold, MM-625 × MM-610. Rest hybrids were showing susceptible symptoms to root-knot nematode infestation presented in Table 4.15 (Plate 4.5a & b).

4.8 Molecular characterization of muskmelon germplasm with simple sequence repeats markers

4.8.1 Genetic diversity studies using SSR markers analysis

The analysis of genetic diversity is a conventional application of SSR markers. For the development of commercial F_1 hybrids for desirable yielding traits, the diversity of parents is of utmost important. Accordingly, the knowledge of genetic diversity of a crop and its quantitative estimation usually helps a breeder in selecting desirable parents for breeding programme. In the present study ten different parents were used for genetic diversity using 121 SSR markers. Out of 121 primers, 70 primers were found to be polymorphic. These 70 primers then used to study parental polymorphism. The pairwise dissimilarity matrix were calculated using DARwin 6.0.21 software and using this dissimilarity matrix dendrogram was constructed using the UPGMA based Neighbor joining tree clustering method. The dissimilarity values ranged from 0.17 to 0.28 indicating the existence of variability is these ten genotypes.

Table 4.16: Cluster analysis on basis of molecular markers

Cluster	Sub cluster		Genotypes
	Major	Minor	
I	IA	1a	Riogold, MM-916/NS-1
		1b	MM-1831, MM-610
	IB		MM-625
II	IIA	2a	Kajri
		2b	MS-1
	IIB		MM Sel-103
III			MM-904, KP_4HM-15

The dendrogram (Fig. 4.6) depicting the genetic relationship among the parental lines. It classified the genotypes into three major clusters, Cluster I, Cluster II, Cluster III. The cluster I, having five genotypes was further sub divided into two major sub clusters IA and IB. Major sub cluster IA further divide into two minor sub clusters having two genotype each. Similarly, Cluster II contained three genotypes, which was further divided into two major sub

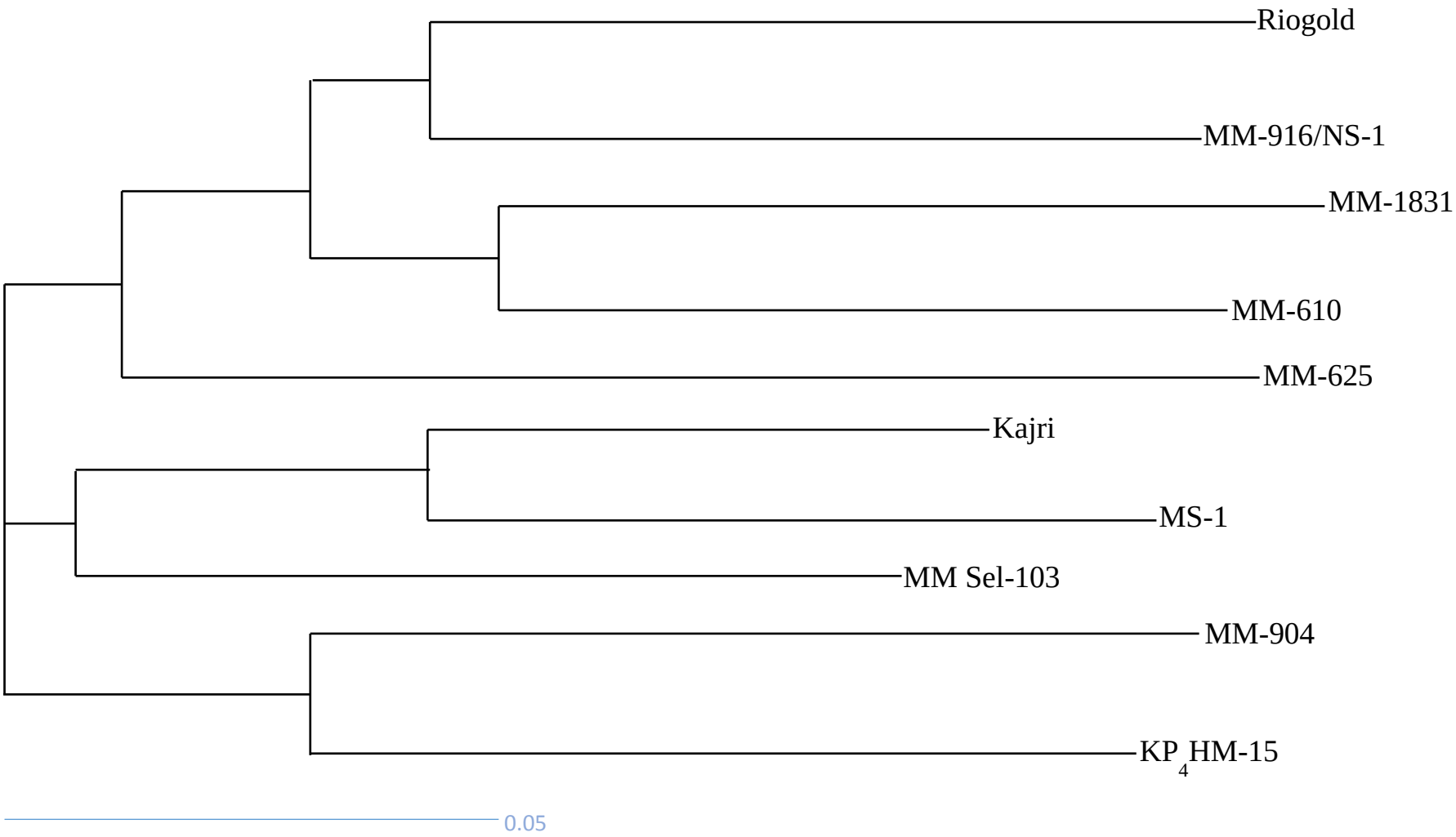


Figure 4.6: Dendrogram showing Neighbor joining tree clustering of ten parental lines

clusters IIA and IIB. Major sub cluster IIA further divided into two minor sub clusters. While two genotypes were clustered in cluster III. Hence, maximum number of genotypes was clustered in Cluster I (Table 4.16).

Parental genotypes present in cluster I gave best performing F_1 hybrids when they mate with parental genotypes of cluster II and III. So, through mating among the genotypes present in these three clusters providing best F_1 hybrids for yield and quality traits. Hence, intermating of these genotypes within clusters caused gene transfer or genetic introgression among melons genotypes.

4.8.2.1 Allelic amplification in melon germplasm

The genetic divergence among fifty-five genotypes of muskmelon was evaluated with 121 SSR primers (Table 3.10). Out of 121 primers, 70 primers showed amplification. The no. of alleles amplified ranged from 2 to 6 with an average of 3.04 alleles per locus (Table 4.17). The variation in the allele no. produced by SSR markers demonstrates heterozygosity in different alleles at a given locus. All these amplified fragments produced greatly the state of genetic variability. One marker amplified six alleles, five markers amplified five alleles, fourteen revealed four alleles, twenty-six markers amplified three alleles and for the remaining, thirty-four amplified two alleles (Table 4.17).

4.8.2.3 Polymorphic information content

The polymorphic information content value which is a measure of allelic diversity ranged from 0.3 (TJ147) to 9.6 (CMCTN4) with the mean value of 0.76 across all the genotypes (Table 4.17). A similar range of PIC value of SSR markers was recorded in muskmelon by Ning *et al* (2014). Primers CMCGGN210, CMCTTN179, DE1329, DE1630 and CSWCT10 amplified 5 alleles and have PIC values 0.78, 0.74, 0.53, 0.78, 0.74, respectively. All the 70 primers revealed PIC value more than 0.50 except 2 primers TJ147 (0.3) and CMACGN289 (0.5). It has been observed that marker CMMS35_3 amplified six alleles and had PIC value 0.78 while CMCTN4 amplified four alleles and had PIC value 0.96. Similarly, DE1836 amplified three alleles and had PIC value 0.68 while DM0196 amplified two alleles and had PIC value 0.82. therefore, there was no solid relationship between the PIC value and the no. of alleles amplified by a marker.

4.8.2.2 Percent polymorphism

Seventy SSR primers amplified a total of 1025 alleles across the genotypes with an average of 42.7 alleles per genotype. An average number of the amplified fragment for polymorphic markers was 26.4, while monomorphic markers it was 16.3. The maximum number of alleles (55) was amplified in hybrid MM-904 × MM-625 while minimum (36) by two hybrids MM Sel-103 × Riogold and MS-1 × Riogold. The % age of polymorphic marker was highest in hybrid MM-904 × MM-625 (78.6). Average polymorphism (%) across all the cultivars was 61 (Table 4.18).

Table 4.17: Number of alleles amplified, polymorphism (%), Polymorphic Information Content (PIC) value of SSR markers

S. No.	Primers	Total No. of alleles	Monomorphic allele	Polymorphic allele	Polymorphism (%)	PIC value
1	**CMTTCN273**	2	1	1	50.0	0.75
2	**DE1256**	2	1	1	50.0	0.95
3	**DE1337**	3	1	2	66.7	0.94
4	**CMMS35_3**	6	2	4	66.7	0.78
5	**CMCTN4**	4	0	4	100.0	0.96
6	**DE1177**	2	1	1	50.0	0.87
7	**DE2033**	2	1	1	50.0	0.55
8	**DM0298**	3	2	1	33.3	0.91
9	**CMBR120**	3	1	2	66.7	0.94
10	**CMAAGN283**	2	0	1	50.0	0.55
11	**CMCGGN210**	5	4	2	40.0	0.78
12	**CMCTTN179**	5	3	2	40.0	0.74
13	**CMGCTN187**	4	3	2	50.0	0.74
14	**DE1329**	5	2	3	60.0	0.53
15	**DE1630**	5	2	3	60.0	0.78
16	**DE1187**	4	2	2	50.0	0.7
17	**CSWCT10**	5	3	2	40.0	0.74
18	**DE1239**	4	4	1	25.0	0.78
19	**CMBR026**	4	1	3	75.0	0.83
20	**CMBR023**	3	1	2	66.7	0.82
21	**DE1462**	2	1	1	50.0	0.85
22	**CMTTTGN20**	2	1	1	50.0	0.82
23	**DM0551**	3	1	2	66.7	0.78
24	**DE1840**	3	2	1	33.3	0.6
25	**DE1354**	2	1	1	50.0	0.56
26	**DM0561**	3	1	2	66.7	0.7
27	**DM0214**	4	1	3	75.0	0.81
28	**CMBR123**	2	1	1	50.0	0.75
29	**DM0159**	2	1	1	50.0	0.85
30	**DE1875**	3	1	2	66.7	0.8
31	**DE1345**	3	1	2	66.7	0.75
32	**DM0550**	2	1	1	50.0	0.87
33	**CMCTN85**	3	1	2	66.7	0.87
34	**DE1487**	2	1	1	50.0	0.71
35	**DM0145**	3	1	2	66.7	0.72
36	**DE1836**	3	1	2	66.7	0.68

Table 4.17: Continued….

S. No.	Primers	Total No. of alleles	Monomorphic allele	Polymorphic allele	Polymorphism (%)	PIC value
37	**DE1378**	2	1	1	50.0	0.79
38	**DE1083**	4	1	3	75.0	0.64
39	**DM0024**	3	2	1	33.3	0.81
40	**DM0196**	2	1	1	50.0	0.82
41	**DE1292**	4	1	3	75.0	0.66
42	**DE1101**	3	1	2	66.7	0.84
43	**DE1231**	2	1	1	50.0	0.82
44	**CNGAN224**	2	1	1	50.0	0.61
45	**DM0220**	4	1	3	75.0	0.58
46	**DM0500**	3	1	2	66.7	0.64
47	**CMATN22**	3	1	2	66.7	0.71
48	**DE1326**	2	1	1	50.0	0.74
49	**CMMS35_5**	4	1	3	75.0	0.85
50	**DM0706**	3	1	2	66.7	0.91
51	**DM0098**	2	1	1	50.0	0.58
52	**DM0618**	3	1	2	66.7	0.86
53	**DM0913**	3	1	2	66.7	0.7
54	**DE1410**	3	2	1	33.3	0.74
55	**DE1321**	4	2	2	50.0	0.91
56	**CMAGN45**	3	1	2	66.7	0.61
57	**CMGAN51**	2	1	1	50.0	0.7
58	**DM0229**	3	2	1	33.3	0.75
59	**CMAAAGN14**	3	1	2	66.7	0.74
60	**TJ147**	3	2	1	33.3	0.3
61	**DM0503**	3	1	2	66.7	0.72
62	**DE1534**	3	2	1	33.3	0.83
63	**CMAAGN255**	2	1	1	50.0	0.79
64	**DM0634**	2	1	1	50.0	0.9
65	**CMACGN289**	2	1	1	50.0	0.5
66	**DM0555**	4	1	3	75.0	0.82
67	**DE1610**	4	1	3	75.0	0.74
68	**DE1980**	2	1	1	50.0	0.92
69	**DE1081**	2	1	1	50.0	0.95
70	**DM0839**	4	2	2	50.0	0.78
Total		**213**	**93**	**122**	**3931.7**	**53.02**
Mean		**3.04**	**1.33**	**1.74**	**56.2**	**0.76**

Table 4.18: Total number of alleles amplified in each of forty-five genotypes using seventy SSR markers

Cross combination	Number of amplified alleles		Total	P (%)
	MM*	PM**		
MS-1 × Kajri	20	24	44	62.9
MS-1 × KP_4HM-15	15	26	41	58.6
MS-1 × MM Sel-103	18	23	41	58.6
MS-1 × MM-904	13	34	47	67.1
MS-1 × MM-625	22	26	48	68.6
MS-1 × MM-610	16	24	40	57.1
MS-1 × MM-1831	20	23	43	61.4
MS-1 × MM 916/ NS-1	15	26	41	58.6
MS-1 × Riogold	11	25	36	51.4
Kajri × KP_4HM-15	15	28	43	61.4
Kajri × MM Sel-103	21	22	43	61.4
Kajri × MM-904	15	32	47	67.1
Kajri × MM-625	21	27	48	68.6
Kajri × MM-610	20	24	44	62.9
Kajri × MM-1831	16	25	41	58.6
Kajri × MM 916/NS-1	17	25	42	60.0
Kajri × Riogold	12	27	39	55.7
KP_4HM-15 × MM Sel-103	15	25	40	57.1
KP_4HM-15 × MM-904	20	26	46	65.7
KP_4HM-15 × MM-625	15	33	48	68.6
KP_4HM-15 × MM-610	14	26	40	57.1
KP_4HM-15 × MM-1831	15	29	44	62.9
KP_4HM-15 × MM 916/NS-1	12	29	41	58.6
KP_4HM-15 × Riogold	14	24	38	54.3
MM Sel-103 × MM-904	11	31	42	60.0
MM Sel-103 × MM-625	18	26	44	62.9
MM Sel-103 × MM-610	17	22	39	55.7
MM Sel-103 × MM-1831	16	22	38	54.3
MM Sel-103 × MM 916/NS-1	15	22	37	52.9
MM Sel-103 × Riogold	13	23	36	51.4
MM-904 × MM-625	16	39	55	78.6
MM-904 × MM-610	11	34	45	64.3
MM-904 × MM-1831	18	28	46	65.7
MM-904 × MM 916/NS-1	14	30	44	62.9
MM-904 × Riogold	16	30	46	65.7
MM-625 × MM-610	20	28	48	68.6
MM-625 × MM-1831	18	30	48	68.6
MM-625 × MM 916/NS-1	19	27	46	65.7
MM-625 × Riogold	18	26	44	62.9
MM-610 × MM-1831	17	27	44	62.9
MM-610 × MM 916/NS-1	18	27	45	64.3
MM-610 × Riogold	17	27	44	62.9
MM-1831 × MM 916/NS-1	17	26	43	61.4
MM-1831 × Riogold	19	23	42	60.0
MM 916/NS-1 × Riogold	20	22	42	60.0
Total	**392.0**	**633.0**	**1025.0**	**1464.3**
Mean	**16.3**	**26.4**	**42.7**	**61.0**

Abbreviations: *MM: Monomorphic markers, **PM: Polymorphic markers, P: Polymorphism

4.8.2.4 Specific alleles

Ten SSR primers were found to have higher selective potential for differentiation of the genotypes as they are showing unique/specific alleles in melon cultivars. SSR primers generally amplified more than one allele. However, two allele was amplified in two cultivars that differentiate these genotypes from the other. Therefore, forty-three genotypes can be differentiated from each other using the markers which revealed unique alleles. Six markers, DM0561, CMAAAGN14, TJ147, CMMS35_3, CMAGN45 and DE1337 each revealed unique alleles in five different genotypes, two markers DM0839, DE1836 revealed in two genotypes, CMBR023 identified in three genotypes and DM0214 identified only two cultivars. From the data recorded it was revealed that markers with maximum no. of alleles (4) had proved its ability to distinguish cultivars through specific alleles (Table 4.19).

Table 4.19: Specific/unique alleles detected by SSR primers and identified melon genotypes

S. No.	Markers	No. of allele	unique allele	Genotype identified
1	**DM0561**	4	2	MM Sel-103, MM-610
2	**CMAAAGN14**	3	1	KP_4HM-15, MM-904
3	**TJ147**	3	1	KP_4HM-15, MM-904
4	**DM0839**	4	1	MS-1
5	**DE1836**	4	1	MS-1
6	**CMMS35_3**	4	2	MM-904, MM-916/NS-1
7	**CMAGN45**	3	1	KP_4HM-15, MM-916/NS-1, Riogold
8	**DE1337**	4	1	MM-625, MM-1831
9	**CMBR023**	3	1	Kajri, MM Sel-103
10	**DM0214**	4	1	MM-904

4.8 Parental polymorphism and identification of F_1 hybrids

For parental polymorphism total 121 markers were applied on all the ten parents. Out of 121 primers, 70 primers showed different percent polymorphism (Plate 4.7a). Total percent polymorphism for all the genotypes was 58.8%. For the confirmation of F_1 hybrids the selected markers showing higher polymorphic value were applied on the forty-five hybrids. Total five selected markers were applied out of which 1-2 markers amplified in the hybrids (Table 4.20 and Plate 4.7b). Thus, these SSR markers will be used in identification of these hybrids.

Table 4.20: Identification of F_1 hybrids using SSR markers

S. No.	Cross combination	Total Markers used	Marker identifying the hybrids	No. of Alleles
1	**MS-1 × Kajri**	CMMS35_3, CMBR023, DE1840, DM0145, DM0839	DE1840, DM0145	2
2	**MS-1 × KP_4HM-15**	CMMS35_3, TJ125, DM0145, CMTTTGN20, CMAAAGN14	TJ125, DM0145	2
3	**MS-1 × MM Sel-103**	DE1292, TJ125, DM0145, CMTTTGN20, CMAAAGN14	TJ125, DM0145	2
4	**MS-1 × MM-904**	CMTTTGN20, DM0214, DE1836, DE1345, CMAAAGN14,	CMAAAGN14	2
5	**MS-1 × MM-625**	CMMS35_3, DE1329, DM0839, CMTTTGN20, CMBR123	DM0839	2
6	**MS-1 × MM-610**	DE1462, DM0561, DM0839, DM0839, CMMS35_3	DM0839, CMMS35_3	2
7	**MS-1 × MM-1831**	CMMS35_3, DE1840, CMBR123, DE1345, CMAGN45	DE1840	2
8	**MS-1 × MM 916/ NS-1**	CMMS35_3, DE1462, DM0839, CMAGN45, CMAGN45	DM0839, CMAGN45	2
9	**MS-1 × Riogold**	DM0145, DE1836, CMAAAGN14, DM0839	CMAAAGN14	2
10	**Kajri × KP_4HM-15**	DE1462, DM0551, DE1354, DE1345, DE1836	DE1345, DE1836	2
11	**Kajri × MM Sel-103**	DE1337, DM0551, DM0561, CMMS35_5, DE1534	DM0561, CMMS35_5	2
12	**Kajri × MM-904**	DE1836, CMMS35_3, DM0551, DE1292, DM0098	CMMS35_3, DM0551	2
13	**Kajri × MM-625**	DE1329, CMBR023, DE1462, DE1840, DM0145, TJ147	DE1840, DM0145	2
14	**Kajri × MM-610**	DE1329, CMBR023, DE1337, TJ147, DE1840	DE1337	2
15	**Kajri × MM-1831**	DE1462, DM0551, CMMS35_5, CMAGN45, DE1345	CMMS35_5, CMAGN45	2
16	**Kajri × MM 916/NS-1**	DE1337, CMMS35_3, CMCTN85, CMAGN45, CMAAAGN14	DE1337, CMCTN85	2
17	**Kajri × Riogold**	CMBR023, DE1462, DE1840, DM0145, DE1836	DE1840	2
18	**KP_4HM-15 × MM Sel-103**	DE1354, DE1345, CMAAAGN14, DM0098, CMMS35_5	DE1345, CMAAAGN14	2
19	**KP_4HM-15 × MM-904**	TJ125, DM0551, DM0214, CMAAAGN14, CMMS35_5	CMAAAGN14, CMMS35_5	2
20	**KP_4HM-15 × MM-625**	DE1329, DM0551, DM0145, CMMS35_5, CMAAAGN14	CMMS35_5, CMAAAGN14	2
21	**KP_4HM-15 × MM-610**	DE1462, DM0561, DE1836, CMAAAGN14, DM0839	DE1836, CMAAAGN14	2
22	**KP_4HM-15 × MM-1831**	DM0551, DE1345, CMAAAGN14, CMAGN45, DM0839	CMAAAGN14	2
23	**KP_4HM-15 × MM 916/NS-1**	CMMS35_3, DE1462, DE1345, CMAGN45, TJ147	CMAGN45	2
24	**KP_4HM-15 × Riogold**	DE1345, DE1345, CMAAAGN14, DE1980, TJ147	DE1345, CMAAAGN14	2

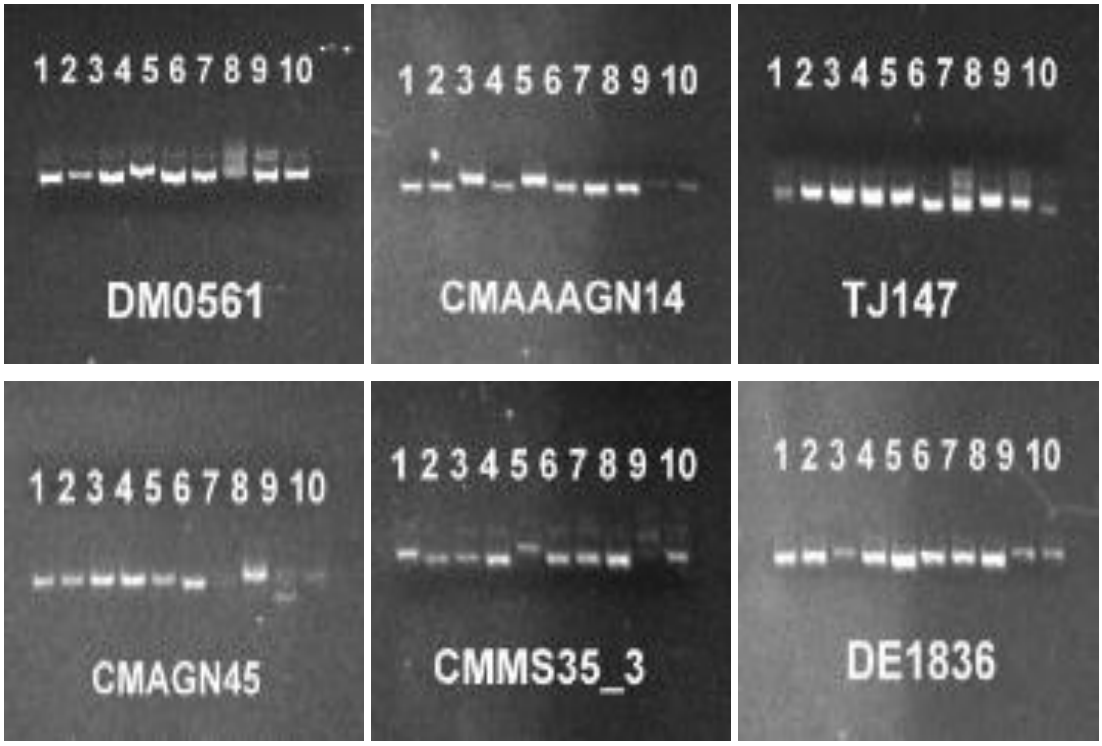


Plate 4.7a: Parental polymorphism using SSR markers

Where Parent 1: MS-1, 2: Kajri, 3: KP4HM-15, 4: MM Sel-103, 5: MM-904, 6: MM-625, 7: MM-610, 8: MM-1831, 9: MM-916/NS-1, 10: Riogold

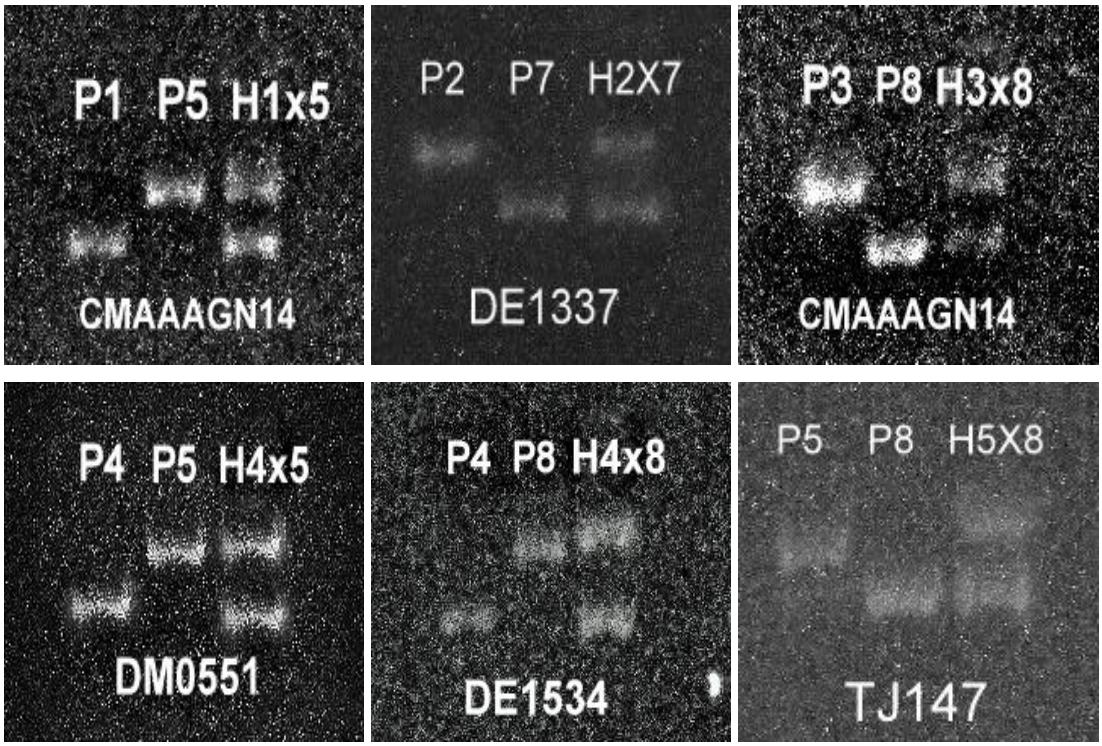


Plate 4.7b: Identification of F_1 hybrids using SSR markers

Where P: Parent, H: hybrid

S. No.	Cross combination	Total Markers used	Marker identifying the hybrids	No. of Alleles
25	**MM Sel-103 × MM-904**	DE1836, CMAAAGN14, CMBR023, DE1534, DM0561	CMBR023, DE1836	2
26	**MM Sel-103 × MM-625**	TJ147, DE1534, DE1329, DE1378, DE1083	TJ147	2
27	**MM Sel-103 × MM-610**	DE1337, DE2033, DM0839, TJ147, DE1292	DE1337	2
28	**MM Sel-103 × MM-1831**	DE1354, DE1378, DE1083, CMAGN45, DE1534	DE1534	2
29	**MM Sel-103 × MM 916/NS-1**	DE1374, DE1337, DM0561, CMAAAGN14, DE1462	DM0561, CMAAAGN14	2
30	**MM Sel-103 × Riogold**	CMBR023, DE1354, CMAAAGN15, DM0561, TJ147	DM0561, CMAAAGN15	2
31	**MM-904 × MM-625**	DM0214, DE1101, DM0145, CMMS35_5, DM0098	CMMS35_5	2
32	**MM-904 × MM-610**	DM0214, DE1101, DM0145, CMMS35_5, CMAAAGN14	CMAAAGN14	2
33	**MM-904 × MM-1831**	DM0214, CMMS35_5, TJ147, CMAAAGN14, DM0098	TJ147, CMAAAGN14	2
34	**MM-904 × MM 916/NS-1**	DM0214, DE1345, CMMS35_3, CMAAAGN14, DM0098	CMMS35_3, CMAAAGN14	2
35	**MM-904 × Riogold**	DM0214, DE1345, CMMS35_3, CMAAAGN14, DM0839	CMAAAGN14, DM0839	2
36	**MM-625 × MM-610**	DM0551, DE1345, DE1292, DE1101, DM0839	DM0839	2
37	**MM-625 × MM-1831**	DM0551, TJ147, DE1292, DE1101, DM0839	TJ147	2
38	**MM-625 × MM 916/NS-1**	CMMS35_3, CMTTTGN20, DE1836, DE1345, DM0145	DE1836	2
39	**MM-625 × Riogold**	CMTTTGN20, DE1836, DE1345, DE1610, DM0145	DE1610	2
40	**MM-610 × MM-1831**	DE1462, DM0551, DM0561, DE1345, TJ147	TJ147	2
41	**MM-610 × MM 916/NS-1**	CMAAAGN14, CMMS35_3, DM0839, DE1292, CMTTTGN20	CMAAAGN14	2
42	**MM-610 × Riogold**	CMAAAGN14, CMMS35_3, DM0839, DE1292, CMTTTGN20	CMAAAGN14	2
43	**MM-1831 × MM 916/NS-1**	DE2033, DE1840, CMMS35_5, DM0839, CMAAAGN14	DE1840, CMMS35_5	2
44	**MM-1831 × Riogold**	DE2033, DE1840, DE1836, CMMS35_5, CMAAAGN14	CMMS35_5	2
45	**MM 916/NS-1 × Riogold**	DE1345, DM0145, CMMS35_5, CMAGN45, CMAAAGN14	CMMS35_5	2

Implications of this study in muskmelon breeding

From the present investigation, it is concluded that the hybrids *viz.*, MS-1 × MM 916/ NS-1, KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-904, Kajri × MM-625, Kajri × MM-904, MM-625 × MM 916/NS-1, MM-1831 × MM 916/NS-1, MM-610 × MM 916/NS-1 and MM 916/NS-1 × Riogold performed well for most of the studied traits. These cross combinations were significantly better and statistically at par with the best standard checks for fruit yield and TSS content along with some other important yield attributes traits. The inbred lines had good general combing ability (GCA) effect reflecting in the F_1 hybrids exhibiting good amount of SCA effect. The results of the present investigation were based on single location estimation. Therefore, the above F_1 hybrids should be tested over multi-locations to make the results more dependable and of wider suitability. The promising hybrids also have ability to provide transgressive segregants in the early segregating generations. The transgressive segregants so generated can be utilized to develop superior inbred lines. The predominance of non-additive gene action (dominance) in the inheritance of the characters suggested that heterosis breeding may be beneficial to obtain immediate improvements in the muskmelon crop. Through the utilization of molecular markers, it was confirmed that the genetic variability exists in the inbred lines. The parental lines showed high level of polymorphism among them. Specific/Unique SSR markers viz., DM0561, CMAAAGN14, TJ147, CMMS35_3, CMAGN45 and DE1337, DM0839, and DE1836 confirmed the parental polymorphism and hybridity. Thus, the SSR markers were more reliable for studying the genetic diversity and to identify the F_1 hybrids.

CHAPTER V

SUMMARY

The present investigation entitled "Heterosis and combining ability studies in muskmelon (*Cucumis melo* L.)" was performed at the Department of Vegetable Science and School of Agricultural Biotechnology, Punjab Agricultural University, Ludhiana, during the spring-summer seasons of 2019 and 2020. The study was conducted to attain the information on heterosis, general combining ability and specific combining ability of all the cross combinations through diallel analysis. The inheritance of different characters was studied from the present data. The correlation and path analysis carried out to identify the relationship between different growth and yield attributes. Genetic diversity among the parental lines and molecular characterization of F_1 hybrids were carried out using SSR markers.

In this investigation, forty-five F1 hybrids were developed using ten diverse parental lines in half diallel mating design. All the crosses were evaluated against the parents and commercial checks, and popular hybrids, MH-27, MH-51, and Farmer Glory in Randomized' Block Design (RBD). The data were recorded for average fruit weight (g), days taken to first female flower emergence, days taken to first fruit harvest, polar diameter (cm), equatorial diameter (cm), flesh thickness (cm), rind thickness (mm), fruit cavity area (cm^2), fruit shape index, vine length (m), number of branches, total soluble solids (TSS), ascorbic acid, acidity, β-carotene, firmness ($lb/inch^2$), pH, dry matter (%), reaction to root-knot nematode, reaction to fusarium wilt infestation and reaction to cucumber green mottle virus infestation on randomly selected plants in each plot.

Analysis of variance for experimental design showed that variance due to genotypes was significant for all the studied parameters. This implied a sufficient genetic variation among the genotypes which indicated that further analysis of variance for combining ability was suitable. The combining ability analysis revealed that general combining ability effects and specific combining ability effects were significant for all the traits under investigation.

Analysis of general combining ability effect indicated that MM-625 is the top general combiner for fruit yield per hectare followed by days taken to the first female flower, rind thickness, fruit cavity area, and β-carotene content. Parent MM-610 was observed as good general combiner for average fruit weight, ascorbic acid content, dry matter content, and reaction to fusarium wilt infestation. Parent Riogold was good combiner for traits, days to first fruit harvest, flesh thickness, vine length, and firmness. Parent Kajri was the best combiner for polar diameter, titrable acidity, pH, and reaction to root-knot nematode.

Analysis of specific combining ability showed that MS-1 × MM-610 was the best specific combiner for fruit yield per hectare, average fruit weight, and flesh thickness. The hybrid, MM Sel-103 × MM-904 had maximum significant SCA effect for number of fruits

per vine. The hybrid, MS-1 × Kajri had the maximum significant SCA effect for TSS content, and reaction to fusarium wilt, while for β-carotene content, vine length and fruit shape index hybrid Kajri × MM-625 showed the best SCA effect. The hybrid, Kajri × Riogold revealed the greatest SCA effect for days taken to first female flower emergence, and dry matter content. The hybrid MS-1 × MM 916/NS-1 the best specific combiner for rind thickness, fruit cavity area and fruit shape index. The hybrid MS-1 × Riogold highest SCA effect for reaction to root-knot nematode and reaction to viral disease KP_4HM-15 × MM Sel-103 was the best specific combiner. The hybrid showing best specific combining ability for reaction to fusarium wilt, number of branches and polar diameter was MM Sel-103 × MM-625. The cross combination Kajri × Riogold was detected good specific combiner for equatorial diameter, and pH value.

The twelve cross combinations showed heterobeltiosis for fruit yield per hectare. The best crosses with highest heterosis value were KP4HM-15 × MM Sel-103, KP4HM-15 × MM-904, MM Sel-103 × MM-610 and MM Sel-103 × MM-625 and these hybrids also showed significant heterobeltiosis for reaction to viral disease and fusarium wilt infestation. Cross combination showing the highest heterobeltiosis for TSS content were Ms-1 × Kajri, MM Sel-103 × MM 916/NS-1, Kajri × MM 916/NS-1, and MM-1831 × MM 916/NS-1 and these hybrids also showed significant heterobeltiosis for days taken to first female flower emergence, days taken to first fruit harvest, vine length, for reaction to viral disease and fusarium wilt infestation. The highest heterobletiosis for β-carotene was shown by hybrids Kajri × MM-625, MM-904 × MM-625, Kajri × MM 916/NS-1, and MM Sel-103 × MM 916/NS-1 and these hybrids also showed significant heterobeltiosis for reaction to viral disease and fusarium wilt infestation. The highest heterobletiosis for number of 'fruits' per vine were shown by crosses MM Sel-103 × MM-904, KP4HM-15 × MM-904, KP4HM-15 × MM Sel-103, and MM Sel-103 × MM-625 and these hybrids also showed significant heterobeltiosis for days taken to first female flower emergence, days taken to first fruit 'harvest', and reaction to viral disease. The highest heterobletiosis for firmness was shown by hybrids MM-1831 × MM 916/NS-1, MM-1831 × Riogold, MM-625 × MM 916/NS-1, and MM 916/NS-1 × Riogold and these hybrids also showed significant heterobeltiosis for reaction to viral disease and fusarium wilt infestation.

The highest and positive heterosis over standard checks MH-27, MH-51, and Farmer Glory for fruit yield per hectare was observed in cross combinations KP_4HM-15 × MM Sel-103, KP_4HM-15 × MM-625, MS-1 × MM-610, and MM Sel-103 × MM-625. The highest heterosis for TSS content over these three standard checks was shown by hybrids MM-1831 × MM 916/NS-1, MM Sel-103 × MM 916/NS-1, KP4HM-15 × MM Sel-103, KP4HM-15 × MM-1831, MS-1 × Kajri and MM-610 × MM 916/NS-1. These hybrids also showed significant result for firmness, and reaction to viral disease. Out of forty 45 hybrids, only one

hybrid MM-610 × MM-1831 showed significant result over MH-27 and two hybrids MS-1 × MM-1831 and MM-610 × MM-1831 over Farmer Glory for β-carotene content while for ascorbic acid content Kajri × MM-625, MM-904 × MM-625 MM 916/NS-1 × Riogold, MM-1831 × Riogold were showing significant result over three checks. The highest firmness over three standard checks was shown by KP_4HM-15 × MM-625 and KP_4HM-15 × MM Sel-103 showed significant positive value over Farmer Glory only. All the hybrids showed negative and significant heterosis over the three standard checks for reaction to viral disease. The best crosses were KP_4HM-15 × MM Sel-103, MS-1 × MM-625, MS-1 × Riogold, KP_4HM-15 × MM-610, and MM-904 × MM 916/NS-1. The estimated significant heterosis over the standard checks for reaction to fusarium infestation were observed in MM Sel-103 × MM-625, MS-1 × Kajri, Kajri × MM-904, and MM-610 × Riogold.

The gene action for inheritance of different character revealed that dominance gene effects were observed for all the characters showing positive and significant statistical values. The study of inheritance indicated the predominance of non-additive gene action. The low narrow sense heritability was observed for most of the important yield characters signifying the value of heterosis breeding to get higher gain in muskmelon.

For correlation coefficient analysis and path analysis in the present study indicated that fruit yield (t ha^{-1}) exhibiting significant and positive genotypic and phenotypic correlation with average fruit weight, number of fruits per vine, flesh thickness, fruit cavity area, vine length, number of branches, β-carotene content, and acidity while significant and negative genotypic and phenotypic correlation was detected in days taken to first female flower emergence and pH value. The direct and indirect effect of different characters on fruit 'yield' per hectare was 'studied' through path analysis.

For estimation of genetic variability and association among parental lines molecular study was undertaken. In this investigation genetic divergence among ten parents was estimated for parental polymorphism with 121 microsatellite markers. From total markers, 70 markers amplified a total of 1025 alleles across the genotypes with mean value 42.7 alleles per genotype. An average number of polymorphic markers was 26.4, while monomorphic markers was 16.3. Ten SSR primers were found to have higher discriminating potential for differentiation of the genotypes as they revealed 10 unique/specific alleles in ten genotypes. For the confirmation of F_1 hybrids the selected markers showing higher polymorphic value were utilized on the forty-five hybrids. Thus, these SSR markers will be used in identification of these hybrids.

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Annexure 1: Mean values of parents for two replications

Parents	Average fruit weight (g)	No of fruits per vine	Fruit yield (t ha^{-1})	Days to first female flower	Days to first fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)
Ms-1	687.5	3.3	21.6	59.5	96.5	9.9	10.9	2.1	4.5	9.0	0.9	7.8
Kajri	550.0	4.0	20.5	68.5	100.5	8.6	10.0	2.2	3.0	6.3	0.9	8.6
KP4HM-15	636.7	2.5	14.7	59.5	101.0	9.2	10.6	2.3	3.3	7.5	1.0	8.2
MM Sel-103	691.2	2.4	15.3	64.0	104.0	10.7	12.1	2.2	6.3	14.4	0.9	6.8
MM-904	635.0	2.5	15.0	62.0	101.0	11.2	12.0	2.0	3.0	6.4	1.2	5.7
MM-625	849.7	2.3	18.6	59.5	104.0	9.8	10.8	2.6	7.0	15.1	0.8	6.0
MM-610	733.3	2.3	15.7	61.0	103.0	10.8	11.7	2.3	4.5	10.9	1.0	6.1
MM-1831	866.7	3.3	27.0	61.5	103.5	11.2	12.1	2.9	5.8	14.8	1.0	7.3
MM 916/NS-1	893.0	3.2	26.6	63.5	101.0	11.0	11.4	2.4	4.3	10.2	1.0	5.8
Riogold	839.4	2.9	23.3	62.0	97.5	10.0	9.5	3.2	5.3	17.0	0.9	5.8

Annexure 1: Mean values of parents for two replications

Parents	No of Branches	TSS (□Brix)	β-carotene (mg/100g)	Firmness in (lb/ inch2)	Ascorbic Acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter %	Reaction to root-knot nematode (GI)	Reaction to viral disease (PDI)	Reaction to fusarium wilt (PDI)
Ms-1	4.3	8.7	1.7	14.5	26.3	0.2	5.0	97.4	4.4	13.1	36.0
Kajri	4.5	6.8	0.5	11.0	21.2	0.1	4.8	86.6	2.1	25.0	38.3
KP4HM-15	2.7	11.2	0.6	5.9	17.8	0.1	4.1	86.2	3.2	26.3	23.5
MM Sel-103	4.3	9.2	1.7	7.9	11.8	0.2	4.5	93.8	3.8	35.0	35.9
MM-904	3.5	9.0	0.5	5.5	25.4	0.2	5.2	93.7	3.7	18.1	37.6
MM-625	3.7	10.4	1.6	10.7	27.2	0.1	4.4	97.4	3.2	23.9	33.7
MM-610	4.3	10.3	2.5	8.9	26.5	0.2	3.9	93.5	3.0	26.3	19.5
MM-1831	4.0	10.4	1.5	6.3	23.7	0.2	3.6	96.2	4.4	15.9	23.0
MM 916/NS-1	4.7	9.0	1.5	5.9	21.7	0.2	4.7	89.6	3.8	15.0	37.7
Riogold	5.3	9.1	2.3	10.8	19.1	0.2	4.3	96.3	4.0	26.3	34.5

Annexure 2: Mean performance of hybrids for two replications

Parents/Traits	Average fruit weight (g)	No of fruits per vine	Fruit yield (t ha^{-1})	Days to first female flower	Days to first fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)
Ms-1 × Kajri	758.4	3.0	21.4	58.0	97.0	10.1	10.7	2.4	5.2	15.5	0.93	6.34
Ms-1 × KP4HM-15	734.6	3.0	20.8	57.5	97.0	10.6	11.7	1.9	5.2	13.1	1.00	6.55
Ms-1 × MM Sel-103	629.7	3.0	17.8	57.5	95.5	10.5	11.3	2.4	4.8	13.3	0.93	6.02
Ms-1 × MM-904	609.2	3.0	17.0	54.0	93.5	10.3	10.8	2.2	4.3	9.6	1.08	6.14
Ms-1 × MM-625	843.8	3.3	25.9	56.5	95.0	10.2	10.6	2.8	7.0	19.3	0.93	6.17
Ms-1 × MM-610	1028.0	3.6	35.1	57.5	95.0	12.0	11.7	2.8	5.8	14.9	1.00	6.24
Ms-1 × MM-1831	541.3	2.7	13.7	57.5	95.0	10.6	10.7	2.3	4.7	11.1	1.01	5.32
Ms-1 × MM 916/ NS-1	668.4	2.7	17.0	55.5	95.0	10.4	11.2	2.7	6.5	17.9	1.11	5.85
Ms-1 × Riogold	699.5	2.3	15.0	56.0	95.0	10.9	11.8	2.5	5.0	9.6	0.94	4.88
Kajri × Kp4hm-15	567.1	2.6	13.9	57.5	100.0	11.0	11.3	1.5	3.3	5.1	0.77	5.74
Kajri × MM Sel-103	837.5	2.2	17.0	60.0	100.0	11.5	10.6	2.6	5.0	12.8	0.85	6.20
Kajri × MM-904	488.9	2.5	11.5	59.5	96.5	11.0	10.3	2.1	3.3	7.3	0.92	5.89
Kajri × MM-625	659.8	3.6	22.2	58.5	94.5	12.1	12.1	2.6	6.2	16.6	0.93	5.22
Kajri × MM-610	615.4	2.3	13.4	59.5	101.0	11.9	13.3	2.2	5.0	9.5	0.93	7.67
Kajri × MM-1831	670.6	2.2	13.5	60.0	101.0	12.1	12.6	2.7	5.0	13.1	0.93	6.06
Kajri × MM 916/NS-1	661.2	2.3	14.0	54.5	95.0	12.8	12.4	2.1	3.8	10.9	0.86	7.17
Kajri × Riogold	924.3	2.7	23.8	54.0	91.5	12.0	11.7	2.6	3.3	8.9	0.92	7.57
KP4HM-15 × MM Sel-103	859.5	4.6	37.1	56.5	96.0	11.1	11.9	2.4	3.7	10.0	0.95	9.45
KP4HM-15 × MM-904	697.5	5.0	32.6	57.0	95.0	11.2	11.4	1.9	3.7	7.1	1.12	8.97
KP4HM-15 × MM-625	916.8	4.2	36.0	56.5	95.0	10.4	10.3	2.5	4.3	11.5	0.97	8.10
KP4HM-15 × MM-610	707.1	2.5	16.9	56.5	94.5	10.6	10.8	2.4	3.7	11.0	1.02	8.21
KP4HM-15 × MM-1831	756.2	3.8	27.4	57.0	94.5	12.3	12.0	2.5	2.5	6.4	0.97	9.54
KP4HM-15 × MM 916/NS-1	603.5	3.2	18.1	56.0	92.0	12.2	11.5	1.9	4.7	6.8	0.96	11.32

Annexure 2: Continued.

Hybrids	Average fruit weight (g)	No of fruits per vine	Fruit yield (t ha^{-1})	Days to first female flower	Days to first fruit harvest	Polar diameter (cm)	Equatorial diameter (cm)	Flesh thickness (cm)	Rind thickness (mm)	Fruit cavity area (cm^2)	Fruit shape index	Vine length (m)
KP4HM-15 × Riogold	750.4	4.5	31.6	56.0	91.5	12.7	11.2	2.5	5.0	12.1	0.95	5.56
MM Sel-103 × MM-625	883.9	4.2	34.6	55.0	99.5	11.7	11.8	3.4	5.8	19.5	0.87	9.02
MM Sel-103 × MM-610	997.9	3.5	33.3	56.5	96.0	10.1	10.9	2.3	5.5	13.3	0.88	6.62
MM Sel-103 × MM-1831	1000.6	2.3	22.0	57.0	91.5	8.1	9.9	2.9	5.5	15.9	0.83	7.45
MM Sel-103 × MM 916/NS-1	622.2	2.7	15.7	56.5	93.5	7.9	10.0	2.2	3.8	8.9	0.92	7.04
MM Sel-103 × Riogold	801.9	3.0	22.8	52.5	92.5	7.5	10.2	2.8	4.2	12.8	0.86	5.90
MM-904 × MM-625	543.9	3.5	17.7	59.0	96.0	8.6	10.7	2.6	6.0	13.5	0.98	7.97
MM-904 × MM-610	597.6	3.0	16.7	58.5	91.5	10.5	12.0	2.3	3.7	9.7	1.09	6.90
MM-904 × MM-1831	505.6	4.6	21.9	56.5	91.5	10.4	12.4	2.2	4.2	7.0	0.97	6.55
MM-904 × MM 916/NS-1	449.4	3.3	14.1	57.5	91.5	11.2	12.6	2.0	4.0	8.2	0.96	5.49
MM-904 × Riogold	628.9	2.7	15.9	56.5	91.0	10.0	10.7	2.3	4.0	8.9	1.11	6.10
MM-625 × MM-610	1018.9	3.0	28.4	57.0	96.0	9.1	10.1	2.5	5.0	13.3	0.98	5.90
MM-625 × MM-1831	859.8	2.9	23.5	57.0	91.0	10.4	11.5	2.7	5.7	16.9	0.92	5.54
MM-625 × MM 916/NS-1	822.2	3.3	25.3	53.5	91.5	11.0	12.0	2.0	4.0	8.3	0.91	5.22
MM-625 × Riogold	931.0	2.3	19.9	54.0	91.5	11.3	12.2	2.6	5.5	14.2	0.93	7.35
MM-610 × MM-1831	868.1	2.3	18.6	55.5	97.5	10.8	11.5	2.6	6.8	17.0	1.00	7.16
MM-610 × MM 916/NS-1	1073.1	2.3	23.6	55.0	96.5	10.6	11.1	2.6	6.3	16.1	0.97	7.17
MM-610 × Riogold	889.2	2.3	19.0	60.0	96.5	9.6	10.5	3.0	6.7	20.1	0.99	7.07
MM-1831 × MM 916/NS-1	875.9	2.5	20.3	58.5	97.5	10.6	11.3	2.4	5.0	13.8	0.96	7.87
MM-1831 × Riogold	855.0	2.3	18.3	57.5	97.0	11.7	12.5	2.9	5.2	15.2	0.98	6.64
MM 916/NS-1 × Riogold	1037.9	3.0	28.9	59.5	96.5	10.9	11.8	3.1	5.2	14.6	0.96	6.19

Annexure 2: Continued.

Hybrids	No of Branches	TSS (□ Brix)	β-carotene (mg/100g)	Firmness in (lb/ inch2)	Ascorbic Acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter %	Reaction to root-knot nematode (GI)	Reaction to viral disease (PDI)	Reaction to fusarium wilt (PDI)
Ms-1 × Kajri	4.34	13.17	1.22	7.15	19.50	0.100	4.25	92.00	3.60	20.63	12.50
Ms-1 × KP4HM-15	4.50	12.05	1.70	6.65	12.77	0.135	4.45	86.20	4.00	19.08	33.90
Ms-1 × MM Sel-103	4.33	10.69	1.52	9.00	24.25	0.115	3.65	93.86	3.90	21.70	24.00
Ms-1 × MM-904	4.34	10.67	1.09	7.70	22.75	0.150	4.50	93.27	4.80	19.23	35.50
Ms-1 × MM-625	4.84	10.47	2.33	9.55	10.75	0.170	2.75	96.47	4.20	12.70	33.00
Ms-1 × MM-610	4.00	10.57	1.96	7.70	23.14	0.175	4.75	97.32	4.05	18.28	28.50
Ms-1 × MM-1831	4.34	11.00	2.15	7.75	26.20	0.145	3.80	93.93	3.30	21.63	35.73
Ms-1 × MM 916/ NS-1	4.17	11.55	1.56	9.30	21.32	0.175	3.60	90.53	4.40	23.90	31.50
Ms-1 × Riogold	3.50	9.37	1.01	9.45	12.50	0.150	3.25	79.70	2.90	11.30	33.50
Kajri × Kp4hm-15	4.00	6.54	0.49	7.30	17.80	0.125	4.50	93.88	3.80	21.25	35.50
Kajri × MM Sel-103	4.50	10.70	1.93	7.80	17.95	0.140	4.05	98.09	2.85	32.04	20.00
Kajri × MM-904	4.17	12.20	0.21	7.65	13.80	0.130	4.25	95.65	2.60	18.13	16.00
Kajri × MM-625	4.00	9.53	3.43	9.35	19.14	0.105	3.35	93.83	2.55	15.26	35.50
Kajri × MM-610	3.84	9.35	0.45	8.95	22.19	0.100	5.70	94.03	2.25	14.75	27.50
Kajri × MM-1831	5.50	11.89	2.09	8.70	20.65	0.115	5.35	89.57	3.30	19.08	27.50
Kajri × MM 916/NS-1	4.17	12.83	2.30	8.50	23.07	0.160	3.45	95.83	4.50	31.24	31.00
Kajri × Riogold	4.17	11.77	1.78	7.50	17.97	0.205	3.40	99.57	3.50	21.88	32.00
KP4HM-15 × MM Sel-103	4.00	13.50	1.91	4.65	17.52	0.240	3.70	94.76	4.00	10.25	35.22
KP4HM-15 × MM-904	4.34	8.84	0.60	5.20	21.60	0.130	3.60	86.20	2.90	12.50	30.87
KP4HM-15 × MM-625	4.50	11.82	2.08	4.85	22.00	0.305	3.50	90.92	3.75	22.42	32.50
KP4HM-15 × MM-610	4.34	11.63	1.20	4.25	13.00	0.175	3.45	92.15	3.10	11.88	36.12
KP4HM-15 × MM-1831	5.00	13.25	0.75	5.30	9.33	0.175	3.50	97.77	3.80	24.88	35.00
KP4HM-15 × MM 916/NS-1	4.50	13.03	1.38	6.00	20.99	0.195	3.75	98.74	4.50	25.63	37.00

Annexure 2: Continued.

Hybrids	No of Branches	TSS (□ Brix)	β-carotene (mg/100g)	Firmness in (lb/ inch2)	Ascorbic Acid (mg/100g)	Titrable acidity (g anhydrous citric acid/ 100 ml fruit juice)	pH	Dry matter %	Reaction to root-knot nematode (GI)	Reaction to viral disease (PDI)	Reaction to fusarium wilt (PDI)
KP4HM-15 × Riogold	4.84	12.10	1.71	5.45	12.22	0.145	3.50	90.21	3.60	27.15	35.18
MM Sel-103 × MM-625	5.50	11.84	2.30	5.55	12.28	0.125	3.45	79.70	3.60	28.03	12.00
MM Sel-103 × MM-610	4.17	9.54	2.16	5.85	16.77	0.190	3.90	96.41	3.00	26.25	19.50
MM Sel-103 × MM-1831	4.00	10.22	0.95	7.70	11.67	0.130	4.50	90.91	3.75	15.63	37.00
MM Sel-103 × MM 916/NS-1	4.00	13.64	2.60	5.90	17.67	0.130	4.50	91.10	4.40	25.00	35.50
MM Sel-103 × Riogold	4.17	10.90	1.24	5.55	12.67	0.095	3.45	94.30	4.50	23.10	32.25
MM-904 × MM-625	3.84	12.62	2.91	5.75	20.99	0.125	3.40	98.24	4.25	26.75	37.56
MM-904 × MM-610	3.50	9.62	0.61	5.50	14.67	0.175	3.35	97.20	4.15	23.88	37.36
MM-904 × MM-1831	3.84	10.95	1.38	5.35	15.67	0.095	4.00	91.37	4.15	18.98	36.05
MM-904 × MM 916/NS-1	3.50	12.78	0.99	5.15	17.28	0.175	3.55	96.20	3.75	13.11	40.50
MM-904 × Riogold	3.84	8.20	2.04	6.35	18.14	0.155	3.35	96.00	3.95	24.90	37.00
MM-625 × MM-610	4.00	12.00	2.35	7.95	22.99	0.155	3.35	97.79	2.80	26.25	36.00
MM-625 × MM-1831	4.00	11.17	2.04	7.45	23.75	0.115	4.10	95.58	4.35	18.20	27.00
MM-625 × MM 916/NS-1	4.00	11.82	1.76	13.75	13.80	0.110	4.40	97.37	4.50	23.10	38.50
MM-625 × Riogold	4.50	10.59	1.44	10.95	19.82	0.090	4.25	87.02	4.05	24.95	36.25
MM-610 × MM-1831	4.00	11.07	2.20	7.30	26.85	0.115	3.65	86.04	4.50	25.80	35.50
MM-610 × MM 916/NS-1	4.67	13.17	3.02	8.90	18.17	0.155	4.05	91.60	5.00	19.14	20.00
MM-610 × Riogold	4.00	11.60	1.84	8.65	19.00	0.060	4.60	97.41	4.50	16.14	19.50
MM-1831 × MM 916/NS-1	4.34	14.92	1.18	11.70	14.06	0.130	3.40	89.58	4.65	24.75	29.00
MM-1831 × Riogold	3.67	12.75	2.68	16.50	16.33	0.115	5.10	89.16	4.25	18.83	35.50
MM 916/NS-1 × Riogold	4.34	11.75	2.69	13.90	23.06	0.140	3.40	90.10	4.85	13.10	32.50

Annexure 3: Brief morphological characterization of F1 hybrids

Genotypes	Leave shape	Fruit Shape	Netting	Suture	Rind color	Flesh color	Flesh texture	Seed cavity	Scar shape	Scar size	Ribs
MS-1×Kajri	Entire	Round	Present	Present D	Red Pattern	Orange	Mealy	Compact	Round	Small	Present
MS-1×KP4HM- 15	Penta lobate	Round	Present	Present	Light Yellow	Orange	Mealy	Large	Round	Medium	Present
MS-1×MM Sel – 103	Penta lobate	Round	Present	Present	Yellow	Orange	Mealy	Small	Round	Medium	Present
MS-1×MM - 904	Penta lobate	Oval	Present	Present	Yellow	Green+Orange	Intermediate	Large	Round	Medium	Present
MS-1×MM - 625	Penta lobate	Round	Present	Absent	Dark Green	Orange	Intermediate	Small	Round	Small	Absent
MS-1×MM – 610	Penta lobate	Round	Present	Absent	Green	Orange	Intermediate	Medium	Round	Small	Absent
MS-1×MM – 1831	Penta lobate	Round	Present	Present	Yellow	Orange	Mealy	Small	Round	Small	Absent
MS-1×MM-916/NS-1	Penta lobate	Oval-Round	Present	Absent	Light Green	Orange	Intermediate	Medium	Round	Small	Present
MS-1×Riogold	Penta lobate	Round	Present	Absent	Dark Green	Orange	Intermediate	Small	Round	Small	Absent
Kajri×KP4HM- 15	Entire	Flat-Round	Present	Present Dark	Red Pattern	Green	Mealy	Small	Round	Small	Absent
Kajri×MM Sel – 103	Penta lobate	Flat-Round	Present	Present Dark	Red Pattern	Green	Mealy	Small	Round	Small	Absent
Kajri×MM - 904	Penta lobate	Round	Absent	Present	Red Pattern	Green	Mealy	Small	Round	Small	Absent
Kajri×MM - 625	Entire	Round	Present	Absent	White Orange Pattern	Orange	Intermediate	Small	Round	Very Small	Present
Kajri×MM – 610	Penta lobate	Flat Round	Present	Absent	Red Pattern	Green+Orange	Mealy	Small	Round	Small	Absent
Kajri×MM – 1831	Entire	Round	Present	Absent	Red Pattern	Orange	Mealy	Small	Round	Small	Absent

Annexure 3. Continued

Genotypes	Leave shape	Fruit Shape	Netting	Suture	Rind color	Flesh color	Flesh texture	Seed cavity	Scar shape	Scar size	Ribs
Kajri×MM-916/NS-1	Penta lobate	Flat-Round	Present	Absent	White Background	Orange	Mealy	Small	Round	Small	Absent
Kajri×Riogold	Entire	Round	Present	Absent	Yellow spot	Orange	Intermediate	Small	Round	Small	Present
KP4HM- 15×MM Sel – 103	Penta lobate	Round	Absent	Present Dark	Light Green	Green+Orange	Mealy	Medium	Round	Small	Present
KP4HM- 15×MM - 904	Penta lobate	Oval-Round	Absent	Present	White background	Green	Mealy	Medium	Round	Small	Absent
KP4HM- 15×MM - 625	Penta lobate	Round	Absent	Absent	White Background	Orange	Mealy	Medium	Round	Small	Absent
KP4HM- 15×MM – 610	Penta lobate	Flat-Round	Absent	Present	White Yellow	Orange	Mealy	Small	Round	Small	Absent
KP4HM- 15×MM – 1831	Penta lobate	Round	Absent	Absent	Yellow	Green	Mealy	Medium	Round	Small	Present
KP4HM- 15×MM-916/NS-1	Penta lobate	Round	Present	Present	White Plain Background	Orange	Mealy	Large	Round	Small	Present
KP4HM- 15×Riogold	Penta lobate	Round	Absent	Absent	White Background	Green+Orange	Mealy	Small	Round	Medium	Absent
MM Sel – 103×MM - 904	Penta lobate	Round	Absent	Present	Yellow	Green+Orange	Mealy	Small	Round	Medium	Present
MM Sel – 103×MM - 625	Penta lobate	Round	Present	Absent	White Background	Dark Orange	Intermediate	Small	Round	Small	Absent
MM Sel – 103×MM – 610	Penta lobate	Round	Present	Present	Yellow Background	Orange	Mealy	Small	Round	Small	Absent
MM Sel – 103×MM – 1831	Penta lobate	Flat-Round	Present	Present Dark	Dark Yellow	Light Orange	Mealy	Small	Round	Small	Absent
MM Sel–103×MM-916/NS-1	Penta lobate	Flat-Round	Present	Present	Light Yellow	Orange	Mealy	Small	Round	Small	Absent
MM Sel – 103×Riogold	Penta lobate	Flat-Round	Present	Present	Yellow	Orange	Intermediate	Medium	Round	Medium	Absent

Annexure 3. Continued

Genotypes	Leave shape	Fruit Shape	Netting	Suture	Rind color	Flesh color	Flesh texture	Seed cavity	Scar shape	Scar size	Ribs
MM - 904×MM - 625	Penta lobate	Round	Present	Present	White Background	Orange	Mealy	Small	Round	Small	Present
MM - 904×MM – 610	Penta lobate	Oval-Round	Present	Present	Green	Green+Orange	Mealy	Small	Round	Small	Present
MM - 904×MM – 1831	Penta lobate	Round	Present	Absent	Yellow	Green+Orange	Mealy	Small	Round	Small	Absent
MM - 904×MM-916/NS-1	Penta lobate	Round	Present	Absent	Yellow	Green+Orange	Mealy	Medium	Round	Small	Absent
MM - 904×Riogold	Penta lobate	Round	Present	Absent	Yellow	Green+Orange	Mealy	Medium	Round	Small	Absent
MM - 625×MM – 610	Penta lobate	Round	Present	Absent	Yellow	Orange	Mealy	Small	Round	Small	Present
MM - 625×MM – 1831	Penta lobate	Round	Present	Absent	Green	Orange	Intermediate	Small	Round	Small	Absent
MM - 625×MM-916/NS-1	Penta lobate	Flat-Round	Present	Absent	Yellow	Orange	Intermediate	Medium	Round	Small	Present
MM - 625×Riogold	Penta lobate	Round	Present	Absent	Green	Orange	Intermediate	Small	Round	Small	Absent
MM – 610×MM – 1831	Penta lobate	Round	Present	Absent	Yellow	Orange	Mealy	Small	Round	Small	Absent
MM – 610×MM-916/NS-1	Penta lobate	Round	Present	Absent	White Background	Orange	Mealy	Medium	Round	Small	Present
MM – 610×Riogold	Penta lobate	Round	Present	Absent	White Background	Orange	Intermediate	Small	Round	Small	Absent
MM – 1831×MM-916/NS-1	Penta lobate	Round	Present	Absent	White Background	Orange	Intermediate	Small	Round	Medium	Absent
MM – 1831×Riogold	Penta lobate	Round	Present	Absent	Yellow	Orange	Intermediate	Small	Round	Small	Absent
MM-916/NS-1×Riogold	Penta lobate	Round	Present	Absent	Yellow	Orange	Mealy	Medium	Round	Medium	Present

Annexure 4: Meteorological data for the month of February, 2020 PAU Ludhiana

Date	Temperature		Relative humidity (%)		Rainfall (mm)	Evaporation	Sunshine (hr)	Wind (km/hr)
	Maximum	Mean	Morning	Evening				
1	15.6	15.6	97	80	0.0	1.2	7.5	2.3
2	18.0	18.0	97	58	0.0	1.2	8.0	2.6
3	18.6	18.6	90	43	0.0	1.6	8.8	1.9
4	18.6	18.6	97	50	0.0	1.2	3.2	2.8
5	17.4	17.4	94	52	0.0	1.6	6.7	2.8
6	18.8	18.8	94	40	0.0	1.4	9.0	1.3
7	18.0	18.0	88	58	0.0	1.4	7.0	2.7
8	19.0	19.0	94	48	0.0	1.6	8.4	2.5
9	20.0	20.0	97	49	0.0	1.6	8.0	1.3
10	19.0	19.0	97	51	0.0	1.6	8.0	2.1
11	20.4	20.4	94	45	0.0	1.8	8.3	2.2
12	22.0	22.0	95	49	0.0	2.0	7.9	6.6
13	23.4	23.4	92	58	0.0	2.0	8.9	4.6
14	21.6	21.6	97	56	0.0	2.0	10.0	5.1
15	22.2	22.2	83	45	0.0	2.0	10.7	3.7
16	24.6	24.6	97	38	0.0	2.0	10.3	2.2
17	23.4	23.4	97	38	0.0	2.0	10.1	2.8
18	23.8	23.8	97	36	0.0	2.4	10.5	3.3
19	22.0	22.0	69	49	0.0	4.0	1.9	16.6
20	24.2	24.2	70	52	6.0	4.0	5.3	10.6
21	21.6	21.6	72	59	0.0	2.0	5.2	3.0
22	23.2	23.2	97	53	0.0	2.0	9.8	2.7
23	23.8	23.8	95	49	0.0	2.0	9.3	2.9
24	24.0	24.0	92	48	0.0	2.0	9.0	2.3
25	25.6	25.6	97	50	0.0	2.0	8.2	1.3
26	25.2	25.2	95	55	0.0	2.0	5.6	2.3
27	24.4	24.4	93	54	0.0	2.0	2.1	5.7
28	22.2	22.2	85	65	0.0	2.6	1.7	13.3
29	16.6	16.6	90	63	9.0	2.6	2.2	6.2
Mean	**21.3**	**21.3**	**91.4**	**51.4**	**15.0**	**57.8**	**7.3**	**4.1**

Annexure 4: Meteorological data for the month of March, 2020 PAU Ludhiana

Date	Temperature		Relative humidity (%)		Rainfall (mm)	Evaporation	Sunshine (hr)	Wind (km/hr)
	Maximum	Mean	Morning	Evening				
1	25.0	11.0	93	42	0.0	2.6	8.8	1.7
2	25.4	11.8	97	51	0.0	2.6	9.7	1.5
3	25.4	12.0	95	50	0.0	2.6	10.4	2.2
4	26.6	11.6	95	40	0.0	2.6	9.5	2.0
5	24.6	12.5	86	51	0.0	3.0	6.6	8.8
6	18.0	14.6	80	74	18.6	4.0	0.0	12.3
7	17.0	11.8	95	83	0.0	1.8	0.8	3.5
8	22.6	9.2	97	52	0.0	2.0	10.6	2.5
9	22.4	9.0	95	46	0.0	2.4	11.2	4.5
10	23.6	8.0	94	36	0.0	2.4	11.2	1.9
11	20.1	10.6	74	82	10.8	2.8	0.0	10.6
12	23.8	14.4	82	54	5.8	1.8	8.7	8.8
13	24.2	11.2	73	50	0.0	1.6	9.5	5.4
14	15.8	13.4	80	79	12.0	2.0	0.0	3.2
15	22.6	9.6	95	47	0.0	2.0	10.6	1.6
16	24.4	10.0	93	52	0.0	2.0	10.4	2.6
17	25.6	11.0	95	50	0.0	2.2	10.8	3.2
18	26.4	12.6	95	51	0.0	2.4	10.4	2.7
19	27.6	14.2	93	47	0.0	2.4	10.2	1.6
20	28.2	13.4	91	41	0.0	2.6	8.0	1.6
21	26.0	15.0	84	58	0.0	2.4	1.8	1.6
22	28.0	12.8	84	45	0.0	2.6	10.7	2.5
23	29.4	14.2	91	36	3.0	3.0	9.7	1.8
24	25.6	18.4	80	77	0.0	3.2	1.0	5.1
25	28.0	14.6	87	47	1.6	3.2	6.4	2.1
26	27.0	15.8	92	58	16.4	2.6	1.8	3.8
27	21.4	18.2	90	70	0.0	2.4	0.0	5.9
28	26.0	15.0	96	58	0.0	3.2	9.3	2.8
29	26.4	15.0	89	45	0.0	3.6	11.6	4.2
30	26.8	14.4	89	41	0.0	3.6	10	4.6
31	26.8	15.5	90	59	0.8	1.8	0.5	5.8
Mean	**24.5**	**12.9**	**89.4**	**53.9**	**69.0**	**79.4**	**7.1**	**3.9**

Annexure 4: Meteorological data for the month of April, 2020 PAU Ludhiana

Date	Temperature		Relative humidity (%)		Rainfall (mm)	Evaporation	Sunshine (hr)	Wind (km/hr)
	Maximum	Mean	Morning	Evening				
1	29.0	13.6	85	41	0.0	3.2	12.0	4.3
2	28.4	15.2	88	29	0.0	3.6	11.8	4.4
3	28.0	11.6	84	32	0.0	4.0	12.0	3.9
4	30.0	12.8	84	34	0.0	4.2	11.5	3.2
5	31.0	16.0	80	34	0.0	4.0	10.2	2.4
6	30.8	16.2	74	40	0.0	4.6	11.8	5.3
7	26.6	16.4	72	62	0.0	3.2	1.8	3.9
8	29.2	13.0	91	26	0.0	4.0	11.6	3.7
9	31.2	14.5	78	27	0.0	4.0	8.1	3.5
10	33.4	17.8	69	27	0.0	4.2	8.5	3.3
11	34.4	17.4	78	26	0.0	4.3	11.0	3.0
12	34.5	16.4	79	26	0.0	4.6	10.8	2.7
13	36.4	17.6	72	28	0.0	5.0	9.5	2.8
14	39.0	20.2	71	20	0.0	6.4	9.0	4.8
15	39.6	25.0	47	20	0.0	6.0	10.5	3.4
16	36.6	21.0	73	20	0.0	6.2	9.5	4.6
17	29.6	23.0	48	51	4.6	5.0	4.0	7.9
18	34.2	16.8	72	31	0.0	4.6	10.6	5.3
19	33.6	16.8	68	31	0.0	4.8	12.2	3.2
20	31.4	18.4	70	56	5.2	3.2	2.4	2.6
21	31.4	14.4	92	37	0.0	4.0	12.2	2.6
22	33.8	16.8	69	31	0.0	4.6	12.8	1.8
23	35.6	18.8	69	26	0.0	4.2	9.8	1.7
24	36.4	17.8	51	25	0.0	5.0	12.4	2.4
25	31.2	20.2	58	53	0.0	4.6	5.3	3.8
26	31.0	20.6	72	43	3.4	5.0	7.2	9.7
27	29.6	20.6	72	52	0.0	5.0	7.2	10.1
28	35.0	20.2	76	32	0.0	5.6	11.6	2.7
29	36.0	19.8	64	29	0.0	5.4	12.2	2.6
30	37.4	24.0	73	31	0.0	5.8	11	3.6
Mean	**32.8**	**17.8**	**72.6**	**34.0**	**13.2**	**138.3**	**9.7**	**4.0**

Annexure 4: Meteorological data for the month of May, 2020 PAU Ludhiana

Date	Temperature		Relative humidity (%)		Rainfall (mm)	Evaporation	Sunshine (hr)	Wind (km/hr)
	Maximum	Mean	Morning	Evening				
1	39.0	21.4	47	28	0.0	7.8	11.7	7.3
2	35.0	25.4	68	40	12.0	6.0	3.6	7.0
3	33.2	21.4	80	45	4.2	5.2	8.0	8.0
4	33.0	19.2	72	39	0.0	5.6	10.2	1.9
5	35.6	21.4	71	34	0.0	5.2	11.6	4.7
6	34.0	20.4	67	33	0.0	5.6	3.1	3.8
7	35.8	19.0	56	26	0.0	5.4	11.7	3.1
8	38.0	19.6	55	30	0.0	6.0	12.4	2.6
9	39.4	22.4	47	26	0.0	6.0	10.6	5.9
10	32.0	22.2	61	40	0.8	6.8	4.9	9.7
11	35.6	22.6	55	35	4.6	6.6	10.1	9.9
12	34.8	21.2	79	31	0.0	5.4	10.4	2.7
13	33.6	24.6	71	42	0.0	3.8	2.1	1.0
14	32.0	22.6	68	55	19.6	5.6	6.2	7.6
15	34.0	19.4	74	33	0.0	5.4	13.0	5.0
16	37.0	20.8	63	20	0.0	6.4	12.8	4.4
17	37.8	22.8	59	16	0.0	7.0	12.3	4.1
18	38.4	22.0	53	14	0.0	7.6	12.1	3.9
19	37.0	19.6	51	10	0.0	6.4	7.5	3.6
20	37.4	18.6	47	16	0.0	6.4	13.0	5.6
21	40.0	19.6	45	14	0.0	8.4	12.9	5.8
22	42.5	22.8	53	15	0.0	8.4	11.8	1.8
23	43.2	24.6	31	13	0.0	8.6	11.0	6.1
24	41.2	24.4	48	17	0.0	8.6	12.3	3.2
25	41.6	24.2	45	14	0.0	8.6	12.8	3.6
26	43.0	25.8	48	15	0.0	8.6	12.4	3.2
27	43.4	25.4	32	18	0.0	10.6	12.3	8.0
28	39.0	27.4	38	28	0.0	10.6	9.2	14.3
29	33.2	23.4	51	41	0.0	9.6	4.9	13.7
30	34.6	24.2	62	38	7.8	7.8	6.2	10.4
31	30.0	21.4	88	57	0.6	3.0	1.6	5.3
MEAN	**36.9**	**22.3**	**57.6**	**28.5**	**49.6**	**213.0**	**9.5**	**5.7**

Annexure 4: Meteorological data for the month of June, 2020 PAU Ludhiana

Date	Temperature		Relative humidity (%)		Rainfall (mm)	Evaporation	Sunshine (hr)	Wind (km/hr)
	Maximum	Mean	Morning	Evening				
1	33.6	21.4	67	45	0.0	5.2	11.7	3.4
2	34.6	23.0	64	44	0.0	5.6	8.2	3.0
3	34.6	22.2	59	31	0.2	4.2	4.0	2.2
4	37.0	22.0	61	25	0.0	7.0	12.5	5.5
5	35.6	23.8	65	30	0.0	7.2	9.1	8.6
6	30.4	20.6	76	60	0.4	6.4	3.4	5.4
7	34.6	23.4	71	41	0.0	6.4	10.8	3.6
8	38.4	25.0	61	31	0.0	7.4	12.7	2.9
9	37.6	26.8	57	44	0.0	8.0	12.0	4.3
10	37.4	26.8	56	33	0.0	8.0	9.1	4.5
11	40.2	26.6	56	33	0.0	8.2	11.8	4.3
12	41.5	29.2	62	28	4.4	7.2	10.2	4.5
13	38.2	25.8	63	33	0.0	8.0	12.0	5.0
14	40.4	27.2	54	26	0.0	8.0	12.2	3.9
15	41.2	26.4	67	25	0.0	8.0	12.4	6.8
16	41.6	28.8	63	20	0.0	9.6	12.7	7.6
17	41.2	29.8	63	37	0.0	10.0	12.3	8.1
18	41.4	30.0	66	30	0.0	10.0	11.5	7.2
19	39.2	28.0	68	46	1.0	10.0	10.0	9.1
20	39.4	25.4	68	42	0.0	8.0	7.8	6.4
21	36.2	28.6	51	49	0.0	7.0	7.3	8.2
22	37.4	26.6	78	39	0.0	8.0	8.9	7.3
23	37.4	27.2	63	44	0.0	8.2	11.0	8.9
24	35.2	29.6	71	58	0.0	6.0	6.8	7.6
25	33.4	28.6	65	61	0.0	6.0	2.5	3.7
26	37.6	26.2	67	43	0.0	6.0	6.4	3.1
27	38.6	28.6	69	40	0.0	6.0	5.3	3.3
28	40.4	30.0	75	36	3.6	8.0	10.4	6.0
29	36.5	29.6	57	47	0.0	6.4	5.7	7.3
30	36.6	27.0	75	55	0.0	6.4	9.3	5.6
Mean	**37.6**	**26.5**	**64.6**	**39.2**	**9.6**	**220.4**	**9.3**	**5.6**

VITA

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