HETEROSIS AND COMBINING ABILITY STUDIES ON YIELD, QUALITY AND STORAGE TRAITS INVOLVING BUSH AND BUTTERNUT TYPE GENOTYPES IN PUMPKIN (*Cucurbita moshata* Duch. ex Poir.)

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 on yield, quality and storage traits involving bush and butternut type genotypes in pumpkin (*Cucurbita moshata* Duch. ex Poir.)''** submitted to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science** in the subject of **Horticulture (Vegetable Science) (Minor Subject: Plant Breeding and Genetics),** is a bonafide research work carried out by **Nishan Singh (L-2014-A-157-M)**, under my supervision and that no part of this dissertation 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 this thesis entitled, **"Heterosis and combining ability studies on yield, quality and storage traits involving bush and butternut type genotypes in pumpkin (*Cucurbita moshata* Duch. ex Poir.)"** submitted by **Nishan Singh (L-2014-A-157-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science** in the subject of **Horticulture (Vegetable Science)** **(Minor Subject: Plant Breeding and Genetics)**, has been approved by the student's Advisory committee after an oral examination on the same in collaboration with an External Examiner.

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Any piece of work requires determination, dedication and the warmth bliss and grace of **Almighty** that equip one to perform any task with fervor and zest. I pay my sincere offerings to "**Waheguru**" the Almighty with whose grace I have been able to add a new dimension in my life.

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ABSTRACT

The present study was conducted in diallel fashion to estimate combining ability and heterosis involving bush and butternut type genotypes of pumpkin. Among nine parents, MSBN 3621-9-3-1 was the best combiner for characters related to bushy growth habit, butternut fruit type and earliness; CFR 2211-2 for number of primary branches, early female flowering, TSS and dry matter; MBN 6242-3-1 (Butternut type) for pulp thickness (0.44) and fruit yield per vine (0.63); MVSR 6711-14-2 for early male flowering and vitamin-C; BN-364 for number of fruits per vine (0.22) and total carotenoids. Among bushy and butternut crosses, number of primary branches, internodal length, early flowering and fruiting, fruit shape index, fruit yield per vine, TSS and dry matter content and vitamin-C were controlled by additive as well as non-additive gene effects and can be exploited through heterosis breeding or recurrent selection. High additive and additive × additive genetic variance for peduncle length, polar diameter, pulp thickness, total carotenoids and total sugar highlighted the exploitation through selection. However, non-additive gene effects for short vine, equator diameter, number of fruits per vine and less average fruit weight suggested use of heterosis breeding. On the basis of significant economic heterosis over PPH-1 and PPH-2, crosses MBN 6242-3-1 × CFR 2211-2 (122.56 and 176.51%, respectively) was best for yield per vine and BUMOV 41212-3-1 × BN-364, PS × BN-364, BUMOV 41212-3-1 × MSBN 3621-9-3-1, MSBN 3621-9-3-1 × MBN 6242-3-1 were best for less fruit weight as well as more number of fruits per vine among bushy and butternut genotypes. On the basis of *per se* performance, MSBN 3621-9-3-1 × MBN 6242-3-1 (34.76 MT/ha), MSBN 3621-9-3-1 × CFR 2211-2 (33.02 MT/ha), BN-364 × MSBN 3621-9-3-1 (32.07 MT/ha), MVSR 6711-14-2 × MSBN 3621-9-3-1 (30.81 MT/ha) were high yielding bushy hybrids with early maturity and butternut fruits. In character association, vine length was highly correlated with internodal length (0.85) and earliest node to female flower (0.85). Fruit yield per vine was highly associated with average fruit weight (1.00), node to first fruit (0.98) and vine length (0.97), while average fruit weight was influenced with quality traits such as total sugar (0.34) and vitamin-C (0.31).

***Key words*:** Bush pumpkin, butternut fruit, combining ability, heterosis, correlation

Signature of Major Advisor **Signature of Student**

ਖੋਜ ਗ੍ਰੰਥ ਦਾ ਸਿਰਲੇਖ	:	ਪੇਠੇ (*ਕੁਕਰਬੀਟਾ ਮੌਸਚੈਟਾ* ਡਚ. ਐਕਸ ਪੋਆਇਰ.) ਦੀਆਂ ਝਾੜੀਦਾਰ ਅਤੇ ਬਟਰਨੱਟ ਲਾਈਨਾਂ ਵਰਤ ਕੇ ਝਾੜ, ਕੁਆਲਿਟੀ ਅਤੇ ਸਟੋਰੇਜ਼ ਵਿਸ਼ੇਸ਼ਤਾਵਾਂ ਲਈ ਹਾਈਬ੍ਰਿਡ ਅਤੇ ਸੰਯੋਗ ਸਮਰੱਥਾ ਦੀ ਤਫਤੀਸ਼
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ਸਾਰ–ਅੰਸ਼

ਮੌਜੂਦਾ ਤਫ਼ਤੀਸ਼, ਪੇਠੇ ਦੀਆਂ ਛੋਟੀਆਂ ਵੇਲਾਂ ਅਤੇ ਬਟਰਨੱਟ ਫ਼ਲ ਵਾਲੀਆਂ ਲਾਈਨਾਂ ਦੀ ਸੰਯੋਗ ਅਤੇ ਹਾਈਬ੍ਰਿਡ ਸਮਰੱਥਾ ਲਈ ਕੀਤੀ ਗਈ। ਝਾੜੀਦਾਰ ਵਾਧੇ, ਬਟਰਨੱਟ ਫਲ ਅਤੇ ਅਗੇਤੇਪਣ ਲਈ ਐਮ ਐਸ ਬੀ ਐਨ 3621-9-3-1 ਦਾ ਵਧੀਆ ਸੁਮੇਲ ਪਾਇਆ ਗਿਆ। ਜ਼ਿਆਦਾ ਮੁਢਲੀਆਂ ਟਹਿਣੀਆਂ, ਅਗੇਤੇ ਮਾਦਾ ਫੁੱਲ, ਟੀ ਐਸ ਐਸ ਅਤੇ ਸੁੱਕੇ ਮਾਦੇ ਲਈ ਸੀ ਐਫ ਆਰ 2211–2 ਨੂੰ ਵਧੀਆ ਪਾਇਆ ਗਿਆ। ਫ਼ਲ ਦੇ ਗੁੱਦੇ ਦੀ ਮੋਟਾਈ ਅਤੇ ਪ੍ਰਤੀ ਵੇਲ ਫ਼ਲ ਦੇ ਝਾੜ ਲਈ ਐਮ ਬੀ ਐਨ 6242–3–1 ਵਧੀਆ ਸੀ। ਅਗੇਤੇ ਨਰ ਫੁੱਲਾਂ ਅਤੇ ਵਿਟਾਮਿਨ–ਸੀ ਲਈ ਐਮ ਵੀ ਐਸ ਆਰ 6711–14–2 ਦਾ ਵਧੀਆ ਸੁਮੇਲ ਸੀ। ਪ੍ਰਤੀ ਵੇਲ ਫ਼ਲਾਂ ਦੀ ਔਸਤ ਗਿਣਤੀ ਅਤੇ ਕੁੱਲ ਕੈਰੋਟੀਨ ਲਈ ਬੀ ਐਨ–364 ਦਾ ਵਧੀਆ ਸੁਮੇਲ ਸੀ। ਸਭ ਤੋਂ ਵਧੀਆ ਝਾੜੀਦਾਰ ਅਤੇ ਬਟਰ ਨੱਟ ਕ੍ਰਾਸਾਂ ਵਿੱਚੋਂ, ਜ਼ਿਆਦਾ ਮੁੱਢਲੀਆਂ ਟਹਿਣੀਆਂ, ਗੰਢਾਂ ਵਿਚਲੀ ਲੰਬਾਈ, ਅਗੇਤੇ ਫੁੱਲ ਅਤੇ ਫ਼ਲ, ਫ਼ਲ ਆਕਾਰ ਇੰਡੈਕਸ, ਪ੍ਰਤੀ ਵੇਲ ਝਾੜ, ਟੀ ਐਸ ਐਸ, ਸੁੱਕਾ ਮਾਦਾ ਅਤੇ ਵਿਟਾਮਿਨ ਸੀ ਲਈ ਅਡੀਟਿਵ ਅਤੇ ਨਾਨ–ਅਡੀਟਿਵ ਜੀਨ ਪ੍ਰਭਾਵ ਪਾਏ ਗਏ, ਜਿਸ ਕਰਕੇ ਹਾਈਬ੍ਰਿਡ ਸਮਰੱਥਾ ਅਤੇ ਰੈਕਰੈਂਟ ਸਿਲੈਕਸ਼ਨ ਰਾਹੀਂ ਸੰਸ਼ੋਧਨ ਕੀਤਾ ਜਾ ਸਕਦਾ ਹੈ। ਫ਼ਲ ਦੀ ਡੰਡੀ, ਪੋਲਰ ਵਿਆਸ, ਗੁੱਦੇ ਦੀ ਮੋਟਾਈ, ਕੁੱਲ ਕੈਰੋਟੀਨ ਅਤੇ ਕੁੱਲ ਮਿਠਾਸ ਲਈ ਅਡੀਟਿਵ ਅਤੇ ਅਡੀਟਿਵ × ਅਡੀਟਿਵ ਜੈਨਿਟਿਕ ਪ੍ਰਭਾਵ ਵੱਧ ਸੀ, ਜਿਸ ਕਰਕੇ ਹਾਈਬ੍ਰਿਡਾਜੇਸ਼ਨ ਅਤੇ ਪੈਡੀਗਰੀ ਸਲੈਕਸ਼ਨ ਮੁਤਾਬਿਕ ਸੰਸ਼ੋਧਨ ਕੀਤਾ ਜਾ ਸਕਦਾ ਹੈ। ਪਰੰਤੂ, ਝਾੜੀਦਾਰ ਵੇਲਾਂ, ਮੱਧ ਵਿਆਸ, ਪ੍ਰਤੀ ਵੇਲ ਫ਼ਲਾਂ ਦੀ ਗਿਣਤੀ ਅਤੇ ਔਸਤ ਫ਼ਲ ਭਾਰ ਲਈ ਨਾਨ–ਅਡੀਟਿਵ ਜੀਨ ਪ੍ਰਭਾਵ ਜ਼ਿਆਦਾ ਹੋਣ ਕਰਕੇ ਹੈਟਰਾਸਿਸ ਬ੍ਰੀਡਿੰਗ ਦੀ ਵਰਤੋਂ ਕੀਤੀ ਜਾ ਸਕਦੀ ਹੈ। ਪੀ ਪੀ ਐਚ–1 ਅਤੇ ਪੀ ਪੀ ਐਚ–2 ਤੋਂ ਉੱਪਰ ਮਹੱਤਵਪੂਰਨ ਹਾਈਬ੍ਰਿਡ ਸਮਰੱਥਾ ਦੇ ਆਧਾਰ ਤੇ ਝਾੜੀਦਾਰ ਅਤੇ ਬਟਰਨੱਟ ਕ੍ਰਾਸਾਂ ਵਿੱਚੋਂ ਐਮ ਬੀ ਐਨ 6242–3–1 × ਸੀ ਐਫ ਆਰ 2211–2 ਪ੍ਰਤੀ ਵੇਲ ਝਾੜ ਲਈ ਵਧੀਆ ਪਾਇਆ ਗਿਆ ਅਤੇ ਬੀ ਯੂ ਐਮ ਓ ਵੀ 41212–3–1 × ਬੀ ਐਨ–364, ਪੀ ਐਸ × ਬੀ ਐਨ–364, ਬੀ ਯੂ ਐਮ ਓ ਵੀ 41212–3–1 × ਐਮ ਐਸ ਬੀ ਐਨ 3621–9–3–1, ਐਮ ਐਸ ਬੀ ਐਨ 3621–9–3–1 × ਐਮ ਬੀ ਐਨ 6242–3–1 ਘੱਟ ਫ਼ਲ ਭਾਰ ਅਤੇ ਜ਼ਿਆਦਾ ਪ੍ਰਤੀ ਵੇਲ ਫ਼ਲ ਲਈ ਵਧੀਆ ਪਾਏ ਗਏ। ਝਾੜੀਦਾਰ ਅਤੇ ਬਟਰਨੱਟ ਕਰਾਸਾਂ ਵਿੱਚੋਂ *ਪਰ ਸੀ* ਕ੍ਰਿਤੀ ਦੇ ਆਧਾਰ ਤੇ ਐਮ ਐਸ ਬੀ ਐਨ 3621–9–3–1 × ਐਮ ਬੀ ਐਨ 6242–3–1, ਐਮ ਐਸ ਬੀ ਐਨ 3621–9–3–1 × ਸੀ ਐਫ ਆਰ 2211–2, ਬੀ ਐਨ–364 × ਐਮ ਐਸ ਬੀ ਐਨ 3621–9–3–1, ਐਮ ਵੀ ਐਸ ਆਰ 6711–14–2 × ਐਮ ਐਸ ਬੀ ਐਨ 3621–9–3–1 ਅਗੇਤੇ ਪੱਕਣ ਵਾਲੇ, ਬਟਰਨੱਟ ਫ਼ਲ ਵਾਲੇ ਅਤੇ ਵੱਧ ਝਾੜ ਵਾਲੇ ਹਾਈਬ੍ਰਿਡ ਪਾਏ ਗਏ। ਗੁਣਾਂ ਦੀ ਸਾਂਝ ਵਿੱਚ, ਵੇਲ ਦੀ ਲੰਬਾਈ ਦੀ ਗੰਢਾਂ ਵਿੱਚਲੀ ਲੰਬਾਈ ਅਤੇ ਅਗੇਤੀ ਮਾਦਾ ਫੁੱਲ ਗੰਢ ਨਾਲ ਵਧੀਆ ਸਾਂਝ ਪਾਈ ਗਈ। ਪ੍ਰਤੀ ਵੇਲ ਝਾੜ ਦੀ ਵੀ ਔਸਤ ਫ਼ਲ ਭਾਰ, ਅਗੇਤੀ ਫ਼ਲ ਗੰਢ ਅਤੇ ਵੇਲ ਦੀ ਲੰਬਾਈ ਨਾਲ ਵਧੀਆ ਸਾਂਝ ਪਾਈ ਗਈ, ਜਦਕਿ ਔਸਤ ਫ਼ਲ ਭਾਰ ਤੇ ਮਿਆਰ ਵਿਸ਼ੇਸ਼ਤਾਵਾਂ ਜਿਵੇਂ ਕਿ ਕੁੱਲ ਮਿਠਾਸ ਅਤੇ ਵਿਟਾਮਿਨ–ਸੀ ਦਾ ਪ੍ਰਭਾਵ ਪਾਇਆ ਗਿਆ।

ਮੁੱਖ ਸ਼ਬਦ: ਝਾੜੀਦਾਰ ਪੇਠਾ, ਬਟਰਨੱਟ ਫ਼ਲ, ਸੰਯੋਗ ਸਮਰੱਥਾ, ਹਾਈਬ੍ਰਿਡ ਸਮਰੱਥਾ, ਕੋਰੀਲੇਸ਼ਨ

ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿੱਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER-I

INTRODUCTION

Pumpkin (*Cucurbita moschata* Duch ex Poir. 2n = 2x = 40) is economically important and summer hardy vegetable with very good storage life among 27 species of genus *Cucurbita* in *Cucurbitacea* family. Among these species, *Cucurbita moschata*, *Cucurbita maxima, Cucurbita ficifolia, Cucurbita pepo and Cucurbita mixta* are commonly cultivated. These species are considered to be originated in Central America (Maynard *et al* 2001) and dispersed to other continents by trans-oceanic voyagers in 16^{th} century, which later became a familiar and important vegetable crop in tropical and sub-tropical regions of India, Russia, Ukraine, Mexico, U.S.A and China (Gray and Trumbull 1983). In India, pumpkin locally known as '*Halwa kaddu'*, '*Sita Phal'* '*Misti kumra'* or '*Misti lau*'or '*Misti kadu*, is grown on 50 thousand hectares with the 1141 thousand MT production and 22.80 MT/ha productivity. Bihar, Chhattisgarh, Jharkhand, Karnataka, Punjab, Rajasthan, U.P. and Tamil Nadu are major pumpkin producing states. In Punjab, pumpkins are cultivated on 0.11 thousand ha with 1.61 thousand MT production and 14.64 MT/ ha productivity (Anonymous 2016).

Pumpkins have been used in traditional medicine in China, Argentina, India, Mexico, Brazil, and Korea. Every plant part has health promoting and medicinal value. Its pulp and seeds are rich source of proteins, antioxidant vitamins and minerals (iron, calcium and zinc), but also low in fat and calories (Smith and Eyzaguirre 2007). The edible portion of fruit (100g) is furnished with 90 ml water, 8 g carbohydrate, 1g protein, 0.5 g fibers, 20 mg calcium, 0.8 mg iron, 210 mg β-carotene, 0.05 mg thiamine, 0.05 mg riboflavin,0.5 mg niacin and 15 mg ascorbic acid (Tindall 1987). Polyunsaturated fatty acids and phytosterols in pumpkin seeds can prevent chronic diseases, while leaves being haematinic, analgesic are used for burn treatment. Its pulp relieves from intestinal inflammation or enteritis, dyspepsia, benign prostate hyperplasia, stomach disorder and reduces blood cholesterol and peel damage from the sun (Facciola 1990, Seutu and Debjani 2007, Aruah *et al* 2012).

Pumpkin excels other cucurbits due to its better storage potential and transport qualities. Generally, its full ripe fruits can be stored for 3-4 months under ordinary temperature and relative humidity conditions (Yawalkar 1985, Rahman *et al* 2013). Therefore, it can meet the demand of vegetables supply during lean season. The storability of fruits is affected with the high temperature and low humidity, particularly during summer season. Consequently, quality is affected due to change in physico-chemical traits, but variability in storage traits like dry matter content, reducing sugar etc existed among different genotypes (Maiti *et al* 2006).

Pumpkin vines grow up to 2.5-3.0 meters and occupy large space during cultivation. To accommodate more number of plants per unit area dwarf nature of plant is desirable. In pumpkin, this trait is controlled by a dominant gene and reported to have tight linkage to some markers also (Cao *et al* 2005, Li *et al* 2007, Wu *et al* 2007). Bushy trait in *C. maxima*is controlled by two recessive genes and found orthologous to the dwarf genes in *C. pepo* (Denna and Munger, 1963).

The fruit size another important trait for consumer acceptability, varies from 2.0 kg to 20.0 kg (Maynard *et al* 2002). In India, majority genotypes are large fruited and vegetable venders sell fruits after cutting, which is unhygienic practice. Moreover, the bigger fruits are difficult to handle in marketing chain. Therefore, small sized fruits are required to counter this problem. The available pumpkins in the market have larger fruit cavity and lesser pulp; as a result consumer portion is reduced. Butternut segment of pumpkin is available in American and European continent, which have small seed cavity, greater pulp thickness and less number of seeds

Hence, pumpkins have lot of variability in vegetative, flowering, yield and storage characteristics (Pandey *et al* 2002 & 2003, Murkovic *et al* 2000). The improvement of bushy and butternut trait through breeding depends upon the availability of inbreds having short vine, early maturity and more pulp thickness as well as high yield. The assessment of general combining ability (GCA) and specific combining ability (SCA) not only provides certain cross combinations with relatively better or worse performance than their expected average, but also unveils the genetic behavior of different traits due to additive and non-additive genetic variances, respectively. For outlining the improvement method of any crop, the involvement of type of genetic variances for different yield and quality characters becomes a prerequisite.

The monoecious nature of flower and availability of more number of seed per fruit made the hybrid seed production economical. Therefore, bushy plants and butter nut fruits type can be exploited through heterosis breeding. There are many reports showing high heterosis to the extent of 97.52-181.5% for yield, 70% for number of female flowers, 68.7% for fruit weight, 150% for number of fruits, 48.47% for pulp thickness and 113.28% for total carotenoids (Pandey *et al* 2003, Bairagi *et al* 2005, Pandey *et al* 2010, Mohanty and Mishra 1999, Pandey *et al* 2002).

Although, a lot of studies are available on genetic variability, combining ability and heterosis breeding of pumpkin, but relatively less attention has been paid towards the improvement of existing germplasm for economical fruit weight with thick pulp for consumer's preference and bushy growth habit for intensive cultivation. The Department of Vegetable Science, Punjab Agricultural University has developed bushy and butternut (BN) genotypes with early flowering and fruit setting nature. The involvement of such genotypes in breeding programme provides scope for initiating the improvement for economical fruit size with more pulp thickness along with suitability for intensive cultivation in pumpkin.

In view of the above said issues, the present investigation entitled ‘Heterosis and combining ability studies on yield, quality and storage traits involving bush and butternut type genotypes in pumpkin (*Cucurbita moshata* Duch. ex Poir.)’has been planned with following objectives:

1. To study the general combining ability and specific combining ability effects for growth, earliness, yield and quality traits.
2. To assess gene action governing various traits.
3. To estimate the extent of heterosis in F_1 hybrid.

CHAPTER- II

REVIEW OF LITERATURE

Pumpkin is a highly cross pollinated vegetable crop due to the occurrence of monoecious flowers. For its improvement through various breeding principles and programmes, the availability of genetic variation is of foremost importance. Furthermore, it depends upon the heritability of different vegetative, flower, fruit and quality characters. Pumpkins has lot of variability in yield, quality and contributing characters (Pandey *et al* 2002 & 2003, Murkovic *et al* 2000). Heterosis can be easily exploited in cross pollinated vegetables that necessitate the development of stable inbred lines. These inbred lines are evaluated for their specific as well as general combining ability before their exploitaion in heterosis breeding or hybridization followed by different methods of population improvement in pumpkin. Some of available research work relevant to the present study has been reviewed in this chapter under following headings:

2.1 Genetic variation

2.2 Combining ability

2.3 Heterosis

2.4 Correlation analysis

2.1 Genetic variability

Pumpkin is a highly cross pollinated crop. Huge genetic variability is observed for number of branches per plant, vine length, number of female flowers/plant, number of male flowers/plant, single fruit weight, number of fruits per vine and fruit yield/plant. Among pumpkin genotypes, high genotypic coefficient of variability (GCV) suggested the involvement of highly diverse genotypes in pumpkin. High GCV for male flowers per plant, female flowers per plant, days taken to maturity, mean fruit weight, number of fruits per vine, number of seeds per fruit, yield per plant, TSS and total carotenoids content suggests greater scope of selection for their improvement, while low GCV for days to first female flower opening indicates the greater influence of environment in its expression (Mangal *et al* 1979, Gopalakrishanan *et al* 1980, Kumaran *et al* 1997, Mohanty 2000). Vine length, number of leaves per plant and fruit size index are however less influenced by the environment because of higher phenotypic and genotypic variability (Borthakur and Shadeque1990). In contrast, Rana *et al* (1986) suggested greater scope of selection for days to first female flower due to the presence of high genetic variability. However, high level of environmental influence was observed in the expression of number of branches per plant and internodal length in pumpkin (Fayeun *et al* 2012). All the characters showed high heritability along with high genetic advance in percent of mean except days to first male flowering and days to first female flowering **(**Kumar *et al* 2011, Cyril *et al* 2014, Sultana *et al* 2015). The characters exhibiting high GCV and PCV values have greater scope for further improvement by genetic manipulation (Naik and Prasad 2016).

In bottle gourd also, there was a great deal of significant variation for all the characters among the genotypes. High genotypic co-efficient of variation (GCV) was observed for fruit weight (39.48%). Phenotypic co-efficient of variances of all traits were found to be higher than the genotypic co-efficient of variances. High heritability with high genetic advance in percent of mean for all characters suggested additive gene control. The selection would be effective for genetic improvement of this trait (Sharma and Sengupta 2013).

High genotypic coefficient of variation for fruit yield, number of fruits per vine, fruit length, stem length and pulp thickness was found in 24 genotypes of snake gourd (Rahman *et al* 2002). In bitter gourd hybrids, high genotypic (GCV) and phenotypic coefficient of variation (PCV) were reported for number of fruits per vine, fruit weight and fruit length, whereas low GCV and PCV were determined for days to first male and female flower anthesis (Pathak *et al* 2014).

Among 58 long type accessions of cucumber (Faruk Hossain *et al* 2010), the highest GCV was recorded in yield per plant (42.75%) followed by number of fruits per vine (33.41%), fruit length (27.57%), number of lateral shoots (24.19%), average fruit weight (22.14%), petiole length (16.10%) and node order at which male and female flower opened (13.28% and 12.62%). However, high variability for number of branches per vine, average fruit weight, total number of fruits per vine and total fruit yield per vine was also observed in F_2 generation. Moderate PCV and GCV were observed for total number of fruits per vine, fruit diameter and total fruit yield per vine. Higher variability coupled with moderate to low genetic gain was noticed for vine length, number of branches per vine, days to first fruit harvest, fruit length, fruit diameter, average fruit weight and total fruit yield per vine. Furthermore, moderate heritability and genetic gain was recorded for fruit length (Arunkumar *et al* 2011).

High genotypic coefficient of variation suggested the highest variability for fruits per plant and fruit yield per vine among 25 pointed gourd genotypes. High heritability coupled with high genetic advance indicated the effectiveness of selection for these characters (Malek *et al* 2007), Jahan *et al* (2012) also estimated the heterotic effects and genetic components of variation for qualitative and quantitative characters in sweet gourd and on the basis of high phenotypic coefficients of variation, indicated considerable role of environment in the expression of these characters.

2.2 Combining ability

The general combining ability (GCA) highlights the average performance of an inbred involved in different hybrid combinations, while specific combining ability (SCA) provides certain cross combinations with relatively better or worse performance than their expected average.

The general combining ability variance unveils the additive and additive x additive type of interactions, while the specific combining ability variance discloses non-additive genetic variance. For improvement of any crop, the involvement of type of genetic variances for different yield and quality characters becomes a prerequisite. Highly significant general (GCA) and specific combining ability (SCA) variances suggested the involvement of both additive and non-additive gene effects in the expression of many pumpkin traits (Hussien and Hamed 2015, EL-Tahawey 2015). The ratios of GCA/SCA higher than unity recommended importance of additive and additive × additive type of gene action for main stem length, number of branches/plant, number of nodes to first female flowers, average length, diameter and weight of fruit, average pulp thickness, number of fruits/plant, and total yield per plant in pumpkin (Hussien and Hamed 2015). However, Tamil selvi *et al* (2015) reported higher variance due to *SCA* than the *GCA* and indicated the predominance of non-additive gene effects for yield and its component characters in pumpkin ***(****Cucurbita moschata* Duch.ex Poir). For quality contributing traits in pumpkin, predominance of additive-additive gene action was reported for most of the characters but hollowness and dry matter content governed predominantly by additive-dominance gene action, pulp thickness and brix percentage were found to have predominantly dominant-dominant gene action (Shohel Rana *et al* 2015). The less than one ratio of σ^2 GCA to σ^2 SCA for days from sowing to first pistillate flower in summer squash indicated the importance of non-additive gene action for this characters (Ahmed *et al* 2003). In luffa also, additive gene effects were more important for vine length, days to opening of the first male flower, number of male and female flowers/plant, number of nodes, number of fruit/plant, fruit length, fruit diameter, and number of seed/fruit (Tyagi *et al* 2010). Higher specific combining ability (SCA) variances than the general combining ability (GCA) variances also revealed the predominance of non-additive gene action for all traits in bottle gourd (Janaranjani *et al* 2016).

In pumpkin, Vadhalagundu local, Kasi Harit, CO 2 and Arka suryamukhi with significant GCA were found as best combiners for the traits associated with earliness, yield and nutritional quality. Among hybrids, Kasi Harit x Avinashi local followed by Vadhalagundu local x CO 2 were identified as good specific combiner for traits associated with earliness, yield and fruit quality (Tamil Selvi *et al* 2015). while the parents IB 23, IB 40 and IB 57 were found good general combiner for dry matter content, fruit length and non-reducing sugar and the hybrids IB 40 X IB 50 was good for hollowness and β-carotene; IB 40 X IB 47 for pulp thickness; IB 40 X IB 57 for brix (%) and IB 23 X IB 57 for reducing sugar (Shohel Rana *et al* 2015). From the estimates of GCA, El-Tahawey (2015) reported none of the parents as good general combiner for the characters consistently, but Indian line was the best combiner for vine length, number of fruits/plant and seed oil content; Red Kuri for flowering earliness and both Indian line and A15 for pulp thickness, average fruit weight and total yield/plant. The cross combination Indian line x A15 showed the highest positive estimated SCA values for number of fruits/ plant, total yield/ plant.

Among parental lines in Luffa, 'Slumber Long' hybrid was the best combiner for fruit yield/plant and fruit size (Tyagi *et al* 2010). 'Pusa Naveen × NDBG-164', 'Pusa Naveen × Punjab Komal', and 'NDBG-121 × Samrat' were promising F1 hybrids in bottle gourd (Janaranjani *et al* 2016).

2.3 Heterosis

In pumpkin**,** F_1 crosses, S93 x CM-12, Pusa Vishwas x S.122 and Pusa Vishwas x CM-12 were found to be performing hybrid for total yield with 80.45, 44.64 and 40.04 per cent higher yield than the best parents, respectively and the high yield in F_1 hybrid attributed to higher fruit weight, number of fruits per vine and longer vine length (Sirohi *et al* 1985 and Sirohi 1994). Mohanty and Mishra (1998, 1999) reported -28.9 to 6.5, -23.7 to 11.4, -46.7 to 12.7, -43.2 to 7.1, 0.6 to 64.0 and 0.0 to 70.0 per cent heterobeltiosis over better parent for days to first male flower, days to first female flower, node of first male flower, node of first female flower, number of male flowers per plant and number of female flowers per plant, respectively. The crosses involving high GCA x high GCA and high GCA x low GCA cross with diverse parents showed higher heterosis and the hybrids Ambili x Pusa Vishwas, Ambili x BBS-10, Baidyabati x Pusa Vishwas, Baidybati x BBS-8, Ambili x Cuttack Local and Guamal Local x Ambili were best for developing early varieties with higher number of female flowers and Ambili x BBS-10 was best performing hybrid for highest yield per plant. S-107B x S-12, S-107B x S-17, and S-124-10 x S-15 revealed the maximum and significantly desirable heterosis for short vine (-14.09%), early fruit maturity (-6.52%) and fruit pulp thickness (21.5%) respectively (Sirohi *et al 2002)*. Mahajan and Sirohi (2002) found S-12 x S-20, S-20 x S-17, S-124–10 x S-15and Pusa Vishwas x S-15 as best performing hybrids with 30.2, 17.5, 13.5 and 10.9% commercial heterosis for days to 1^{st} female flower, number of fruits per vine, average fruit weight and days to 1^{st} fruit picking, respectively.

Nisha and Veeraragavathatham (2014) found crosses $P_3 \times P_1$, $P_3 \times P_2$, $P_4 \times P_3$ and $P_5 \times P_3$ as promising combinations for earliness and other desirable characters including yield per plant. The maximum significant true heterosis in desirable direction for total yield (71.8%) followed by number of branches (67%), average fruit weight (41.9%), NF (40.5%), MSL (39.5%), NNF (29.1%), average fruit length (28.7%) and average fruit diameter (12.4%) (Hussein and Hamed 2015) Most F_1's were positively heterobeltiotic for number of seeds/fruit and seed oil content, while had negative heterobeltiosis for weight of seeds/fruit, weight of 100 seeds and seed yield/plant. But for total yield, Large blue Hubbard x A15 and Indian line x A15 were highly heterotic (77.6% and 54%) over the mid and better parent, respectively. The hybrids in pumpkin showed heterosis percentages in range from -56.1 to 77.6% and from -66.8 to 54% over the mid and better parent, respectively (EL-Tahawey *et al* 2015). Estimates of standard heterosis for fruit yield, earliness, quality and component traits in pumpkin unveiled the potential of 'Kasi Harit' × 'Avinashi Local' and 'Vadhalagundu Local' × 'CO 2' for exploitation of heterosis (Tamil Selvi and Jansirani 2016).

Davoodi *et al* (2016) crossed *C. pepo* and *C. moschata* and examined standard heterosis in vegetative, fruit yield, yield components, and qualitative characteristics in hybrids. The highest standard heterosis over *C. moschata* variety (MO6) was from the MO11 × P25 hybrid, over standard *C. pepo* variety (P1) was from the P1 × MO9 hybrid and over the standard C. pepo variety in this type (P25) was from the P5 × MO3 hybrid. Specific crosses between *C. pepo* and *C. moschata* and some interspecific hybrids have superior yield and qualitative traits.

On the basis of study maximum standard heterosis in ridge gourd, Narasannavar *et al* (2014) observed best hybrids: KRG-7 x ASM for vine length (9.20%), KRG-11 x PN (141.38%) for number of branches, KRG-9 x ASJ (-56.92%) and KRG-2 x ASM (-19.35%) for node to first female flower, KRG-17 x PN (-40.34%) for sex ratio, KRG-10 x PN (13.95%) for number of fruits per vine, KRG-6 x ASJ (36.34%) for average fruit weight, KRG-1 x ASJ (36.91%) for fruit length, KRG-12 x PN (55.09%, 70.27%, respectively) for fruit diameter and pulp thickness, KRG-3 x ASM (26.53%, 26.46%) for fruit yield per plot and fruit yield per hectare. For total yield per vine, KRG-3 × ASJ (23.61%) followed by KRG-3 × PN (13.80%), KRG-10 × PN (12.45%) and KRG-11 × PN (6.00%) exhibited the highest standard heterosis.

In bitter gourd, the heterosis for yield per vine ranged from 27.3 to 86.1% over better parent (Behera 2008). Among 90 bitter gourd hybrids, 'Preethi'×'MC-30', 'KR'×'USL', 'MC-105'×'MC-10', and 'Priyanka'×'CO-1' were the best performers with respect to yield and quality (Thangamani and Pugalendhi 2013). Al-mamun *et al* (2016) classified 16 hybrids as heaviest, smallest, longest and shortest types on the basis of fruit characteristics in bitter gourd and reported highest yields in P3 × P5 followed by hybrids P4 × P1 and P4 × P3. Hybrids P5 × P4, P3 × P5, and P2 × P5 had 102%, 82.6%, and 82.4% higher heterobeltiosis for fruit yield/plant, respectively.

In cucumber, Hanchinamani and Patil (2009) noticed maximum positive heterosis for yield over mid (94.03) and better (31.73) parents in the hybrids L4 x T1 and L4 x T2, respectively. Increase in average weight of fruit and total number of fruits per vine were mainly responsible for this increase. Airina *et al* (2013) found significant heterosis for all the characters studied except average fruit weight. The hybrids EC 709119 x IC 538155 followed by EC 709119 x IC 527427, EC 709119 x IC 538186 and EC 709119 x IC 410617 exhibited high heterobeltiosis for fruit yield and fruits per plant in cucumber.

In sweet gourd, OP 10 × OP 20, OP 20 × OP 02, OP 10 × OP 02 and OP 04 × OP 02 exhibited significant ($p<0.05$) positive heterosis for majority of the characters studied and identified as promising for commercial cultivation (Jahan *et al* 2012).

2.4 Correlation analysis

Path co-efficient analysis revealed out the direct and indirect contribution of various vegetative, fruit, quality characters towards the maximum yield of that particular crop. The inter-relationship between different characters helps in making simultaneous selection for different economic characters. In cucurbits, vine length, number of fruits per vine and average fruit weight were considered as important traits for selection at phenotypic as well as genotypic levels in pumpkin, cucumber, bottle gourd, bitter gourd, sanke gourd, muskmelon, ash gourd (Cyril *et al* 2014, Arunkumar *et al* 2011, Janaranjani and Kanthaswamy 2015, Pathak *et al* 2014, Rahman et al 2002, Potekar *et al* 2014, Resmi and Sreelathakumary 2012).

On basis of correlation analysis in pumpkin, fruit yield per vine was significantly and positively correlated with fruit number per vine, pulp thickness and total carotenoids content and negatively associated with days taken for earliest anthesis, node number for earliest female anthesis, sex ratio, days to first harvest, fruit weight, equatorial diameter, polar diameter and crude fibre content. Therefore, selection of pumpkin genotypes with narrow sex ratio, more number of fruits per vine, fruits with high pulp thickness and total carotenoids content was found helpful in improving yield per vine and quality of pumpkin fruits (Gopalakrishinan *et al* 1980, Tamil selvi *et al* 2012). Days to first female flower is reported to have strong negative correlation with yield per plant, while number of female flowers per plant found to have highly significant positive correlation with number of fruits per vine and yield per plant. Days to female flowering showed highly significant negative correlation with vine length, number of primary branches per plant, internodal length, number of female flowers per plant and number of fruits per vine. Vine length showed positive association with inter nodal length, number of leaves per plant, number of female flowers per plant, fruit weight and fruit size index (Borthakur and Shadeque 1994). Therefore, the selection directed towards leaf length, leaf width, petiole length, vine length, number of fruits per vine, fruit length and fruit width was effective in improving vegetative and seed yield (Cyril *et al* 2014). Sultana *et al* (2015) reported significant and negative association of days to first male flowering (rg = -0.623, rp = -0.550) and days to first female flowering (rg= -0.689, rp= -0.543) with fruit yield per vine. The highest and high positive direct effects to fruit yield were revealed from number of female flowers (0.887) and days to first female flowering (0.798). Similarly fruit breadth (0.899) has the highest positive indirect effect and fruit length (0.381) and single fruit weight (0.398) also have significant positive correlation with fruit yield/plant. Overall, the days to first female flowering, number of female flowers, fruit length, fruit breadth and single fruit weight can be useful parameters for selection criteria to increase fruit yield/plant in pumpkin. Further, Sultana *et al* (2015) it was found that positive and strong association of number of female flowers/plant (rg=0.918, rp=0.839), number of male flowers/plant (rg=0.687, rp=0.638), fruit length (rg=0.691, rp= 0.520), fruit breadth (rg=0.518, rp=0.420) and single fruit weight (rg=0.492, rp= 0.431) with fruit yield/plant and revealed the importance of these characters in determining fruit yield/plant**.**

Correlation and path analysis in cucumber by Faruk Hossain *et al* (2010) and Arunkumar *et al* (2011) revealed that correlation coefficient for fruit yield was positively correlated with total number of fruits per vine, average fruit weight, fruit length, fruit diameter, number of branches per vine and vine length. While it was significant and negatively correlated with days to first male flower, days to first female flower and days to first fruit harvest. Path analysis revealed maximum positive direct effect of total number of fruits per vine, number of branches per vine and vine length on yield, whereas, negative and maximum direct effect of days to first female flower, fruit diameter, days to first fruit harvest and fruit length.

In muskmelon, fruit weight is positively and significantly correlated, but characters like vine length, internodal length, days for first female flower opening, number of fruits per vine, length of fruit, diameter of fruit and TSS, exhibited positive but non-significant correlation with yield per vine, while, Node to first female flower and days for first fruit harvest showed negative and non-significant correlation with yield per vine. On the basis of path coefficient analysis, internodal length, number of fruits per vine, diameter of fruit and fruit weight showed high positive direct effects on yield of muskmelon (Potekar *et al* 2014).

In bottle gourd also, it is reported that number of fruit per vine, number of fruit picking and fruit pulp thickness, number of primary branches per vine, total vine length (m), internodal length (cm), fruit weight (g), and fruit diameter (cm) was significantly and positively correlated with yield. On the basis of path analysis, total vine length (m), number of fruit per vine, days to first male flower and first female flower anthesis, fruit cavity size, fruit weight, days to first fruit harvest, and total soluble solids (TSS) exerted positive and direct effects on yield (Janaranjani and Kanthaswamy 2015, Janaranjani *et al* 2016, Deepthi *et al* 2015).

In ash gourd, fruit length, fruit girth, average fruit weight, had positive and significant correlation with yield and fruit length, average fruit weight and fruits per plant and considered as the most reliable selection indices for effective improvement in fruit yield (Resmi and Sreelathakumary 2012). In snake gourd, Rahman *et al* (2002) reported that fruit yield had significant positive correlation with number of fruits per vine, fruit length and stem length. The highest direct effect was recorded for number of fruits per vine. On the basis of correlation analysis for horticultural characters in bitter gourd hybrids, number of fruits per vine showed significant positive correlation for yield. Furthermore, it was found to be directly correlated with fruit weight, number of fruits per vine and fruit length, hence selection based on these characters would be more rewarding (Pathak *et al* 2014).

CHAPTER – III

MATERIALS AND METHODS

The investigation entitled "Heterosis and combining ability studies on yield, quality and storage traits involving bush and butternut type genotypes in pumpkin (*Cucurbita moshata* Duch. ex Poir.)" was carried out at research farm of the Department of Vegetable Science, Punjab Agricultural University, Ludhiana (30 º 54' North, 75 º 48' East and 247 m above sea level) during the spring-summer season of year 2014-15 and 2015-16.

Experimental material

The experimental material consisted of bush and butternut type as well as vine and round fruited inbred lines maintained in the Department (Table 3.1). All possible crosses were made among inbreds by following diallel mating with exclusion of reciprocals [n (n-1/2)] during summer season of 2015. The parents were also maintained by selfing, simultaneously.

Table 3.1: Decription of parents on basis of growth habit and fruit shape

Parents	Growth habit	Fruit shape	Source
Punjab Samrat	Vine	Flat round	PAU, Ludhiana
BUMOV 41212-3-1	Vine	Oval	PAU, Ludhiana
BN-364	Bush	Butternut	PAU, Ludhiana
P-1343-17-5-3	Semi Vine	Flat round	PAU, Ludhiana
MVSR 6711-14-2	Bush	Flat round	PAU, Ludhiana
MSBN 3621-9-3-1	Bush	Butternut	PAU, Ludhiana
B-10-224-3	Vine	Flat round	PAU, Ludhiana
MBN 6242-3-1	Vine	Butternut	PAU, Ludhiana
CFR 2211-2	Bush	Flat round	PAU, Ludhiana

Methodology

Seeds of all inbred lines were sown on 5th February during 2015 and 16th February during 2016 in plug-trays. Trays were protected from low temperature for the better emergence of seedlings. The seedlings at two to three true leaf stage were hardened in open. Ten plants of each parent were transplanted in middle of March 2015 and possible crosses as per diallel crossing system excluding reciprocals were made. Next season, 36 hybrids, 9 parents and two checks (PPH-1 and PPH-2) were transplanted in Randomized Block Design (RBD) suggested by Snedecor and Cochran (1967) with three replications. Bush type parents and cross including these parents were transplanted on both sides of 1.5 m beds, while parents and crosses involving vine parents were raised at 3 m row distance. A uniform distance of 45 cm was maintained between the plants in single row. The crop was raised as per PAU Package of Practices for the pumpkin (Anonymous 2016). The parents and their crosses were evaluated for

Field view of pumpkin trial

Narrow planting of bushy hybrid

heterosis and combining ability during summer season of 2016. The fruits were harvested at ripe maturity as single harvest at the end.

3.1 Observations recorded

The following observations were recorded on five randomly selected plants in each replication:

3.1.1 Vine length (cm): It was measured at the end of season and averaged for each replication.

3.1.2 Internodal length (cm): It was recorded as average of five internodal lengths from the base of a mature plant and averaged.

3.1.3 Leaf length (cm): The distance between tip and pedicel end of leaf was measured from from five randomly selected middle leaves on full grown vines and averaged.

3.1.4 Leaf width (cm): The widest end of five randomly selected middle leaves of full grown vines was measured and averaged.

3.1.5 Petiole length (cm): It was measured from base of leaf to the point where it is attached to vine from five randomly selected middle leaves of full grown vines and averaged.

3.1.6 Number of primary branches: Primary branches arose from the main stem were noted at the end of season on five vines and for each replication.

3.1.7 Earliest node to female flower: The specific node of first appearance of pistilate flower on 50% of the plants was recorded and averaged for each replication.

3.1.8 Days to 50% female flowering: The number of days from transplanting to the appearance of pistilate flowers on 50% plants was recorded and averaged for each replication.

3.1.9 Earliest node to male flower: The specific node of first appearance of staminate flower on 50% plants was recorded and averaged for each replication.

3.1.10 Days to 50% male flowering: The number of days from transplanting to the appearance of staminate flowers on 50% plants was recorded and averaged for each replication.

3.1.11 Node to first fruit: It was recorded as the average of lower most node of fruit bearing on five plants.

3.1.12 Days to fruit maturity: It was recorded as number of days from date of transplanting to the first harvest of the fruit.

3.1.13 Peduncle length (cm): It was measured from base of fruit to the point where it is attached to vine from five randomly selected fruits at marketable stage and averaged for each replication.

3.1.14 **Polar diameter (cm):** The distance between blossom and stem end of five randomly selected mature fruits was measured and averaged for each replication.

3.1.15 **Equatorial diameter (cm):** The horizontal distance between two distal ends at the widest middle of five fruits was measured and averaged for each replication.

3.1.16 **Fruit shape index:** The ratio of polar to equatorial diameter of five fruits was calculated and averaged.

3.1.17 **Fruit peel colour:** It was recorded as pale, green, dark green, light green, mottled or striped colour at marketable stage of the fruit.

3.1.18 **Fruit peel hardiness:** It was recorded manually as soft, intermediate or hard peel hardiness at mature stage of the fruit.

3.1.19 **Pulp colour:** It was recorded as green, yellow or orange pulp colour at mature stage of the fruit.

3.1.20 **Pulp thickness (cm):** It was measured with the help of scale from five longitudinally cut fruits and averaged for replication.

3.1.21 **Number of fruits per vine:** It was recorded as average of total number of fruits harvested from five plants.

3.1.22 **Average fruit weight (kg):** It was recorded as average weight of the five randomly selected fruits.

3.1.23 **Fruit yield per vine (kg):** It was recorded as average fruit yield of five plants.

3.2 Quality parameters

3.2.1. **Dry matter content (%DW/WW):** Five gram pulp of each entry in three replicates was accurately weighed, taken in glass crucibles and dried in oven at 60-65°C for 48 hours. The crucibles containing the dried pulp were weighed for calculating the dry matter percentage.

3.2.2. **Total Soluble Solid (°Brix):** The total soluble solid (TSS) were recorded with the help of hand refractometer by putting a drop of juice from the sliced fruit pulp. TSS of five fruits was averaged for each replication.

3.2.3. **Vitamin-C (mg/100g of FW):** Vitamin-C was estimated as per the procedure given by Harris and Ray (1935). The reagent and procedure are given as:-

(i) **Metaphosphoric acid solution :-** Metaphosphoric acid (15g) was dissolved in acetic acid (40 ml) and volume was scaled upto 500 ml with distilled water.

(ii) **2, 6 dichlorophenol indophenol Dye :-** 2, 6 dichlorophenol indophenol Dye (62.5 mg) was dissolved in 100 ml of distilled water and then 52.5 mg sodium bicarbonate ($NaHCO_3$) was added to the solution and total volume scaled up to 250 ml with distilled water.

Standardization of dye : - A standard solution (1 mg/ml) of ascorbic acid (25 mg in 25 ml of metaphosphoric acid solution) was prepared. Two millilitres of solution was taken into a conical flask and titrated with dye till the appearance of pink colour. Dye factor was computed as the volume of dye used to reduce 1mg of ascorbic acid.

Principle :- Ascorbic acid reduces the dye to colourless compounds. MPA inhibits oxidation of ascorbic acid catalysed by certain metals i.e. to inactivate enzymes, to precipitate protein and thus to liberate protein bonded ascorbic acid.

Procedure

Five gram of fruit pulp was macirated in 10 ml of metaphosphoric acid and acetic acid solution. Two ml of aliquate was mixed with an equal volume of metaphosphoric acid and acetic acid solution in a conical flask and titrated with standardized dye solution till the appearance of light pink colour that persisted for about 15 seconds. Ascorbic acid content was calculated by the following formula:

$$\text{Ascorbic acid (mg/100 g FW)} = \frac{\text{Dye factor} \times \text{volume make up} \times \text{titration reading}}{\text{Sample weight} \times \text{aliquot taken for estimation}}$$

3.2.4 Total carotenoids (mg/100 g FW)

For the estimation of total caroteneoids, 5g fresh pulp was crushed in 97% petroleum ether + 3% acetone with help of pestle mortar. Further, the extract was transferred to a separating funnel for an hour and same amount of water was added to it. Water was drained and extract was collected and its volume was scaled to 50 ml with petroleum ether and OD was recorded at 452 nm (Mc collum 1955).

Calculations

$$\frac{\text{OD value of sample} \times \text{standard curve value (3.857)}}{\text{sample fresh wt. (g)}} \times 100$$

3.2.5 Estimation of total sugar (Dubois *et al* 1956)

Principle: Sugar from furfurals and hydroxyl-methyl furfurals (pentoses and hexoses, respectively) in the presence of concentrated H_2SO_4, react with phenol to give coloured compounds. All sugars give this test as oligo- and polysaccharides will get hydrolyzed with concentrated H_2SO_4 .

(A) Extraction procedure

(a) Reagent

(i) Ethanol (80%)

(ii) Lead acetate (saturated)

(iii) Sodium oxalate

Weighed 500 mg dried samples and refluxed with 80% ethanol in conical flask fitted with water condenser and refluxed for two hours. Then supernatant was collected and gain refluxed the content with 70% ethanol and pooled the supernatants. Ethanol from pooled extract was removed at 50°C in a flask evaporator under vaccum. Then 1.0 ml of saturated lead acetate was added. This was kept overnight till all the proteins in the extract get precipitated . To this pinch of sodium oxalate was added to remove the lead ions from the extract. It was again kept overnight. Thereafter, the extract was filtered through whatmann No. 1 filter paper. The clear extract thus obtained was made up to 100 ml with distilled water for sugar estimation.

(B) Estimation

(a) Reagents

(i) 5% phenol (w/v) redistilled

(ii) Conc. Sulphuric acid (H_2SO_4) and used

(b) Procedure

To 0.2 ml of sugar extract , 0.8 ml of distilled water and 1.0 ml of 0.5% phenol was added followed by the addition of 5.0 ml of conc. H_2SO_4 . The H_2SO_4 was poured directly in the test tube to ensure proper mixture after 10 min tubes were cooled to room temperature under running water. After 20 min the absorbance was read at 490 nm against reagent blank. The concentration of total sugar was read from standard curve prepared by using glucose in range 10-100 μg/ml.

Calculation

$$\frac{\text{60 μg value of standard} \times \text{sample OD} \times \text{total volume made} \times \text{converter (μg to mg)}}{\text{OD of standard} \times \text{volume used of conc. Sample} \times \text{dry matter taken}}$$

3.3 Statistical analysis

The data recorded for each observation was averaged in each replication. Further, the replicated data of nine inbreds and 36 hybrids was subjected to statistical analysis following BMM software for analysis as follow:

3.3.1 Analysis of variance for RBD

3.3.2 Combining ability analysis

3.3.3 Estimation of heterosis

3.3.4 Analysis of correlation

3.3.1 Analysis of variance for RBD

The average of 45 genotypes (9 parents and 36 hybrids) in each replication for each character was used for the analysis of variance. The analysis of variance for randomized block design was carried out using the following linear model :

$$Y_{ijk} = m + g_{ij} + b_k + e_{ijk}$$

Where,

Y_{ijk} = phenotypic value of the ij^{th} genotypes grown in the k^{th} replication.

m = general population mean

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

b_k = effect of k^{th} replication, where k = 1, ….., r

e_{ijk} = Random error associated with the ijk^{th} observation.

Analysis of variance is based on the above model led to the break up of the variance into the following components.

Analysis of variance for RBD

Source of variation	**d.f.**	**S.S.**	**M.S.S.**	**F-value**
Replications	r-1	S_r	$M_r=S_r/r-1$	M_r/M_e
Genotypes	g-1	S_g	$M_g=S_g/g-1$	M_g/M_e
Error	(r-1) (g-1)	S_e	$M_e=S_e/(r-1)$ (g-1)	
Total	(gr-1)			

Where,

d.f. = Degrees of freedom

S.S.= Sum of squares

M.S.S. = Mean sum of squares

r = Number of replications

g = Number of genotypes

The standard error of difference between the genotypic means based on r replication was estimated as :

$$\text{S.E.(d)} = \pm \left(\frac{2M_e}{r}\right)^{1/2}$$

Critical difference (C.D.) = S.E. (d) x $t_{(r-1)\,(g-1)}$ at 5% and 1% level of significance.

3.3.2 Combining ability analysis

The data arranged in diallel fashion was subjected to analysis of general and specific combining ability and their effects were computed by method-2 (parents and one set of F_1's excluding reciprocal F_1's) and model-1 (fixed effect model) as suggested by Griffing (1956). The analysis of variance for combining ability was based on the following mathematical model :

$$X_{ij} = \mu + g_i + g_j + S_{ij} + \frac{1}{bc}\sum_k \sum_l e_{ijkl}$$

Where,

i,j = 1, …….p, (number of parents)

k = 1,……..b, (number of blocks or replications)

l = 1, ……..c, (number of observations)

μ = Population mean

g_i (or g_j) = General combining ability of i[th] (or j[th]) parent

S_{ij} = Specific combining ability of the crosses between i[th] and j[th] parents such that S_{ij} = S_{ji} and

e_{ijkl} = The environmental effect peculiar to the ijkl[th], observation

The following restriction are imposed on the combining ability analysis :

$$\sum_i g_i = 0$$

and

$$\sum_j S_{ij} + S_{ij} = 0 \quad \text{(for each i)}$$

Based on the model, the following are the components of variance.

Analysis for general combining ability (GCA) and specific combining ability (SCA)

Source of variation	**d.f.**	**SS**	**MSS**	**Expected mean sum of square**
General combining ability	p-1	S_g	M_g	$\sigma_e^2 + (p+2)\left[\frac{1}{p-1}\right]\sum_i g^2$
Specific combining ability	$\frac{p(p-1)}{2}$	S_s	M_s	$\sigma_e^2 + \left[\frac{2}{p(p-1)}\right]\sum_i \sum_j s^2 ij$
Error	m	S_e	M_e	σ_e^2
σ^2_A			$2\left[\frac{M_g - M_s}{p+2}\right]$	
σ^2_D			M_s-M_e	

Where,

$S_g = \frac{1}{p+2}[\Sigma(X_i + X_{ij})^2 - \frac{4}{p} X^2..]$

$S_s = \sum_i \sum_j X_{ij}^2 - \frac{1}{p+2}\sum_i (X_i + X_{ij})^2 + \frac{2}{(p+1)(p+2)} X^2..$

p = number of parents

$M_e = M_e/r$ (where M_e is the error mean square from RBD analysis)

X_{ij} = mean value of the i^{th} parent

X_{ij} = progeny mean value of the i x j^{th} hybrid

X.. = grand total of ½ p(p-1) progenies and P parental values

$\sigma^2 A$ = additive variance

$\sigma^2 D$ = non-additive variance

The following F ratios were used to test GCA and SCA effects, and differences among GCA effects.

$F_{(p-1), m} = \frac{M_g}{M_e}$

and to test for differences among SCA effects.

$F_{p(p-1)/2, m} = \frac{M_s}{M_e}$

Estimation of GCA and SCA effects

General combining ability effects of the i^{th} parent,

$gi = \frac{1}{p+2}(X_i + X_{ii} - \frac{2}{p} x..)$

Specific combing ability effects of the i x j^{th} cross,

$Sij = Xij - \frac{1}{p+2}(X_i + X_{ii} + X_j + X_{ij}) + \frac{2}{(p+1)(p+2)} X..$

Where,

p = number of parents

$X_i.$ = total of the array involving i^{th} parent

$X_{.j}$ = total of the array involving j^{th} parents

X_{ii} = mean value of the i^{th} parent

X_{jj} = mean value of the jth parent

X_{ij} = progeny mean value of i x j^{th} hybrid

$X_{..}$ = grand total

σ_e^2 = error variance

Standard error (S.E.) of estimates

S.E. of effects was estimated as follow:

S.E. for GCA estimates, S.E. (g_i) = ± $\sqrt{\frac{p-1}{p(p+2)}\sigma_e^2}$

S.E. for SCA estimates, S.E. (s_{ij}) = ± $\sqrt{\frac{p^2+p+2}{(p+1)(p+2)}\sigma_e^2}\,(i \neq j)$

Where,

σ_e^2 = error variance

Critical difference (C.D.) of the estimates

C.D. of the effects was calculated by multiplying the corresponding SE(d) values for difference with table value of t for error degree of freedom at both 5% and 1% level of significance.

3.3.3 Estimation of heterosis

Heterosis over the better parents and standard check (MPH-1) was calculated as follow:

Heterobeltiosis (%) = $\frac{\overline{F_1} - \overline{BP}}{\overline{BP}} X\ 100$

Standard or economic heterosis (%) = $\frac{\overline{F_1} - \overline{Check}}{\overline{Check}} X\ 100$

Where,

$\overline{BP}$ =Average performance of the better parent

$\overline{Check}$ = Average performance of the check hybrid

Test of significance for heterosis

Test of significance was carried for the numerator value of the expression. The numerator value for heterosis over standard check and best parent was $\overline{F_1} - \overline{\text{Check}}$ and $\overline{F_1} - \overline{BP}$, respectively. The standard error of difference was computed as under :

$$\text{S.E. (d)} = \pm \sqrt{\frac{2\text{Me}}{\text{r}}}$$

Where,

Me = Error mean square as calculated in RBD using F_1's parents and standard check.

and r = Number of replications

The critical difference (CD) was computed by multiplying the SE of difference with t value for error d.f. at P = 0.05 and 0.01.

3.3.4 Correlation analysis

The data pertaining to different cross combinations for all the characters under investigation was subjected to correlation analysis as suggested by Miller *et al* (1958). However, genotypic and phenotypic correlation analysis was performed using MVM software. The association of vine length was studied with different vegetative and flowering characters; yield per vine was correlated with vine length and other yield related traits and average fruit weight was correlated with different fruit quality characters. The results were interpreted on the basis of yield, bushy growth habit and less fruit weight.

CHAPTER – IV

RESULTS AND DISCUSSION

The results of investigation entitled “Heterosis and combining ability studies on yield, quality and storage traits involving bush and butternut genotypes in pumpkin” were grouped under following heading after analysis of variance (ANOVA) for detailed description:

4.1 ANOVA for the experimental design

4.2 ANOVA for combining ability

4.3 GCA estimates of parents

4.4 SCA estimates of hybrids

4.5 Heterobeltiosis and economic heterosis

4.6 Per se performance of best hybrids

4.7 Correlation analysis

4.1 ANOVA for the experimental design

The means of different genotypes for various characters have been given in Appendix-I. Analysis of variance for the experimental design of all the observations under study is arranged in Table 4.1. The outcome of highly significant genotypic coefficient of variance for all the characters highlighted the substantial amount of variation in the inbred lines selected for the exploration. The highest and the lowest level of GCV and PCV were noticed for vine length (72.46) and (73.55), respectively, days to 50% male flowering (7.57) and (8.43), respectively. Cyril *et al* (2014) in bottle gourd, Pathak *et al* (2014) in bitter gourd, Faruk Hossain *et al* (2010) in cucumber also reported similar results.

4.2 ANOVA for combining ability

The analysis of variance for combining ability of vegetative, flowering, yield and quality characters is enlisted in Table 4.2. Highly significant mean square values for GCA and SCA indicated the involvement of both additive and non-additive gene effects in the inheritance of all the characters under scrutinization. However, the higher magnitudes of dominant genetic variance (σ^2 D) as compared to the additive genetic variance (σ^2 A) highlighted the predominance of non-additive gene effects that is required for the exploitation of heterosis in this crop. In some previous reports also, both additive and dominant (non-additive) genetic components were important for yield and yield components in pumpkin (Mohanty and Mishra 2000, Sirohi *et al* 2002). The greater ratio of σ^2SCA/ σ^2GCA (>1) also suggested that the inheritance of most of the pumpkin traits is controlled by non-additive gene effects. These results were substantiated with the finding in sponge gourd (Ram *et al* 2007 and Naliyadhara *et al* 2010). However, Nisha and Veeraragavathatham (2014) found higher magnitude of *GCA* variance than *SCA* variance for all characters except first female flowering node and 100 seed weight and revealed the preponderance of additive effects in inheritance of pumpkin traits.

Table 4.1: Analysis of variance for experimental design of different characters

Observations	$MS_{Replication}$	$MS_{Genotypes}$	MS_{Error}	GCV	PCV
	d.f.=2	d.f.=44	d.f.=88		
Vine length (cm)	6.94	18776.09**	188.19	72.46	73.55
Internodal length (cm)	0.27	7.53**	0.16	47.80	49.36
Leaf length (cm)	0.22	9.29**	0.54	11.71	12.75
Leaf width (cm)	0.30	15.79**	1.16	10.66	11.86
Petiole length (cm)	73.15**	44.04**	2.54	14.38	15.64
Number of primary branches	0.05	0.58**	0.04	12.63	13.96
Earliest node to female flower	1.33	32.28**	0.52	51.23	52.47
Days to 50% female flowering	65.49**	204.79**	3.95	21.05	21.66
Earliest node to male flower	0.21**	0.20**	0.03	20.28	24.52
Days to 50% male flowering	4.37	29.34**	2.17	7.57	8.43
Node to 1st fruit	1.30*	25.98**	0.35	38.97	39.76
Days to fruit maturity	68.03**	152.33**	0.53	14.45	14.53
Peduncle length (cm)	0.82*	13.16**	0.26	37.16	38.27
Polar diameter (cm)	0.20**	84.92**	0.03	33.85	33.86
Equatorial diameter (cm)	0.43**	53.51**	0.02	28.47	28.49
Fruit shape index	0.003**	1.48**	0.0005	59.24	59.27
Pulp thickness (cm)	0.13**	1.31**	0.01	25.51	25.80
Number of fruits per vine	0.48*	0.54**	0.14	19.31	27.60
Average fruit weight (kg)	0.33**	2.05**	0.06	65.05	67.97
Fruit yield per vine (kg)	0.62	4.86**	0.48	54.30	62.53
TSS (°Brix)	0.53**	11.10**	0.03	33.99	34.14
Total carotenoids (mg/100 g FW)	0.29**	79.83**	0.02	55.50	55.53
Dry matter (%)	0.26**	20.42**	0.03	31.38	31.45
Vitamin-C (mg/100 g FW)	1.06**	2168.72**	0.02	45.35	45.35
Total sugar (mg/100g DW.)	0.03	0.74**	0.03	23.31	24.73

*, ** Significant at 5% and 1% level, respectively.

Table 4.2: Analysis of variance for combining ability of different characters

Observations	GCA	SCA	Error	Components of genetic variance		
	d.f. =8	d.f. =36	d.f.=88	σ^2GCA	σ^2SCA	σ^2SCA/ σ^2GCA
Vine length (cm)	12358.4**	4903.19**	62.73	5.06	41.66	8.23
Internodal length (cm)	1.90**	2.64**	0.05	0.004	0.035	8.75
Leaf length (cm)	6.76**	2.28**	0.18	0.01	0.11	11
Leaf width (cm)	12.29**	3.70**	0.01	0.03	0.25	8.33
Petiole length (cm)	39.22**	9.22**	0.84	0.06	0.55	9.16
Number of primary branches	0.25**	0.18**	0.08	0.001	0.008	8
Earliest node to female flower	22.49**	8.16**	0.17	0.01	0.11	11
Days to 50% female flowering	167.85**	46.13**	1.31	0.10	0.86	8.6
Earliest node to male flower	0.13**	0.051**	0.008	0.0007	0.0057	8.14
Days to 50% male flowering	27.42**	5.86**	0.72	0.05	0.47	9.4
Node to 1st fruit	21.73**	5.75**	0.11	0.009	0.075	8.33
Days to fruit maturity	166.39**	25.08**	0.17	0.01	0.11	11
Peduncle length (cm)	6.08**	4.00**	0.84	0.007	0.057	8.14
Polar diameter (cm)	35.17**	26.78**	0.009	0.0007	0.006	8.57
Equatorial diameter (cm)	28.62**	15.44**	0.008	0.0006	0.005	8.33
Fruit shape index	0.41**	0.50**	0.0001	0.00001	0.0001	10
Pulp thickness (cm)	0.98**	0.31**	0.003	0.0002	0.002	10
Number of fruits per vine	0.34**	0.14**	0.04	0.003	0.030	10
Average fruit weight (kg)	1.28**	0.54**	0.02	0.001	0.01	10
Fruit yield per vine (kg)	3.51**	1.20**	0.15	0.01	0.10	10
TSS (°Brix)	3.85**	3.66**	0.01	0.0008	0.006	7.5
Dry matter (%)	5.81**	7.02**	0.009	0.0007	0.005	7.14
Vitamin-C (mg/100g FW)	451.84**	783.13**	0.007	0.0006	0.005	8.33
Total carotenoids (mg/100g FW)	17.66**	28.60**	0.007	0.0006	0.004	6.66
Total sugar (mg/100g DW.)	0.11**	0.27**	0.009	0.0007	0.006	8.5

*, ** Significant at 5% and 1% level, respectively.

Such differences for inheritance of characters are likely to occur due to dissimilarities in genetic material, mating system, experimental design and above all the environment under which the investigation were carried out.

There was the preponderance of non-additive gene action (dominance and epistasis) when σ^2SCA was more than σ^2GCA and thus heterosis breeding may be rewarded in such characters. Alternatively, population improvement scheme like recurrent selection for specific combining ability is appropriate (Hull 1945). There is preponderance of additive gene action, when σ^2GCA is more than σ^2SCA and progeny selection may be effective for the genetic improvement of such traits. When σ^2GCA is equal to σ^2SCA i.e. σ^2GCA, σ^2SCA = 1both the additive and non-additive gene action have importance in the expression of such characters. In this situation, reciprocal recurrent selection may be resorted to for population improvement.

4.3 GCA of parents

General combining ability (GCA) highlights the average performance of a line in a series of hybrid combinations. GCA effects of parent/inbreds for vegetative, flowering, yield and quality characters under investigation are compared in Table 4.3.

4.3.1 Vine length (cm)

Negative GCA effect is indicators of bush type growth in pumpkin. In present investigation, GCA effects for the parent/inbreds ranged from -47.83 to 38.52. Among 9 parents, MSBN 3621-9-3-1 (-47.83), P-1343-17-5-3 (-43.80), CFR 2211-2 (-22.85) and MVSR 6711-14-2 (-9.05) showing highly significant GCA effects were good general combiners for bushy growth in pumpkin, while other parents were poor general combiners for it (Table 4.3.1). Higher estimates of GCA for less vine length were important potential for generating breeding populations for bushy growth. These parents have high concentration of predominantly additive genes and may lead to high frequency gene flow from one to further generations for better selections. These parents with high GCA can also be used in suitable combinations for developing highly heterotic hybrids for short vine length. Similar results were earlier presented for greater vine length in pumpkin (Nisha and Veeraragavathatham 2014 and Hussien and Hamed 2015, Tamil Selvi *et al* 2015), luffa (Tyagi *et al* 2010), bottle gourd (Janaranjani *et al* 2016) and watermelon (Bahari *et al*. 2012), but this study concentrated on bushy growth of pumpkin for promoting intensive cultivation.

4.3.2 Internodal length (cm)

The reduced internodal length is required for bush type vines in pumpkin**.** Therefore, negative GCA effects were desirable. GCA estimates for this trait were ranged between -0.80 to 0.44. Among parents, only MSBN 3621-9-3-1 (-0.80) and P-1343-17-5-3 (-0.50) demonstrated significantly desirable (negative) GCA and considered as good general combiners (Table 4.3.1). The high estimates of GCA for internodal length in negative direction are useful in developing potential breeding populations for reduced vine length, because these parents offer predominantly additive genes for this character, which can help in superior selections following hybridization. These inbreds with reduced internodal length are also useful in heterosis breeding for bushy growth. Most of the studies in cucurbits are available for greater internodal length.

4.3.3 Leaf length (cm)

Vegetative growth is indicator of higher photosynthetic activity. Positive GCA effects for leaf length means better vegetative growth for providing greater assimilates to the developing fruits. The GCA estimates of inbreds for leaf length ranged from -1.33 to 0.97. Among parents, B-10-224-3 (0.97), MBN 6242-3-1 (0.71), BUMOV 41212-3-1 (0.45), BN-364 (0.44) and CFR 2211-2 (0.39) showed highly significant GCA effects (Table 4.3.1). Thus, these parents were good general combiners for leaf length. The high estimates of GCA in positive direction are useful in developing potential breeding populations for better vegetative growth, because these parents offer predominantly additive genes for this character, which can help in superior selections following hybridization. These parents with more leaf length are also useful in heterosis breeding as the dominant genetic variance was higher than the additive genetic variance for this trait. The results can be substantiated with the findings of El-Tahawey *et al* (2015) in pumpkin.

4.3.4 Leaf width (cm)

Leaf width is also associated with photosynthetic activity. The positive GCA was desirable for greater accumulation of assimilates. In present study, it ranged from -1.94 to 1.56 and only B-10-224-3 (1.56), MBN 6242-3-1 (0.99), BN-364 (0.56) and BUMOV 41212-3-1 (0.46) revealed highly significant (positive) GCA estimates and considered as good general combiners for leaf width (Table 4.3.1). The high estimates of GCA for leaf width in positive direction are useful in developing potential breeding populations for better vegetative growth, because these inbreds offer additive genes effects for this character, which can help in superior selections following hybridization. These inbreds with more leaf width are also useful in heterosis breeding as the dominant (non additive) genetic variance was higher than the additive genetic variance for this trait. The results can be substantiated with the findings of El-Tahawey *et al* (2015) in pumpkin.

4.3.5 Petiole length (cm)

Small petiole length is desirable for bushy growth. Therefore, inbreds with negative and significant GCA should be selected. In present study, GCA estimates for petiole length ranged between -2.48 to 2.17. Among parents, only P-1343-17-5-3 (-2.48), MSBN 3621-9-3-1

(-1.84), MVSR 6711-14-2 (-1.41) and Punjab Samrat (-1.38) showed highly significant (negative) GCA effects (Table 4.3.1). Thus, P-1343-17-5-3 was best general combiner and remaining three were good general combiners for small leaf petioles. These lines with high GCA have concentrated additive gene effects that can be exploited in hybridization following selection and also in heterosis breeding with suitable combinations.

4.3.6 Number of primary branches

Number of primary branches can be improved with best combiners having positive GCA effects for this character. In present study, the highest and the lowest GCA effects were -0.29 to 0.14, respectively. Among parents, CFR 2211-2 (0.14), P-1343-17-5-3 (0.13), MVSR 6711-14-2 (0.09) and MSBN 3621-9-3-1 (0.07) displayed highly significant GCA effects and were good general combiners for this characters (Table 4.3.1). The parents with high estimates of GCA for number of primary branches can generate potential breeding populations because these have high concentration of predominantly additive genes for this character and can lead to high frequency gene flow for superior selections, when used in hybridization. These inbreds in suitable combinations are also useful in heterosis breeding for more number of primary branches. The results were supported with the findings of Hussien and Hamed (2015) in pumpkin and Janaranjani *et al* (2016) in bottle gourd.

Table 4.3.1: General combining ability effects of the parents for vegetative characters

Genotypes	**Vine length (cm)**	**Internodal length (cm)**	**Leaf length (cm)**	**Leaf width (cm)**	**Petiole length (cm)**	**Number of primary branches**
Punjab Samrat	22.30**	0.33**	-0.30*	-0.30	-1.38**	-0.29**
BUMOV 41212-3-1	38.52**	0.39**	0.45**	0.46**	1.12**	0.02
BN-364	-3.21	-0.02	0.44**	0.56**	2.17**	-0.04
P-1343-17-5-3	-43.80**	-0.50**	-1.33**	-1.94**	-2.48**	0.13**
MVSR 6711-14-2	-9.05**	0.10	-0.87**	-0.91**	-1.41**	0.09**
MSBN 3621-9-3-1	-47.83**	-0.80**	-0.48**	-0.47**	-1.84**	0.07*
B-10-224-3	35.45**	0.44**	0.97**	1.56**	2.06**	0.04
MBN 6242-3-1	30.47**	-0.01	0.71**	0.99**	2.15**	-0.19**
CFR 2211-2	-22.85**	0.06	0.39**	0.04	-0.39	0.14**
CD at 5%	4.47	0.13	0.23	0.35	0.51	0.06
CD at 1%	5.86	0.17	0.31	0.45	0.68	0.08

*, ** Significant at 5% and 1% level, respectively.

4.3.7 Earliest node to female flower

Bushy growth habit restricts the excessive vine growth, comes in transition phase and brings early flowering. In pumpkin, lower node of first female flower marks the earlier genotypes. Therefore, negative and significant GCA was desirable. The estimates of GCA ranged from -2.43 to 1.78. Bushy parents, P-1343-17-5-3 (-2.43), MSBN 3621-9-3-1(-1.78) and BN-364 (-0.47) revealed significantt GCA values and considered as good general combiners for early node to first female flower (Table 4.3.2). CFR 2211-1(-0.24) was average combiners for this triat. In contrast, vine parents B-10-224-3 (1.78), BUMOV 41212-3-1(1.41), Punjab Samrat (0.40) and MVSR 6711-14-2 (0.05) with positive significant GCA effects were poor combiners for lower node to first female flower. The importance of lower node to first flower for earliness has also been reported by Nisha and veeraragavathatham (2014) and Tamil selvi1 *et al* (2015) in pumpkin, Janaranjani *et al* (2016) in bottle gourd. High frequency of additive gene effects in good general combiners may provide scope for better selections after hybridization as well as for heterosis breeding with best combinations.

4.3.8 Days to 50 % female flowering

Less number of days taken for appearance of female flowers on 50 % plants are also indicator of earliness. Although ranging between -5.03 and 7.15, GCA in negative direction was desirable for early flowering. The parents P-1343-17-5-3 (-5.03), CFR 2211-2 (-3.18), MSBN 3621-9-3-1(-2.39), MVSR 6711-14-2 (-1.75) and B-10-224-3(-1.06) exhibited highly significant and desirable GCA effects and grouped as good general combiners for early female flowering (Table 4.3.2). MSBN 3621-9-3-1 being bushy and butternut in nature provide good scope for earliness also. Similar results were also presented earlier by Nisha and Veeraragavathatham (2014) in pumpkin, Tyagi *et al* (2010) in luffa, Janaranjani *et al* (2016) in bottle gourd, Bahari *et al*. (2012) in watermelon.

4.3.9 Earliest node to male flower

The monoecious nature of pumpkin also necessitates the simultaneous appearance of male flowers, so that effective and early pollination of the female buds can be affected by the insects. In this study, GCA estimates for earliest node to male flower ranged between -0.07 and 0.25. Among parents, P-1343-17-5-3 (-0.07), MSBN 3621-9-3-1 (-0.07), MVSR 6711-14-2 (-0.06) and CFR 2211-1 (-0.06) had significant and desirable GCA effects and considered as good general combiners (Table 4.3.2). The parents B-10-224-3 (-0.04) and MBN 6242-3-1 (-0.01) with desirable, but insignificant GCA effects were average combiners for this trait. Simliar effects for early node to male flowers have also been reported by Janaranjani *et al* (2016) in bottle gourd. P-1343-17-5-3 bear flat round fruits on vines, but bushy and BN nature of MSBN 3621-9-3-1 with early node to female flower provide great scope for the reducing of vine length and bringing earliness in pumpkin breeding. High GCA indicates concentrated additive gene effects that may segregate into high gene frequencies in selected progenies for earliness.

4.3.10 Days to 50% male flowering

The earliness in male flowering also required for effective pollination. The earliest days to 50 % flowering reflects early fruit bearing. In diallel analysis, GCA effects of parents for days to 50 % male flowering ranged between -1.72 and 3.39. Among parents, BUMOV 41212-3-1 (-1.72), MVSR 6711-14-2 (-1.36) and CFR 2211-1 (-1.33), unveiling highly significant and desirable GCA estimates, were considered as good general combiners, whereas the parents P-1343-17-5-1 (-0.42), BN-364 (-0.05) and B-10-224-3 (-0.02) with negative and non-significant GCA effects were average general combiners for days to 50 % male flowering (Table 4.3.2). MVSR 6711-14-2, CFR2211-2 and BN-364 as bushy and butternut was average general combiner for this trait and can be used in suitable combinations with the other parents. Simliar effects for early node to male flowers in luffa and, bottle gourd has also been reported by Tyagi *et al* (2010) and Janaranjani *et al* (2016), respectively.

4.3.11 Node to first fruit

The earliest node of first set fruit unveils earliness of parents. GCA effects were desirable in opposite direction for early node of first fruit. In present investigation, GCA effect for this trait ranged between -2.03 and 1.94. Among parents P-1343-17-5-3 (-2.03), MSBN 3621-9-3-1 (-1.66), MVSR 6711-14-2(-1.06), BN-364(-0.26) and CFR 2211-2 (-0.24) showed significantly desirable (negative) GCA values and considered as good general combiners (Table 4.3.3). MSBN 3621-9-3-1 and BN-364 bear butternut fruits on bushy plants and CFR 2211-2 and MVSR 6711-14-2 being bushy with high additive genetic effects can used in pumpkin breeding for earliness favouring intensive cultivation. The results for earlier node to fruit bearing were also reported by Tamil Selvi *et al* (2015) in pumpkin.

4.3.12 Days to fruit maturity

The number of days to fruit maturity is directly related to early node to first female flower and fruit bearing of a genotype. The GCA effects in negative direction were desirable for this trait that ranged between -5.17 and 6.00. Among parents, P-1343-17-5-3 (-5.17), MSBN 3621-9-3-1 (-3.59), MVSR 6711-14-2 (-3.53) and CFR 2211-2 (-1.98) showed significantly desirable (negative) GCA and these parents were considered good general combiners (Table 4.3.3). Among these parents MSBN 3621-9-3-1 as bushy and BN parent, while MVSR 6711-14-2 and CFR 2211-2 as bushy parent had high additive and additive × additive gene effects for early maturity, hence can be used in hybridization and breeding programme for this bushy trait in pumpkin. The results for days to fruit maturity were also reported by Tamil Selvi *et al* (2015) in pumpkin.

Table 4.3.2: General combining ability effects of the parents for early flowering and fruiting

Genotypes	Earliest node to female flower	Days to 50% female flowering	Earliest node to male flower	Days to 50% male flowering	Node to first fruit	Days to fruit maturity
Punjab Samrat	0.40**	7.15**	0.25**	3.39**	1.94**	6.55**
BUMOV 41212-3-1	1.41**	4.96**	0.09**	-1.72**	1.31*	2.97**
BN-364	-0.47**	0.72*	.00	-0.05	-0.26**	-0.29*
P-1343-17-5-3	-2.43**	-5.03**	-.07**	-0.42	-2.03**	-5.17**
MVSR 6711-14-2	0.05	-1.75**	-.06*	-1.36**	-1.06*	-3.53**
MSBN 3621-9-3-1	-1.78**	-2.39**	-.07**	1.24**	-1.66**	-3.59**
B-10-224-3	1.78**	-1.06**	-0.04	-0.02	1.21**	2.82**
MBN 6242-3-1	1.27**	0.57	-.01	0.27	0.78**	2.22**
CFR 2211-2	-0.24*	-3.18**	-.06*	-1.33**	-0.24*	-1.98**
CD at 5%	0.23	0.64	0.05	0.47	0.19	0.23
CD at 1%	0.30	0.84	0.06	0.62	0.25	0.31

*, ** Significant at 5% and 1% level, respectively.

4.3.13 Peduncle length (cm)

Smaller peduncle length is required for concentrated bearing on bushy plants of pumpkin. Therefore, GCA effects in opposite direction were desirable in this study. GCA estimates for this trait ranged between -1.28 and 1.26. Among parents, MSBN 3621-9-3-1 (-1.28) and P-1343-17-5-3 (-0.80) exhibit showed highly significant (negative) GCA effect, thus these parents were considered as good general combiners (Table 4.3.3). On the basis of high additive gene effects for smaller peduncle of fruit, bushy and BN parent, MSBN 3621-9-3-1, can be involved in hybridization and effective selections can be made for this trait.

4.3.14 Polar diameter (cm)

Butternut fruit types in pumpkin bear long fruits. In this study, GCA effects in positive direction offer opportunity to select for butternut pumpkins. The GCA effect for this trait ranged between -2.60 and 3.40. Among parents, B-10-224-3 (3.40), CFR 2211-2 (1.22), MSBN 3621-9-3-1 (0.43) and MBN-6242-3-1 (0.19) carried significantly desirable GCA effects and were considered as good general combiners (Table 4.3.3). Other parents with significantly negative GCA were poor general combiners for fruit length. Various studies on polar diameter of pumpkin (Hussien and Hamed 2015, Tamil selvi *et al* 2015, Shohle Rana *et* *al* 2015), luffa (Tyagi *et al* 2010) and bottle gourd (Janaranjani *et al* 2016) substantiated our results. CFR 2211-2, MSBN 3621-9-3-1 and MBN 6242-3-1 being bushy and BN parents offer opportunity for the development of BN fruit shape.

4.3.15 Equatorial diameter (cm)

Butternut fruit types in pumpkin bear fruits with narrow neck. In this study, GCA effects in negative direction offer opportunity to select for butternut pumpkins. The GCA effect for this trait ranged between -2.29 and 2.54. Among parents, MSBN 3621-9-3-1 (-2.29), P-1343-17-5-3 (-2.02), BN-364,(-0.98), Punjab Samrat (-0.50) carried significantly desirable GCA effects and considered as good general combiners (Table 4.3.3). Other parents with significantly positive GCA were poor general combiners for reducing fruit width. various studies on equatorial diameter of pumpkin (Hussien and Hamed 2015, Tamil selvi *et al* 2015, Shohel Rana *et al* 2015), luffa (Tyagi *et al* 2010) and bottle gourd (Janaranjani *et al* 2016) substanciated our results. MSBN 3621-9-3-1 and BN-364 bear butternut fruits and can be involved for breeding such fruit types through hybridization and selection.

4.3.16 Fruit shape index

Fruit shape index gives an idea about roundness, flatness as well as elongation of fruits. The positive GCA effects were desirable for this character that ranged between -0.40 and 0.26. Among parents, MSBN 3621-9-3-1(0.26), B-10-224-3 (0.18), CFR 2211-2 (0.12) and Punjab Samrat (0.11), showed highly significant and desirable GCA effects (Table 4.3.3) and considered as good general combiners. MSBN 3621-9-3-1 was represented as best bushy parent with butter fruit type that can be used in hybridization and breeding programme for bushy pumpkin.

4.3.17 Pulp thickness (cm)

Increased pulp thickness results into reduction in seed cavity that is desirable for improving quality in pumpkin. The positive GCA effects were desirable for this character that ranged between -0.40 and 0.44. Among parents, only MBN 6242-3-1(0.44), BUMOV 41212-3-1(0.23), CFR 2211-2 (0.21), B-10-224-3(0.16) and MVSR 6711-14-2 (0.05) showed highly significant GCA effect and considered as good general combiners (Table 4.3.3). Nisha and Veeraragavathatham (2014), El-Tahawey (2015), Hussien and Hamed (2015), Tamil Selvi *et al* (2015), Shohel Rana *et al* (2015) in pumpkin and Janaranjani *et al* (2016) in bottle gourd also reported similar results for pulp thickness.MBN 6242-3-1, CFR 2211-2 and MVSR 6711-14-2, having bushy or butternut nature were best combiners for this trait and high additive genetic component for it can help in improving pulp thickness in butter nut fruit type selections in pumpkin.

Table 4.3.3: General combining ability effects of the parents for fruit characters

Genotypes	Peduncle length (cm)	Polar diameter (cm)	Equatorial diameter (cm)	Fruit shape index	Pulp thickness (cm)
Punjab Samrat	-0.08	-0.02	-0.50**	0.11**	-0.07
BUMOV 41212-3-1	0.53**	-1.06	1.12	-0.22	0.23**
BN-364	-0.09	-0.63	-0.98**	-0.01	-0.22
P-1343-17-5-3	-0.80**	-1.50	-2.02**	0.001	-0.40
MVSR 6711-14-2	0.08	-2.60	0.41	-0.28	0.05**
MSBN 3621-9-3-1	-1.28**	0.43**	-2.29**	0.26**	-0.40
B-10-224-3	1.26**	3.43**	1.50	0.18**	0.16**
MBN 6242-3-1	0.46**	0.19**	2.54	-0.17	0.44**
CFR 2211-2	-0.09	1.75**	0.20	0.12**	0.21**
CD at 5%	0.16	0.05	0.05	0.007	0.03
CD at 1%	0.21	0.07	0.06	0.01	0.04

*, ** Significant at 5% and 1% level, respectively.

4.3.18 Number of fruits per vine

More number of fruits per vine increases yield potential of a genotype. The GCA effects for this trait ranged between -0.22 and 0.23 and positive GCA effects were desirable. Among parents, BUMOV 41212-3-1 (0.23) and BN-364 (0.22) with highly significant GCA effects and parent MSBN 3621-9-3-1 (0.13) with significant GCA effects were considered as good general combiners (Table 4.3.4). However, P-1343-17-5-3 (0.04) was an average general combiner for the number of fruits per vine. Among bushy and BN parents, MSBN 3621-9-3-1 and BN-364 had high additive genetic effects for this trait and can be used for further improvement. High GCA effects for number of fruits per vine are previously reported by Nisha and veeraragavathatham (2014) and Hussien and Hamed (2015) and Tamil Selvi *et al* (2015) in pumpkin, Tyagi *et al* (2010) in luffa and Janaranjani *et al* (2016) in bottle gourd.

4.3.19 Average fruit weight (kg)

Generally, pumpkin fruits are too big to be used by the nuclear family. Bushy and BN vines bear fruits of economical size. In this study, GCA effects in negative direction offer opportunity to economize pumpkin fruit weight. The GCA effects for this trait ranged between -0.45 and 0.55. Among parents, P-1343-17-5-3 (-0.45), MSBN 3621-9-3-1 (-0.40) and BN-364 (-0.19) carried significant (negative) GCA effects and considered as good general combiners (Table 4.3.4). Punjab Samrat (-0.006) and MVSR 6711-14-2 (-0.09) were average general combiners for lower fruit weight. Nisha and Veeraragavathatham (2014), Tamil Selvi *et al* (2015) and El-Tahawey (2015) also reported high GCA for fruit weight in pumpkin, but in positive direction. Bushy and BN parents, MSBN 3621-9-3-1 and BN-364, can be used for reducing fruit size in pumpkin.

4.3.20 Fruit yield per vine (kg)

Fruit yield per vine is directly affected by fruit weight and number of fruits harvested from single vine. GCA effects in positive direction are desirable for high yields in pumpkin that ranged between -0.74 and 0.89. Among parents, B-10-224-3 (0.89), MBN 6242-3-1 (0.63) and BUMOV 41212-3-1(0.54) showed significantly higher (positive) GCA effects and considered as good general combiners (Table 4.3.4). MBN 6242-3-1 is butternut parent was the best parent for this character. Nisha and veeraragavathatham (2014) and Hussien and Hamed (2015), El-Tahawey (2015) and Tamil Selvi *et al* (2015) in pumpkin, Tyagi *et al* (2010) in luffa and Janaranjani *et al* (2016) in bottle gourd also reported high GCA effects for fruit yield per vine.

Table 4.3.4: General combining ability effects of the parents for yield characters

Genotypes	Number of fruits per vine	Average fruit weight (kg)	Fruit yield/ vine (kg)
Punjab Samrat	-0.13*	-0.006	-0.24*
BUMOV 41212-3-1	0.23**	0.07	0.54**
BN-364	0.22**	-0.19**	-0.16
P-1343-17-5-3	0.04	-0.45**	-0.74**
MVSR 6711-14-2	-0.06	-0.09	-0.22
MSBN 3621-9-3-1	0.13*	-0.40**	-0.60**
B-10-224-3	-0.02	0.55**	0.89**
MBN 6242-3-1	-0.20**	0.44**	0.63**
CFR 2211-2	-0.22**	0.09*	-0.10
CD at 5%	0.12	0.08	0.22
CD at 1%	0.15	0.10	0.29

*, ** Significant at 5% and 1% level, respectively.

4.3.21 TSS (º Brix)

The positive GCA effects are desirable for high TSS level in parents. In present investigation, GCA effect for this trait ranged between -1.17 and 0.91. Among parents, B-10-224-3 (0.91), P-1343-17-5-3(0.44), CFR 2211-2 (0.39) and MSBN 3621-9-3-1 (0.17) showed highly significant and desirable GCA effects and considered as good general combiners (Table 4.3.5). The results of TSS were substantiated with the findings of Shohel Rana *et al*

(2015), Janaranjani *et al* (2016)**.** MSBN 3621-9-3-1 (0.17) and CFR 2211-2 as being bushy and butternut parent were best combiner for this character and high additive genetic component for it can help in improving TSS level in butter nut fruit type selections in pumpkin.

4.3.22 Total carotenoids (mg/100 g FW)

Carotenoids are precursor of vitamin A and its higher levels in pumpkin helps in improving its nutritional status. The positive GCA effects were desirable for this character that, ranged between -2.29 and 2.30. Among parents, BUMOV 41212-3-1(2.30), BN-364 (0.89), CFR 2211-2 (0.29), P-1343-17-5-3(0.27) and MVSR 6711-14-2 (0.21) showed highly significant GCA effects and considered as good general combiners (table 4.3.5). Tamil Selvi *et al* (2015) and Shohel Rana *et al* (2015) also studied carotenoid level in pumpkin. BN-364 (0.89), CFR 2211-2 and MVSR 6711-14-2 being bushy and butternut type were best combiners for improving the total carotenoids level of particular fruit type selections through due to their high additive genetic component.

4.3.23 Dry matter (%)

High dry matter is associated with better storage quality of pumpkin. Therefore, positive GCA effects were desirable for this character. In present investigation, GCA effects for this trait ranged between -0.89 and 1.20. Among parents, CFR 2211-2(1.20), P-1343-17-5-3 (0.88), Punjab Samrat (0.32), BUMOV 41212-3-1(0.11) and B-10-224-3(0.07) displayed highly significant GCA effects and considered as good general combiners (Table 4.3.5). Shohel Rana *et al* (2015) also reported similar results in pumpkin. All the bushy and butternut parents had significant GCA in negative direction and were poor combiner for high dry matter content. These lines in combination with parents having high GCA effects can be used to improve dry matter content in butternut fruit selections.

4.3.24 Vitamin-C (mg/100 g FW)

Vitamin-C is a very good antioxidant and selection for its high level in pumpkin makes it a nutritious vegetable. Therefore, positive GCA effects were desirable for this character. The GCA effect for this trait ranged from -11.47 to 9.45. Among parents BUMOV 41212-3-1(9.45), Punjab Samrat (5.14), MVSR 6711-14-2(4.43), MBN 6242-3-1(1.52), BN-364 (1.44) and CFR 2211-2 (0.11) showed highly significant GCA effects and considered as good general combiners (Table 4.3.5). These results can be substantiated with the finding of Shohel Rana *et al* (2015). Among butternut and bushy parents, MVSR 6711-14-2, MBN 6242-3-1(1.52), BN-364 (1.44) and CFR 2211-2 presented high additive genetic component for vitamin-C and can help in improving its level in butternut fruit type and bush type selections in pumpkin.

4.3.25 Total sugar (mg/100g DW.)

For total sugar, positive GCA effects were desirable. The GCA effect for this trait was ranged from -0.23 to 0.15. Among parents, only BUMOV-41212-3-1 (0.15) showed highly significant GCA effects in positive direction and considered as good general combiner (Table 4.3.5). Shohel Rana *et al* (2015) in pumpkin, Janaranjani *et al* (2016) in bottle gourd and Bahari *et al* (2012) in watermelon also reported similar results. MVSR 6711-14-2 (0.01) as bushy parent was average combiner for total sugar and its additive genetic component can help in improving sugar level in butter nut fruit type through hybridization and selections in pumpkin.

Table 4.3.5: General combining ability effects of the parents for quality characters

Genotypes	TSS (°Brix)	Total carotenoids (mg/100 g FW)	Dry matter (%)	Vitamin-C (mg/100 g FW)	Total sugar (mg/100g DW.)
Punjab Samrat	0.01	-0.31	0.32**	5.14**	0.01
BUMOV 41212-3-1	-0.28	2.30**	0.11**	9.45**	0.15**
BN-364	-0.20	0.89**	-0.41	1.44**	-0.002
P-1343-17-5-3	0.44**	0.27**	0.88**	-5.69	-0.23
MVSR 6711-14-2	-0.27	0.21**	-0.89	4.43**	0.01
MSBN 3621-9-3-1	0.17**	-0.35	-0.41	-11.47	-0.02
B-10-224-3	0.91**	-1.02	0.07*	-4.95	0.01
MBN 6242-3-1	-1.17	-2.29	-0.85	1.52**	0.04
CFR 2211-2	0.39**	0.29**	1.20**	0.11**	0.01
CD at 5%	0.05	0.04	0.05	0.04	0.05
CD at 1%	0.07	0.06	0.07	0.06	0.07

*, ** Significant at 5% and 1% level, respectively.

4.4 SCA estimates of crosses

The results for specific combining ability effects (SCA) of various crosses obtained from diallel mating were presented and discussed as follows:

4.4.1 Vine length (cm)

Vine length determines the planting density of intensive cultivation under field conditions. The improvement of pumpkin towards bushy growth habit of vines would be preferable for this purpose. In present investigation, SCA effects of crosses for this trait ranged from -111.72 (BUMOV 41212-3-1 × MBN 6242-3-1) to -16.62 (BN-364 × P-1343-17-5-3) and observed in desirable direction (negative) in 19 crosses. All crosses with desirable effects unveiled significant SCA. BUMOV 41212-3-1 × MBN 6242-3-1 (-111.72) followed by PS × BUMOV 41212-3-1 (-92.69) and PS × BN-364 (-85.00) were top crosses (Table 4.4.1) with desirable SCA values. PS, BUMOV 41212-3-1 and MBN 6242-3-1 with poor GCA were parents of first two hybrids with high SCA effects that indicated the predominance non-additive gene effects in the inheritance of smaller vines. Therefore, heterosis breeding is better option for the improvement of bushy trait in pumpkin. Similar results of SCA for greater vine length were earlier presented in pumpkin (Nisha and veeraragavathatham 2014 and Hussien and Hamed 2015, Tamil Selvi *et al* 2015), luffa (Tyagi *et al* (2010), bottle gourd (Janaranjani *et al* 2016) and watermelon (Bahari *et al*. 2012), but this study was concentrated on bushy growth of pumpkin for permoting intensive cultivation.

4.4.2 Internodal length (cm)

The reduced internodal length permotes bushy growth habit in pumpkin. The SCA effects for this character were in desirable direction in 18 crosses, but significantly desirable only in 17 crosses, that ranged from -2.33 (PS × P-1343-17-5-3) to -0.56 (MSBN 3621-9-3-1 × MBN 6242-3-1). PS × P-1343-17-5-3 (-2.33) followed by PS × MSBN 3621-9-3-1 (-2.06), PS × BUMOV 41212-3-1 (-1.57), PS × BN-364 (-1.57) and P-1343-17-5-3 × MBN 6242-3-1 (-1.48) were observed as best crosses for reduced internodal length and adjusted as good specific combiners (Table 4.4.1). One of the parents in best crosses involving BN parent (PS × MSBN 3621-9-3-1 and PS × BN-364) crosses was poor general combiner, while other was good or average general combiner for internodal length. Therefore, heterosis breeding and random crossing along with selection among the segregates (recurrent selection) may be utilized to exploit both additive as well as non additive genetic effects in these specific crosses.

4.4.3 Leaf length (cm)

Increased leaf length is required for increased photosynthetic activity and shading effects to the fruits can save from scald in summer months. The SCA effects for this character were positive in 21 crosses, but significant and desirable (positive) only in 10 crosses. The significant and desirable SCA effects ranged between 3.59 (PS × BUMOV 41212-3-1) and 0.72 (MVSR 6711-14-2 × CFR 2211-2). PS × BUMOV 41212-3-1 (3.59) followed by BN-364 × B-10-224-3 (3.21), BN-364 × MVSR 6711-14-2 (1.85) and BN-364 × MBN 6242-3-1 (1.54) were best crosses for leaf length and considered as good specific combiners

(Table 4.4.1). The best crosses for leaf length involving bushy and BN parent viz; BN-364 × B-10-224-3 and BN-364 × MBN 6242-3-1 involved good general combiners indicating the predominance of additive and additive × additive genetic variance that can be exploited through hybridization and selection, while cross BN-364 × MVSR 6711-14-2 resulted from good and poor general combiners depicting the occurrence of both additive and non additive genetic variance that suggested heterosis breeding and recurrent selection methods for improvement of this trait.

4.4.4 Leaf width (cm)

Increased leaf length is also indicator of increased photosynthetic activity and shading effect on fruits in hot summers. The SCA effects for this character were positive in 19 crosses, but only 10 crosses were significantly desirable (positive). The significant and desirable SCA effects ranged between 4.13 (BN-364 × B-10-224-3) to 1.05 (BUMOV 41212-3-1 × CFR 2211-2). BN-364 × B-10-224-3 (4.13) followed by PS × BUMOV 41212-3-1 (3.79), BN-364 × MBN 6242-3-1 (2.87) and PS × MBN 6242-3-1 (2.29), were best crosses with highest positive and desirable SCA estimates and considered as good specific combiners (Table 4.4.1). Top two crosses involving BN parents (BN-364 × B-10-224-3 and BN-364 × MBN 6242-3-1 were resulted from good general combiners, unveiling the predominance of additive and additive × additive genetic variance for leaf width that can be exploited through hybridization and selection.

4.4.5 Petiole length (cm)

Less petiole length is desirable for bushy growth. The SCA effects for this character were in desirable direction in 21 cross, but significant only in 11 crosses. The significant and desirable SCA effects for this trait ranged from -5.51 (PS × BN-364) to -1.85 (P-1343-17-5-3 × MVSR 6711-14-2). PS × BN-364 (-5.51) followed by BUMOV 41212-3-1 × BN-364 (-5.48), P-1343-17-5-3 × CFR 2211-2 (-3.97) and BUMOV 41212-3-1 × P-1343-17-5-3 (-3.73), BUMOV 41212-3-1 × P-1343-17-5-3 were the best crosses for improvement in petiole length (Table 4.4.1). The combination of good and poor general combiners in cross PS × BN-364 highlighted the involvement of both additive as well as non additive gene effects and suggested the improvement through heterosis breeding and recurrent selection, while both the poor general combiners in cross BUMOV 41212-3-1 × BN-364 advocated the improvement through heterosis breeding due to predominance of non-additive gene effects in this cross.

Table 4.4.1: Specific combining ability effects of F_1 hybrids for vegetative characters

F_1 hybrids	Vine length (cm)	Internodal length (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Number of primary branches
PS × BUMOV 41212-3-1	-92.69**	-1.57**	3.59**	3.79**	6.06**	-0.09
PS × BN-364	-85.00**	-1.57**	-1.19**	-0.45	-5.51**	0.16
PS × P-1343-17-5-3	-83.39**	-2.33**	-1.55**	-2.55**	-3.52**	-0.02
PS × MVSR 6711-14-2	52.18**	2.20**	-2.07**	-2.76**	-1.22	0.70**
PS × MSBN 3621-9-3-1	-50.42**	-2.06**	0.03	0.02	-0.11	0.03
PS × B-10-224-3	14.91*	-0.69**	-0.90**	-0.47	4.67**	0.12
PS × MBN 6242-3-1	-39.44**	-0.74**	0.98**	2.29**	-2.66**	-1.23**
PS × CFR 2211-2	159.04**	4.27**	1.50**	1.65**	0.20	-0.11
BUMOV 41212-3-1 × BN-364	80.39**	2.40**	-3.64**	-4.69**	-5.48**	0.65**
BUMOV 41212-3-1 × P-1343-17-5-3	109.59**	2.73**	-1.09**	-1.66**	-3.73**	-0.19*
BUMOV 41212-3-1 × MVSR 6711-14-2	-29.57**	0.16	-1.28**	-1.76**	-0.73	0.05
BUMOV 41212-3-1 × MSBN 3621-9-3-1	79.89**	0.56**	0.69*	1.68**	4.60**	-0.05
BUMOV 41212-3-1 × B-10-224-3	-51.19**	-0.73**	-1.02**	-1.26**	-0.75	-0.53**
BUMOV 41212-3-1 × MBN 6242-3-1	-111.72**	-1.12**	-1.24**	-1.55**	-2.65**	0.40**
BUMOV 41212-3-1 × CFR 2211-2	-60.65**	-1.05**	0.33	1.05*	-0.75	-0.06
BN-364 × P-1343-17-5-3	-16.62*	0.20	-0.16	0.76	1.41	0.12
BN-364 × MVSR 6711-14-2	-25.92**	-0.93**	1.85**	1.80**	0.67	-0.41**
BN-364 × MSBN 3621-9-3-1	-18.58**	0.21	0.77*	0.64	4.87**	0.18
BN-364 × B-10-224-3	91.43**	1.18**	3.21**	4.13**	4.91**	-0.13

F_1 hybrids	Vine length (cm)	Internodal length (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Number of primary branches
BN-364 × MBN 6242-3-1	37.12**	0.02	1.54**	2.87**	2.73**	-0.19*
BN-364 × CFR 2211-2	35.99**	1.06**	0.36	0.39	-0.90	-0.12
P-1343-17-5-3 × MVSR 6711-14-2	-24.33**	-0.83**	0.04	0.82	-1.85*	-0.59**
P-1343-17-5-3 × MSBN 3621-9-3-1	23.32**	-0.16	1.28**	1.16*	1.01	-0.08
P-1343-17-5-3 × B-10-224-3	13.46*	0.38*	0.49	0.19	1.13	-0.23*
P-1343-17-5-3 × MBN 6242-3-1	-33.39**	-1.48**	0.27	0.64	-0.25	0.12
P-1343-17-5-3 × CFR 2211-2	-62.53**	-1.24**	0.09	0.04	-3.97**	-0.30**
MVSR 6711-14-2 × MSBN 3621-9-3-1	2.24	0.51**	0.187	-1.30*	-1.18	-0.53**
MVSR 6711-14-2 × B-10-224-3	171.60**	4.70**	0.10	-0.43	2.43**	-0.02
MVSR 6711-14-2 × MBN 6242-3-1	31.51**	0.73**	-1.03**	-0.84	2.38**	0.50**
MVSR 6711-14-2 × CFR 2211-2	31.39**	0.16	0.72*	1.10*	1.92*	0.06
MSBN 3621-9-3-1 × B-10-224-3	7.60	0.16	0.20	0.17	-0.12	1.16**
MSBN 3621-9-3-1 × MBN 6242-3-1	-55.03**	-0.56**	-1.45**	-1.62**	0.09	0.10
MSBN 3621-9-3-1 × CFR 2211-2	-50.94**	-0.60**	-2.03**	-2.76**	-2.49**	0.16
B-10-224-3 × MBN 6242-3-1	-68.01**	-1.47**	-1.42**	-1.17*	-2.72**	0.28**
B-10-224-3 × CFR 2211-2	-72.14**	-1.11**	-0.45	-0.02	-2.03**	-0.06
MBN 6242-3-1 × CFR 2211-2	10.22	0.32	0.54	0.11	-0.19	-0.21*
CD at 5%	12.72	0.37	0.68	0.99	1.47	0.18
CD at 1%	16.69	0.49	0.89	1.30	1.93	0.24

*, ** Significant at 5% and 1% level, respectively.

4.4.6 Number of primary branches

More number of branches diverts vines towards bushy growth habit. In present study, the SCA effects for this character were desirable in 16 crosses, but only 6 crosses were significant and desirable for more high number of branches. The significant and desirable SCA effects among these crosses ranged from 1.16 (MSBN 3621-9-3-1 × B-10-224-3) to 0.28 (B-10-224-3 × MBN 6242-3-1). MSBN 3621-9-3-1 × B-10-224-3 (1.16) followed by PS × MVSR 6711-14-2 (0.70), BUMOV 41212-3-1 × BN-364 (0.65) and MVSR 6711-14-2 × MBN 6242-3-1 (0.50) were best crosses with desirable SCA value, and considered as good specific combiners (Table 4.4.1). MSBN 3621-9-3-1 being good general combiner and B-10-224-3 as average general combiner were the parents of best cross for number of primary branches. Therefore, hybridization along with selection among the segregates may be utilized to harness additive and additive × additive genetic effects. The results were supported with the findings of Hussien and Hamed (2015) for number of primary branches in pumpkin and Janaranjani *et al* (2016) in bottle gourd.

4.4.7 Earliest node to female flower

The SCA effects for earliest node to female flower are enlisted in Table 4.4.2. Among 36 crosses, significant and desirable SCA estimates were noticed in sixteen crosses that ranged between -5.06 (BUMOV 41212-3-1 × CFR 2211-2) and -0.97 (PS × MBN 6242-3-1). BUMOV 41212-3-1 × CFR 2211-2 (-5.06) followed by B-10-224-3 × MBN 6242-3-1 (-3.64), BUMOV 41212-3-1 × B-10-224-3 (-3.52) and P-1343-17-5-3 × CFR 2211-2 (-3.18) were best crosses with desirable and significant SCA values for earliest node to female flowering. BUMOV 41212-3-1 × CFR 2211-2 (poor × good) cross suggested improvement through recurrent selection for high SCA effects. B-10-224-3 × MBN 6242-3-1 cross involving BN parent was the combination of two poor general combiners, unveiling the preponderance of non-additive especially complementary epistatic effects that can be utilized for commercial exploitation of heterosis. Tami Selvi *et al* (2013 and 2015), Nisha and Veeraragavathatham (2014) and Janaranjani *et al* (2016) also observed similar results in bottle gourd and pumpkin.

4.4.8 Days to 50 % female flowering

The SCA effects for 50 % female flowering are enlisted in Table 4.4.2. Among 36 crosses, significant and desirable SCA estimates were observed in 13 crosses that ranged between -12.41 (PS × P-1343-17-5-3) and -3.04 (MSBN 3621-9-3-1 × CFR 2211-2). PS × P-1343-17-5-3 (-12.41) followed by BUMOV 41212-3-1 × CFR 2211-2 (-9.41), BUMOV 41212-3-1 × B-10-224-3 (-7.65), PS × BN-364 (-5.26) and BN-364 × MSBN 3621-9-3-1(-5.20) were best crosses with highest desirable and significant SCA values for 50 %

percent female flowering and considered as good specific combiners. Among best crosses, PS × BN-364 and BN-364 × MSBN 3621-9-3-1 involved bushy and BN parents which are combination of Poor × poor and poor × good general combiners, respectively. PS × BN-364 had the preponderance of non-additive, especially complementary epistatic effects that can be utilized for commercial exploitation of heterosis, while occurrence of both additive as well as non additive gene effects in cross BN-364 × MSBN 3621-9-3-1suggested the improvement through heterosis breeding and recurrent selection.

4.4.9 Earliest node to male flower

The SCA effects for earliest node to male flower are enlisted in Table 4.4.2. Among 36 crosses, significant and desirable SCA estimates were revealed in 4 crosses that ranged between -0.37 and -0.22. PS × BN-364 (-0.37), BN-364 × MSBN 3621-9-3-1(-0.37), PS × MBN 6242-3-1 (-0.36), BUMOV 41212-3-1 × MBN 6242-3-1 (-0.22) were best crosses with desirable and significant SCA values for earliest node to male flower. Among these crosses high SCA in PS × BN-364 was resulted from poor combiners, while BN-364 × MSBN 3621-9-3-1, PS × MBN 6242-3-1, BUMOV 41212-3-1 × MBN 6242-3-1 involve one poor combiner and the other average or good combiner disclosing non-additive effects in first cross and both additive as well as non additive gene effects in later crosses. These results suggest the exploitation of heterosis breeding in first cross and heterosis as well as recurrent breeding in other three crosses. The results substantiated with the findings of Janaranjani *et al* (2016) in bottle gourd for earliest node to first male flower.

4.4.10 Days to 50 % male flowering

Days to 50 % male flowering represented (Table 4.4.2) significant and desirable SCA effects in 8 out of 36 crosses that ranged between -3.64 and -1.40. MVSR 6711-14-2 × MSBN 3621-9-3-1 (-3.64) followed by BN-364 × MSBN 3621-9-3-1 (-3.61), BN-364 × CFR 2211-2 (-2.64) and PS × MVSR 6711-14-2 (-2.40) were observed as best hybrids with highly significant and desirable SCA values for days to 50 % male flowering. Similar studies for early node to male flowering in luffa and bottle gourd has also been reported by Tyagi *et al* (2010) and Janaranjani *et al* (2016), respectively. First three crosses engaged bushy and BN parents. One good or average and one poor combiner in crosses MVSR 6711-14-2 × MSBN 3621-9-3-1, BN-364 × MSBN 3621-9-3-1and PS × MVSR 6711-14-2 highlighted both additive and non-additive effects thus improvement can be made through heterosis and recurrent breeding. However, BN-364 × CFR 2211-2 (average GCA × good GCA) displayed the cumulative additive effects for days to 50% flowering, where hybridization followed by pedigree selection can be used for this trait.

4.4.11 Node to first fruit

The earliest node of set fruit unveils earliness in hybrids. Among SCA effects of 36 hybrids for this character, significant and desirable (negative) SCA effects were seen in 17 crosses that ranged between -0.59 and -4.16. BUMOV 41212-3-1 × CFR 2211-2 (-4.16) followed by MSBN 3621-9-3-1 × CFR 2211-2 (-2.95), B-10-224-3 × CFR 2211-2 (-2.87) and PS × P-1343-17-5-3 (-2.76) were best hybrids with highly significant and desirable SCA values for earliest node to fruit (Table 4.4.3). High SCA for earliest node to fruit in cross BUMOV 41212-3-1 × CFR 2211-2 (poor GCA × good GCA) due to both additive and non-additive effects and in MSBN 3621-9-3-1 × CFR 2211-2 (good GCA × good GCA) as a result of high magnitude of cumulative effects of additive and additive × additive genes involving bushy and BN parents suggested recurrent selection in first and hybridization and selection in second can improve in earliest node to fruit. Other hybrids involving combination of one good and other poor combiner suggested improvement through heterosis breeding or recurrent selection for high SCA effects.

4.4.12 Days to fruit maturity

The lesser number of days to fruit maturity unveils earliness in hybrids. Among SCA effects of 36 hybrids for this character, significant and desirable (negative) SCA effects were seen in 16 crosses that ranged between -1.06 and -9.66. BUMOV 41212-3-1 × CFR 2211-2 (-9.66), followed by PS × P-1343-17-5-3 (-9.48) and B-10-224-3 × MBN 6242-3-1 (-7.06) were best hybrids with highly significant and desirable SCA values for days to fruit maturity (Table 4.4.3). However, high SCA estimates for days to fruit maturity in crosses PS × BN-364 (Poor × Good) , MSBN 3621-9-3-1 × CFR 2211-2 (good GCA × good GCA), MSBN 3621-9-3-1 × MBN 6242-3-1 (good GCA × poor GCA), MVSR 6711-14-2 × MBN 6242-3-1(good GCA × poor GCA) and BN-364 × MSBN 3621-9-3-1 (good GCA × good GCA) involving bush and BN parent. MSBN 3621-9-3-1 × CFR 2211-2 and BN-364 × MSBN 3621-9-3-1 with high magnitude of additive and additive × additive genes offered improvement through hybridization and selection, while occurrence of both additive and non-additive gene effects in three crosses suggested the improvement through heterosis breeding or recurrent selection for SCA. Similar result was reported by Tyagi *et al* (2010) in luffa.

Table 4.4.2: Specific combining ability effects of F_1 hybrids for flowering characters

F_1 hybrids	Earliest node to female flower	Days to 50% female flowering	Earliest node to male flower	Days to 50% male flowering	Node to first fruit	Days to fruit maturity
PS × BUMOV 41212-3-1	0.74*	-1.65	.051	4.89**	-1.43**	0.57
PS × BN-364	-1.81**	-5.26**	-0.37**	0.20	-2.62**	-5.24**
PS × P-1343-17-5-3	-2.45**	-12.41**	0.39**	3.89**	-2.76**	-9.48**
PS × MVSR 6711-14-2	3.67**	-4.32**	-0.03	-2.40**	0.75**	3.39**
PS × MSBN 3621-9-3-1	0.73*	-0.50	-0.37**	0.83	-0.78**	2.54**
PS × B-10-224-3	3.71**	2.73**	0.74**	2.56**	2.59**	2.00**
PS × MBN 6242-3-1	-0.97**	-4.62**	-0.36**	3.26**	-2.28**	-6.18**
PS × CFR 2211-2	5.70**	5.70**	0.02	1.20	1.50**	5.72**
BUMOV 41212-3-1 × BN-364	1.87**	27.43**	0.14	-1.31	2.11**	0.75*
BUMOV 41212-3-1 × P-1343-17-5-3	3.96**	1.92*	0.15	-0.64	3.31**	2.24**
BUMOV 41212-3-1 × MVSR 6711-14-2	-2.25**	-4.80**	0.13	-0.61	-1.87**	-6.03**
BUMOV 41212-3-1 × MSBN 3621-9-3-1	5.01**	3.55**	0.38**	-1.95**	4.18**	9.06**
BUMOV 41212-3-1 × B-10-224-3	-3.52**	-7.65**	-0.12	-0.70	-2.40**	-3.87**
BUMOV 41212-3-1 × MBN 6242-3-1	-1.05**	-4.44**	-0.22**	-0.67	-1.45**	1.30**
BUMOV 41212-3-1 × CFR 2211-2	-5.06**	-9.41**	-0.12	-1.67*	-4.16**	-9.66**
BN-364 × P-1343-17-5-3	-0.61	-3.56**	-0.10	1.38*	-1.62**	0.57
BN-364 × MVSR 6711-14-2	0.90**	8.83**	-0.11	0.32	1.58**	7.27**
BN-364 × MSBN 3621-9-3-1	-0.34	-5.20**	-0.10	-3.61**	-0.40	-2.00**
BN-364 × B-10-224-3	4.78**	5.92**	-0.03	1.62*	4.17**	9.06**

F_1 hybrids	Earliest node to female flower	Days to 50% female flowering	Earliest node to male flower	Days to 50% male flowering	Node to first fruit	Days to fruit maturity
BN-364 × MBN 6242-3-1	1.75**	0.13	0.11	-0.34	2.12**	4.24**
BN-364 × CFR 2211-2	-0.06	-3.83**	-0.08	-2.64**	-0.10	2.84**
P-1343-17-5-3 × MVSR 6711-14-2	-1.96**	1.25	-0.03	2.01**	-0.06	1.15**
P-1343-17-5-3 × MSBN 3621-9-3-1	0.78*	1.55	-0.03	-1.25	1.53**	2.54**
P-1343-17-5-3 × B-10-224-3	0.65	0.67	0.04	-1.67*	0.60*	-1.06**
P-1343-17-5-3 × MBN 6242-3-1	-1.28**	0.89	0.18*	0.68	-2.10**	-1.87**
P-1343-17-5-3 × CFR 2211-2	-3.18**	-0.07	-0.09	1.71*	-2.34**	-1.60**
MVSR 6711-14-2 × MSBN 3621-9-3-1	-0.28	0.28	0.04	-3.64**	0.56*	2.90**
MVSR 6711-14-2 × B-10-224-3	3.50**	1.73	0.11	0.59	4.81**	3.96**
MVSR 6711-14-2 × MBN 6242-3-1	-1.10**	-0.04	0.01	-1.04	0.84**	-3.84**
MVSR 6711-14-2 × CFR 2211-2	-1.25**	-0.68	-0.10	0.65	0.78**	-2.24**
MSBN 3621-9-3-1 × B-10-224-3	0.34	0.37	-0.03	-1.34	-0.09	1.36**
MSBN 3621-9-3-1 × MBN 6242-3-1	-1.52**	-0.07	-0.06	0.35	-1.38**	-4.45**
MSBN 3621-9-3-1 × CFR 2211-2	-1.92**	-3.04**	-0.09	-0.61	-2.95**	-5.18**
B-10-224-3 × MBN 6242-3-1	-3.64**	-3.95**	-0.06	-1.40*	-2.06**	-7.06**
B-10-224-3 × CFR 2211-2	-1.96**	-1.59	-0.10	1.62**	-2.87**	-6.45**
MBN 6242-3-1 × CFR 2211-2	-1.15**	-0.71	-0.12	-0.67	-0.59*	1.72**
CD at 5%	0.66	1.84	0.15	1.36	0.54	0.67
CD at 1%	0.87	2.41	0.19	1.79	0.71	0.88

*, ** Significant at 5% and 1% level, respectively.

4.4.13 Peduncle length (cm)

Small peduncle is required for the enhancement of concentrated bearing on bushy growth habit. The SCA effects for this character were in desirable trend in 20 crosses but only 15 crosses were significant that ranged from -2.79 (PS × BN-364) to -0.63 (BN-364 × P-1343-17-5-3). PS × BN-364 (-2.79) followed by B-10-224-3 × MBN 6242-3-1 (-2.71), PS × P-1343-17-5-3 (-2.56) and P-1343-17-5-3 × MBN 6242-3-1 (-2.16) were the best crosses and were adjusted as good specific combiners (Table 4.4.3). High SCA in PS × BN-364 (average GCA × average GCA) involving bushy and BN parent offered cumulative additive effects for peduncle length that suggested the use of hybridization followed by pedigree selection for this trait. However, high SCA in B-10-224-3 × MBN 6242-3-1 (poor GCA × poor GCA) presented the high magnitude of non-additive, especially complementary epistatic effects, which can be utilized through commercial exploitation of heterosis.

4.4.14 Polar diameter (cm)

Greater polar diameter is indirectly associated with high yield. The SCA effects for this character desirable and significant in 16 crosses and were ranged from 0.31 (MVSR 6711-14-2 × B-10-224-3) to 15.41 (B-10-224-3 × MBN 6242-3-1). B-10-224-3 × MBN 6242-3-1 (15.41) followed PS × B-10-224-3(11.48), PS × MBN 6242-3-1(9.26) and P-1343-17-5-3 × MBN 6242-3-1(6.93) were the best crosses with desirable SCA estimates and adjusted as good specific combiners (Table 4.4.3). High SCA in cross B-10-224-3 × MBN 6242-3-1 (good GCA × good GCA) involving BN parent indicated the role of cumulative additive gene effects for polar diameter of fruit that suggested the use of hybridization followed by pedigree selection for this trait. High SCA in crosses PS × MBN 6242-3-1(poor GCA × good GCA) and P-1343-17-5-3 × MBN 6242-3-1(poor GCA × good GCA) highlighted occurrence of both additive and non-additive effects for polar diameter, thus improvement can be made through heterosis and recurrent breeding. Our findings were in line with the report of Tyagi *et al* (2010) for fruit length in luffa.

4.4.15 Equatorial diameter (cm)

Smaller equatorial diameter is directly associated with BN fruit types. The SCA effects for this character were significant and desirable (negative) in 20 crosses and were ranged from -0.49 to -6.98. B-10-224-3 × MBN 6242-3-1 (-6.98) followed PS × B-10-224-3(-5.77), BUMOV 41212-3-1 × B-10-224-3(-4.72) and B-10-224-3× CFR 2211-2 (-4.23) were best crosses with highest desirable SCA values and adjusted as good specific combiners (Table 4.4.3). High SCA in cross B-10-224-3 × MBN 6242-3-1and B-10-224-3× CFR 2211-2 (both poor combiners) highlighted occurrence of non-additive effects, especially complementary epistasis for equatorial diameter thus improvement can be made through heterosis breeding. Shohel Rana *et al* (2015) reported positive and significant SCA for fruit breadth in pumpkin, but for the development of BN fruit shape improvement in negative direction is required.

Table 4.4.3: Specific combining ability effects of F_1 hybrids for fruit characters

F_1 hybrids	Peduncle length (cm)	Polar diameter (cm)	Equatorial diameter (cm)	Fruit shape index	Pulp thickness (cm)
PS × BUMOV 41212-3-1	0.34	-2.10	-3.80**	-0.006	-0.41
PS × BN-364	-2.79**	-5.99	-2.31**	-0.45	-0.28
PS × P-1343-17-5-3	-2.56**	4.30**	-3.56**	0.70**	-0.56
PS × MVSR 6711-14-2	3.30**	-1.92	4.02	-0.55	0.21**
PS × MSBN 3621-9-3-1	-2.15**	-6.94	1.68	-0.78	0.58**
PS × B-10-224-3	-0.74**	11.68**	-5.77**	1.36**	-1.11
PS × MBN 6242-3-1	-1.20**	9.26**	-4.51**	1.79**	-0.69
PS × CFR 2211-2	4.11**	-1.89	10.29	-0.82	1.03**
BUMOV 41212-3-1 × BN-364	0.98**	-0.64	3.33	-0.20	0.57**
BUMOV 41212-3-1 × P-1343-17-5-3	1.46**	1.66**	4.90	-0.07	0.31**
BUMOV 41212-3-1 × MVSR 6711-14-2	-0.44	-4.54	-0.57**	-0.30	-0.17
BUMOV 41212-3-1 × MSBN 3621-9-3-1	1.70**	2.11**	3.84	-0.24	0.28**
BUMOV 41212-3-1 × B-10-224-3	-1.06**	-0.22	-4.72**	0.33**	-0.93
BUMOV 41212-3-1 × MBN 6242-3-1	-1.71**	-2.88	0.24	-0.28	0.83**
BUMOV 41212-3-1 × CFR 2211-2	-1.54**	1.14**	-3.96**	0.39**	-0.82
BN-364 × P-1343-17-5-3	-0.63**	-2.29	0.71	-0.26	0.04
BN-364 × MVSR 6711-14-2	-0.06	-0.23	0.22	-0.04	0.18**
BN-364 × MSBN 3621-9-3-1	0.05	1.02**	-1.16**	0.15**	-0.25
BN-364 × B-10-224-3	2.77**	-1.64	4.19	-0.45	-0.06

F_1 hybrids	Peduncle length (cm)	Polar diameter (cm)	Equatorial diameter (cm)	Fruit shape index	Pulp thickness (cm)
BN-364 × MBN 6242-3-1	-0.24	-1.10	-1.21**	-0.11	0.57**
BN-364 × CFR 2211-2	1.89**	3.07**	2.14	0.0003	0.34**
P-1343-17-5-3 × MVSR 6711-14-2	-1.99**	-1.23	-2.69**	0.09**	0.02
P-1343-17-5-3 × MSBN 3621-9-3-1	-0.11	4.66**	-1.37**	0.66**	-0.05
P-1343-17-5-3 × B-10-224-3	0.18	-0.74	1.60	-0.27	0.12*
P-1343-17-5-3 × MBN 6242-3-1	-2.16**	6.93**	-4.14**	1.04**	-0.64
P-1343-17-5-3 × CFR 2211-2	-1.94**	-4.18	-2.63**	-0.20	-0.36
MVSR 6711-14-2 × MSBN 3621-9-3-1	0.53*	1.69**	-1.78**	0.19**	0.01
MVSR 6711-14-2 × B-10-224-3	4.63**	0.31**	7.29	-0.36	0.36**
MVSR 6711-14-2 × MBN 6242-3-1	0.73**	2.62**	-0.49**	0.08**	-0.70
MVSR 6711-14-2 × CFR 2211-2	1.87**	1.90**	4.56	-0.03	1.04**
MSBN 3621-9-3-1 × B-10-224-3	1.75**	-7.61	4.42	-0.98	0.31**
MSBN 3621-9-3-1 × MBN 6242-3-1	-1.77**	-6.33	-1.44**	-0.58	0.03
MSBN 3621-9-3-1 × CFR 2211-2	-1.58**	-8.12	-0.77**	-0.69	-0.11
B-10-224-3 × MBN 6242-3-1	-2.71**	15.41**	-6.98**	2.29**	-0.87
B-10-224-3 × CFR 2211-2	-2.11**	1.56**	-4.23**	0.31**	-0.17
MBN 6242-3-1 × CFR 2211-2	2.15**	-4.15	2.64	-0.48	0.18**
CD at 5%	0.47	0.15	0.14	0.02	0.09
CD at 1%	0.62	0.20	0.18	0.02	0.12

*, ** Significant at 5% and 1% level, respectively.

4.4.16 Fruit shape index

High fruit shape index is an indicator of butternut fruit type. Therefore, positive SCA effects were desirable and significant in 13 crosses. In present investigation, the significant and desirable SCA effects ranged between 0.08 (MVSR 6711-14-2 × MBN 6242-3-1) to 2.29 (B-10-224-3 × MBN 6242-3-1). The best crosses with highest positive and desirable SCA value were B-10-224-3 × MBN 6242-3-1(2.29) followed by PS × MBN 6242-3-1 (1.79), PS × B-10-224-3 (1.36), P-1343-17-5-3 × MBN 6242-3-1 (1.04) and PS × P-1343-17-5-3 (0.70), thus, adjusted as good specific combiners (Table 4.4.3). High SCA for fruit shape index in cross B-10-224-3 × MBN 6242-3-1(2.29) (Good GCA × Poor GCA), PS × MBN 6242-3-1(1.04) (Good GCA × Poor GCA) highlighted occurrence of both additive and non-additive effects for fruit shape index thus improvement in fruit shape can be made through heterosis breeding and recurrent selection for SCA.

4.4.17 Pulp thickness (cm)

More pulp thickness in pumpkin increases the edible part of fruit by reducing the seed cavity, simultaneously. In present investigation, desirable SCA effects for this character were observed in 19 crosses, but only 15 crosses were significant and desirable (positive) that ranged from 0.12 (P-1343-17-5-3 × B-10-224-3) to 1.04 (MVSR 6711-14-2 × CFR 2211-2). MVSR 6711-14-2 × CFR 2211-2 (1.04) followed by PS × CFR 2211-2 (1.03), BUMOV 41212-3-1 × MBN 6242-3-1(0.83) and PS × MSBN 3621-9-3-1(0.58) were the best crosses with highest positive and desirable SCA value for pulp thickness and considered as good specific combiners (Table 4.4.3). High SCA in crosses MVSR 6711-14-2 × CFR 2211-2 (good GCA × good GCA), BUMOV 41212-3-1 × MBN 6242-3-1(good GCA × good GCA) and PS × MSBN 3621-9-3-1(poor GCA × poor GCA) involving bushy and BN parents might be due to high magnitude of cumulative effects of additive and additive × additive genes in first and high frequency of complementary epistatic effects due to non- additive genes. Hybridization and selection can improve in this character in earlier cross and heterosis breeding can be exploited in the later cross. Tamil Selvi *et al* (2013) and Shohel Rana *et al* (2015) reported similar results for pulp thickness on the basis of high SCA effects in pumpkin.

4.4.18 Number of fruits per vine

The number of fruits per vine is directly related to yield potential of a hybrid. The SCA effects for this character (Table 4.4.4) were significantly desirable only in 8 out of 36 hybrids that ranged between 0.35 and 0.77. B-10-224-3 ×MBN 6242-3-1 (0.77), BUMOV 41212-3-1 ×B-10-224-3 (0.51), BUMOV 41212-3-1×CFR 2211-2(0.43) were the best hybrids with highly significant and desirable SCA values for number of fruits per vine (Table 4.4.4). High SCA effect for number of fruits per vine in cross B-10-224-3 ×MBN 6242-3-1 (poor

GCA × poor GCA) might be due to high magnitude of non-additive especially complementary epistatic effects that can be exploited commercially through heterosis breeding for increasing number of fruits per vine. These results were confirmed with the reports of Tamil Selvi *et al* (2013 and 2015) and El-Tahawey (2015) in pumpkin and Janaranjani *et al* (2016) in bottle gourd.

4.4.19 Average fruit weight (kg)

There is need to economise the fruit size in pumpkin. Also the breeding for bushy and butternut pumpkins would have to rely upon compromising the fruit weight. The SCA effects for this character were significant and desirable (negative) in 16 crosses that ranged from -0.22 (BN-364 × MBN 6242-3-1) to -1.28 (B-10-224-3 × MBN 6242-3-1). B-10-224-3 × MBN 6242-3-1(-1.22) followed by P-1343-17-5-3 × MBN 6242-3-1 (-0.73), MSBN 3621-9-3-1 × MBN 6242-3-1 (-0.70) and BUMOV 41212-3-1 × B-10-224-3 (-0.70) were best crosses with highest negative and desirable SCA value for less average fruit weight and were adjusted as good specific combiners (Table 4.4.4). High SCA for less fruit weight in cross B-10-224-3 × MBN 6242-3-1 (poor GCA × poor GCA) and P-1343-17-5-3 × MBN 6242-3-1 (good GCA × poor GCA) involving bushy and BN parents were the result of occurrence of non-additive gene effects in first and both additive and non-additive gene effects in second for less fruit weight that can be exploited through heterosis breeding and recurrent selection. Nisha and Veeraragavathatham (2014) also reported best specific combiners for higher fruit weight in pumpkin.

4.4.20 Fruit yield per vine (kg)

The SCA effects for this character were positive in 14 crosses but out of them only 7 crosses showed significant and desirable (positive) SCA effects, that ranged from 0.96 (MVSR 6711-14-2 × CFR 2211-2) to 2.34 (MVSR 6711-14-2 × B-10-224-3). MVSR 6711-14-2 × B-10-224-3 (2.34) followed by PS × CFR 2211-2 (2.09), BUMOV 41212-3-1 × MSBN 3621-9-3-1 (1.68) and BUMOV 41212-3-1 × P-1343-17-5-3 (1.59) were best crosses with highest positive and desirable SCA value for fruit yield per vine and considered as good specific combiners (Table 4.4.4). High SCA effects for fruit yield in cross MVSR 6711-14-2 × B-10-224-3 (poor GCA×good GCA) followed by PS × CFR 2211-2 (poor GCA×poor GCA), BUMOV 41212-3-1 × MSBN 3621-9-3-1 (good GCA × poor GCA) and BN-364 × B-10-224-3 (poor GCA × good GCA) involving bushy and BN parents were the result of occurrence of both additive and non-additive gene effects that can be exploited through heterosis breeding and recurrent selection. Tamil Selvi *et al* (2013 and 2015) and Tyagi *et al* (2010) also reported best specific combiners for high yield in pumpkin and luffa, respectively.

Table 4.4.4: Specific combining ability effects of F_1 hybrids for yield characters

F_1 hybrids	Number of Fruits per vine	Average fruit weight (kg)	Fruit yield/ vine (kg)
PS × BUMOV 41212-3-1	-0.49**	-0.52**	-1.36**
PS × BN-364	-0.43*	-0.53**	-0.99*
PS × P-1343-17-5-3	-0.15	-0.55**	-0.93*
PS × MVSR 6711-14-2	0.11	0.23*	0.72
PS × MSBN 3621-9-3-1	-0.36*	-0.11	-0.48
PS × B-10-224-3	-0.04	-0.67**	-1.13*
PS × MBN 6242-3-1	0.35*	-0.43**	-0.50
PS × CFR 2211-2	-0.56**	2.56**	2.09**
BUMOV 41212-3-1 × BN-364	-0.27	0.19	0.26
BUMOV 41212-3-1 × P-1343-17-5-3	0.00	0.90**	1.59**
BUMOV 41212-3-1 × MVSR 6711-14-2	-0.007	-0.17	-0.51
BUMOV 41212-3-1 × MSBN 3621-9-3-1	-0.18	0.94**	1.68**
BUMOV 41212-3-1 × B-10-224-3	0.51**	-0.70**	-0.94*
BUMOV 41212-3-1 × MBN 6242-3-1	-0.43	-0.32**	-1.08*
BUMOV 41212-3-1 × CFR 2211-2	0.43*	-0.53**	-0.85
BN-364 × P-1343-17-5-3	0.33	-0.03	0.07
BN-364 × MVSR 6711-14-2	-0.55**	0.22	-0.06
BN-364 × MSBN 3621-9-3-1	0.24	-0.12	-0.17
BN-364 × B-10-224-3	-0.47**	1.19**	1.42**
BN-364 × MBN 6242-3-1	0.40*	-0.22	0.41
BN-364 × CFR 2211-2	0.007	0.06	0.25
P-1343-17-5-3 × MVSR 6711-14-2	0.29	-0.18	-0.16
P-1343-17-5-3 × MSBN 3621-9-3-1	0.25	0.24*	0.46
P-1343-17-5-3 × B-10-224-3	-0.12	0.08	0.13
P-1343-17-5-3 × MBN 6242-3-1	-0.33	-0.73**	-1.43**
P-1343-17-5-3 × CFR 2211-2	-0.39*	-0.49**	-1.11*
MVSR 6711-14-2 × MSBN 3621-9-3-1	-0.12	-0.07	-0.15
MVSR 6711-14-2 × B-10-224-3	-0.01	1.39**	2.34**
MVSR 6711-14-2 × MBN 6242-3-1	0.28	-0.37**	-0.11
MVSR 6711-14-2 × CFR 2211-2	-0.19	0.84**	0.96*
MSBN 3621-9-3-1 × B-10-224-3	-0.46**	0.19	-0.01
MSBN 3621-9-3-1 × MBN 6242-3-1	-0.17	-0.70**	-1.26**
MSBN 3621-9-3-1 × CFR 2211-2	0.26	-0.46**	-0.58
B-10-224-3 × MBN 6242-3-1	0.77**	-1.28**	-1.55**
B-10-224-3 × CFR 2211-2	-0.28	-0.57**	-1.36**
MBN 6242-3-1 × CFR 2211-2	0.09	0.49**	1.08*
CD at 5%	0.34	0.22	0.89
CD at 1%	0.45	0.30	1.17

*, ** Significant at 5% and 1% level, respectively.

4.4.21 TSS (ºBrix)

The SCA effects for this character were desirable in 18 crosses, but significant and desirable (positive) in 17 crosses that ranged from 0.30 (MVSR 6711-14-2 × CFR 2211-2) to 3.75 (P-1343-17-5-3 × B-10-224-3). P-1343-17-5-3 × B-10-224-3 (3.75) followed by P-1343-17-5-3 × MBN 6242-3-1 (3.15), PS × BN-364 (2.83) and PS × BUMOV 41212-3-1 (2.65), were best crosses with highest positive and desirable SCA value for TSS and considered as good specific combiners (Table 4.4.5). The involvement of one good/average and the other poor general combiner in crosses (P-1343-17-5-3 × MBN 6242-3-1 and PS × BN-364) with bushy and BN parents highlighted the occurrence of both additive and non-additive gene effects for TSS that can be exploited through heterosis breeding and recurrent selection. Shohel Rana *et al* (2015) and Janaranjani *et al* (2016) identified best specific combiners for high TSS in pumpkin and bottle gourd, respectively.

4.4.22 Total carotenoids (mg/100 g FW)

The SCA effects for this character were positive in 14 crosses, but significant and desirable (positive) only in 13 crosses that ranged from 2.66 (PS × B-10-224-3) to 10.92 (P-1343-17-5-3 × B-10-224-3). P-1343-17-5-3 × B-10-224-3(10.92) followed by BUMOV 41212-3-1 × CFR 2211-2 (10.91), P-1343-17-5-3 × MBN 6242-3-1(9.09) and P-1343-17-5-3 × MSBN 3621-9-3-1(8.48) were the best crosses with highest positive and desirable SCA value for total carotenoids and considered as good specific combiners (Table 4.4.5). BUMOV 41212-3-1 × CFR 2211-2 involved both good combiners and suggested the predominance of additive genetic variance. The involvement of one good × poor general combiner in crosses (P-1343-17-5-3 × MBN 6242-3-1and P-1343-17-5-3 × MSBN 3621-9-3-1) with bushy and BN parents unveiled the occurrence of both additive and non-additive gene effects for total carotenoids that can be exploited through heterosis breeding and recurrent selection. The results were supported with the findings of Tamil Selvi *et al* (2013) and Shohel Rana *et al* (2015) for high SCA effects in pumpkin.

4.4.23 Dry matter (%)

The increased dry matter is responsible for better storage quality of pumpkin. The SCA effects for this character were positive in 16 crosses and significant and desirable (positive) in 15 crosses that ranged from 0.40 (BN-364 × MVSR 6711-14-2) to 6.79 (PS × BUMOV 41212-3-1). PS × BUMOV 41212-3-1 (6.79) followed by P-1343-17-5-3 × MBN 6242-3-1(5.22), PS × BN-364 (3.89) and MSBN 3621-9-3-1 × CFR 2211-2 (3.69) were best crosses with highest positive and desirable SCA value for dry matter (%) (Table 4.4.5). The connection of one good × poor general combiner in crosses (P-1343-17-5-3 × MBN 6242-3-1 and PS × BN-364) with bushy and BN parents unveiled the occurrence of both additive and non-additive gene effects for dry matter that can be exploited through heterosis breeding and recurrent selection. The results were supported with the findings of Shohel Rana *et al* (2015) for high SCA effects in pumpkin.

Table 4.4.5: Specific combining ability effects of F_1 hybrids for quality characters

F_1 hybrids	TSS (°Brix)	Total carotenoids (mg/100 g FW)	Dry matter (%)	Vitamin-C (mg/100 g FW)	Total sugar (mg/100g DW.)
PS × BUMOV 41212-3-1	2.65**	8.41**	6.79**	116.52**	-0.17
PS × BN-364	2.83**	4.11**	3.89**	10.48**	-0.79
PS × P-1343-17-5-3	-1.73	-2.21	-1.09	-18.47	0.38**
PS × MVSR 6711-14-2	-1.87	-6.57	-2.23	-35.07	0.79**
PS × MSBN 3621-9-3-1	-1.25	-6.01	-2.64	-16.94	-0.54
PS × B-10-224-3	0.81**	2.66**	-3.14	-10.58	-0.57
PS × MBN 6242-3-1	-0.13	-3.28	0.94**	-21.42	-0.47
PS × CFR 2211-2	-3.38	-0.81	-3.15	3.98**	0.48**
BUMOV 41212-3-1 × BN-364	0.33**	-7.24	-1.32	-6.79	0.39**
BUMOV 41212-3-1 × P-1343-17-5-3	1.38**	-1.76	-0.39	-14.92	-0.67
BUMOV 41212-3-1 × MVSR 6711-14-2	-3.40	-7.65	-2.63	-39.38	0.27**
BUMOV 41212-3-1 × MSBN 3621-9-3-1	-0.36	0.01	-1.46	14.09**	0.04
BUMOV 41212-3-1 × B-10-224-3	-1.05	-4.14	-3.92	-21.45	0.42**
BUMOV 41212-3-1 × MBN 6242-3-1	1.41**	-0.90	1.64**	7.55**	0.37**
BUMOV 41212-3-1 × CFR 2211-2	-1.79	10.91**	0.75**	-9.85	0.23**
BN-364 × P-1343-17-5-3	-1.35	-5.77	-2.20	-7.63	-0.26
BN-364 × MVSR 6711-14-2	0.12	2.87**	0.40**	-1.87	-0.54
BN-364 × MSBN 3621-9-3-1	-0.92	-1.32	-1.01	14.19**	-0.46
BN-364 × B-10-224-3	-1.50	7.34**	-2.84	2.34**	0.56**
BN-364 × MBN 6242-3-1	1.76**	3.29**	1.33**	-0.45	0.41**

F_1 hybrids	TSS (°Brix)	Total carotenoids (mg/100 g FW)	Dry matter (%)	Vitamin-C (mg/100 g FW)	Total sugar (mg/100g DW.)
BN-364 × CFR 2211-2	-1.13	-1.28	2.22**	17.05**	0.51**
P-1343-17-5-3 × MVSR 6711-14-2	-1.65	-4.10	-3.72	-2.61	-0.28
P-1343-17-5-3 × MSBN 3621-9-3-1	-1.62	8.48**	-0.12	13.19**	-0.35
P-1343-17-5-3 × B-10-224-3	3.75**	10.92**	3.37**	65.43**	0.71**
P-1343-17-5-3 × MBN 6242-3-1	3.15**	9.09**	5.22*	22.70**	-0.52
P-1343-17-5-3 × CFR 2211-2	1.21**	-2.20	-0.74	0.19**	-0.27
MVSR 6711-14-2 × MSBN 3621-9-3-1	0.61**	-2.76	-1.26	-4.81	-0.48
MVSR 6711-14-2 × B-10-224-3	2.36**	4.47**	2.06**	39.51**	0.48**
MVSR 6711-14-2 × MBN 6242-3-1	0.94**	-3.16	-0.81	-11.32	0.46**
MVSR 6711-14-2 × CFR 2211-2	0.30**	-3.47	-0.74	6.02**	0.17*
MSBN 3621-9-3-1 × B-10-224-3	-0.51	-3.13	-1.43	-0.52	0.56**
MSBN 3621-9-3-1 × MBN 6242-3-1	0.93**	-3.46	0.45**	-3.36	-0.53
MSBN 3621-9-3-1 × CFR 2211-2	-1.50	4.01**	3.69**	-1.77	0.48**
B-10-224-3 × MBN 6242-3-1	0.47**	-4.49	1.72**	-6.97	-0.60
B-10-224-3 × CFR 2211-2	-0.66	-3.97	0.08	-21.40	-0.52
MBN 6242-3-1 × CFR 2211-2	0.91**	4.72**	1.16**	7.50**	0.36**
CD at 5%	0.16	0.14	0.15	0.14	0.15
CD at 1%	0.21	0.18	0.20	0.18	0.20

*, ** Significant at 5% and 1% level, respectively.

4.4.24 Vitamin-C (mg/100 g FW)

The SCA effects for this character were positive in 15 crosses and all of those were significant and in desirable direction that ranged from 0.19 (P-1343-17-5-3 × CFR 2211-2) to 116.62 (PS × BUMOV 41212-3-1). PS × BUMOV 41212-3-1(116.52) followed by P-1343-17-5-3 × B-10-224-3(65.43), MVSR 6711-14-2 × B-10-224-3(39.51) and P-1343-17-5-3 × MBN 6242-3-1(22.70) were the best crosses with highly desirable SCA estimates and considered good specific combiners (Table 4.4.5). The combination of one good × poor general combiner in crosses MVSR 6711-14-2 × B-10-224-3 and P-1343-17-5-3 × MBN 6242-3-1with bushy and BN parents unveiled the occurrence of both additive and non-additive gene effects for vitamin-C content that can be exploited through heterosis breeding and recurrent selection.

4.4.25 Total sugar (mg/100g DW.)

The SCA effects for this character were positive in 19 crosses and out of those only 18 crosses had shown significant and desirable (positive) effects that ranged from 0.04 (BUMOV 41212-3-1 × MSBN 3621-9-3-1) to 0.79 (PS × MVSR 6711-14-2). PS × MVSR 6711-14-2 (0.79) followed by P-1343-17-5-3 × B-10-224-3 (0.56) and MSBN 3621-9-3-1 × B-10-224-3 (0.56) were the best crosses with highest positive and desirable SCA estimates and considered as good specific combiners (Table 4.4.5). The connection of average × average and average × poor general combiner in crosses PS × MVSR 6711-14-2 and PS × BN-364, respectively unveiled the occurrence of both additive in first and non-additive gene effects for total sugar in second that can be exploited through heterosis breeding and recurrent selection for SCA. The results were supported with the findings of Shohel Rana *et al* (2015) for high SCA effects in pumpkin.

4.5 Heterobeltiosis and economic heterosis

The results pertaining to mean performance and per cent heterobeltiosis and commercial heterosis over check hybrids, PPH-1 and PPH-2 are described in the Tables 4.5.

4.5.1 Vine length (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis for short vines over PPH-1 and PPH-2 ranged from -26.07 to 220.40%, -62.42 to 243.27% and -51.54 to 342.62%, respectively. Only one cross-combinations i.e. BN-364 × CFR 2211-2 (-26.07%) had significantly desirable heterobeltiosis, while sixteen and eight hybrids exhibited desirable significant heterosis over PPH-1 and PPH-2 for short vines. The maximum economic heterosis over both checks was shown by BN-364 × MVSR 6711-14-2 (-62.42 and -51.54%, respectively), followed by BN-364 × CFR 2211-2 (-60.82 and -49.48%, respectively) and MVSR 6711-14-2 × MSBN 3621-9-3-1 (-54.05 and -40.76%, respectively) (Table 4.5.1). All these crosses are fusion of bushy and BN parents and these hybrids can be exploited for commercial cultivation. Most of researchers like Nisha and Veeraragavathatham (2014), Hussien and Hamed (2015) and Davoodi *et al* (2016) in pumpkin, Hanchinamani and patil (2009) in cucumber, Narasannavar *et al* (2014) in ridge gourd worked in the direction of increased vine length, but our study was concentrated on bushy growth habit of the pumpkin that was only reported by for vine length in pumpkin.

4.5.2 Internodal length (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for internodal length ranged from -3.88 to 157.60%, -35.04 to 248.71% and 46.28 to 188.33% respectively. Only one cross-combinations i.e. MVSR 6711-14-2 × MSBN 3621-9-3-1(-3.88%) had significantly desirable heterobeltiosis, while nine and sixteen hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for internodal length. The maximum economic heterosis for this trait over both checks was shown by BN-364 × CFR 2211-2 (-35.04 and -46.28%), followed by BN-364 × MBN 6242-3-1 (-26.06 and -38.86%) and BN-364 × MSBN 3621-9-3-1 (-23.07 and-36.39%) (Table 4.5.1). All these crosses are fusion of bushy and BN parents and these hybrids can be exploited for commercial cultivation.

4.5.3 Leaf length (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for leaf length ranged from -26.18 to 89.74%, -13.13 to 36.75% and 0.16 to 57.69%, respectively. B-10-224-3 × CFR 2211-2 (89.74%), followed by MBN 6242-3-1 × CFR 2211-2 (18.21%) and PS × MBN 6242-3-1(8.16%) had maximum heterobeltiosis out of ten significantly desirable cross-combinations, while 24 and 35 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for leaf length. The maximum economic heterosis for this trait was shown by BUMOV 41212-3-1 × B-10-224-3 (36.75 and 57.69%, respectively), followed by BUMOV 41212-3-1 × MBN 6242-3-1 (28.83 and 48.56%, respectively) and MBN 6242-3-1 × CFR 2211-2 (27.58 and 47.12%, respectively) (Table 4.5.2). MBN 6242-3-1 × CFR 2211-2 was fusion of bushy and BN parents and its very high heterosis for leaf length provided a scope for development of hybrids with more vegetative growth. High heterosis for greater leaf length was also reported by El-Tahawey *et al* (2015) in pumpkin.

4.5.4 Leaf width (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for leaf width ranged from -19.55 to 16.24%, -8.37 to 38.13% and 3.51 to 56.06%, respectively. MBN 6242-3-1 × CFR 2211-2 (16.24%) followed by PS × BN-364 (10.18%) and PS × MBN 6242-3-1 (6.97%) had maximum heterobeltiosis out of seven significantly desirable cross-combinations, while 29 and 36 hybrids exhibited significantly desirable

Table 4.5.1: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for vine length (cm) and internodal length (cm)

F_1 Hybrid	Vine length (cm)				Internodal length (cm)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	223.67	191.31	167.32	244.69	3.38	39.09	44.44	19.43
PS × BN-364	77.44	74.65	-7.44	19.34	2.72	117.60	16.23	-3.88**
PS × P-1343-17-5-3	224.33	61.00	168.11	245.70	6.04	16.15	158.11	113.42
PS × MVSR 6711-14-2	73.78	100.00	-11.82	13.70	3.33	55.60	42.30	17.66
PS × MSBN 3621-9-3-1	73.11	67.41	-12.62	12.66	3.00	45.63	28.20	6.00
PS × B-10-224-3	287.22	33.18	243.27	342.62	6.40	23.07	173.50	126.14
PS × MBN 6242-3-1	179.22	1.63	114.19	176.19	3.43	17.86	46.58	21.20
PS × CFR 2211-2	70.89	22.92	-15.27	9.24	2.99	85.71	27.77	5.65
BUMOV 41212-3-1 × BN-364	52.00	17.27	-37.85**	-19.86	2.30	84.00	-1.70**	-18.72**
BUMOV 41212-3-1 × P-1343-17-5-3	171.89	123.87	105.43	164.89	4.31	77.36	84.18	52.29
BUMOV 41212-3-1 × MVSR 6711-14-2	45.00	21.98	-46.21**	-30.65**	2.96	38.31	26.49	4.59
BUMOV 41212-3-1 × MSBN 3621-9-3-1	39.00	-10.69	-53.38**	-39.89**	2.67	29.61	14.10	-5.65**
BUMOV 41212-3-1 × B-10-224-3	174.00	126.62	107.95	168.14	4.50	85.18	92.30	59.01
BUMOV 41212-3-1 × MBN 6242-3-1	178.00	131.83	112.74	174.31	3.72	53.08	58.97	31.44
BUMOV 41212-3-1 × CFR 2211-2	70.44	22.14	-15.81	8.55	2.42	50.31	3.41	-14.48**
BN-364 × P-1343-17-5-3	59.78	34.82	-28.55*	-7.87	2.67	113.60	14.10	-5.65**
BN-364 × MVSR 6711-14-2	31.44	-14.77	-62.42**	-51.54**	2.04	63.20	-12.82**	-27.91*
BN-364 × MSBN 3621-9-3-1	40.33	-7.64	-51.79**	-37.84**	1.80	44.00	-23.07**	-36.39**
BN-364 × B-10-224-3	55.44	25.03	-33.73**	-14.56	3.22	157.60	37.60	13.78

F_1 Hybrid	Vine length (cm)				Internodal length (cm)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × MBN 6242-3-1	66.89	50.85	-20.05	3.08	1.73	38.40	-26.06**	-38.86**
BN-364 × CFR 2211-2	32.78	-26.07*	-60.82**	-49.48**	1.52	21.60	-35.04**	-46.28**
P-1343-17-5-3 × MVSR 6711-14-2	70.11	90.05	-16.20	8.04	2.63	22.89	12.39	-7.06**
P-1343-17-5-3 × MSBN 3621-9-3-1	54.00	23.65	-35.46**	-16.78	3.09	50.00	32.05	9.18
P-1343-17-5-3 × B-10-224-3	248.33	78.23	196.79	282.69	8.16	53.38	248.71	188.33
P-1343-17-5-3 × MBN 6242-3-1	166.56	19.54	99.06	156.68	4.57	57.04	95.29	61.48
P-1343-17-5-3 × CFR 2211-2	161.44	179.93	92.94	148.79	3.53	119.25	50.85	24.73
MVSR 6711-14-2 × MSBN 3621-9-3-1	38.44	4.20	-54.05**	-40.76*	1.98	-3.88**	-15.38**	-30.03**
MVSR 6711-14-2 × B-10-224-3	45.56	23.50	-45.54**	-29.78**	2.70	26.16	15.38	-4.59**
MVSR 6711-14-2 × MBN 6242-3-1	41.22	11.73	-50.73**	-36.47**	2.34	9.34	0.00	-17.31**
MVSR 6711-14-2 × CFR 2211-2	40.33	9.32	-51.79**	-37.84**	1.86	15.52	-20.51**	-34.27**
MSBN 3621-9-3-1 × B-10-224-3	41.78	-4.32	-50.06**	-35.61**	2.89	40.29	23.50	2.12
MSBN 3621-9-3-1 × MBN 6242-3-1	53.22	21.86	-36.39**	-17.98	2.31	12.13	-1.28**	-18.37**
MSBN 3621-9-3-1 × CFR 2211-2	44.11	1.00	-47.28**	-32.02**	2.22	37.88	-5.12**	-21.55**
B-10-224-3 × MBN 6242-3-1	194.67	10.40	132.66	200.00	3.80	30.58	62.39	34.27
B-10-224-3 × CFR 2211-2	184.78	220.40	120.84	184.75	4.03	150.31	72.22	42.40
MBN 6242-3-1 × CFR 2211-2	161.33	179.74	92.81	148.62	2.93	81.98	25.21	3.53
CD at 5%	22.24	22.17			0.65	0.63		
CD at 1%	29.17	29.45			0.85	0.84		

*, ** Significant at 5% and 1% level, respectively.

Table 4.5.2: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for leaf length (cm) and leaf width (cm)

F_1 Hybrid	Leaf length (cm)				Leaf width (cm)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	17.34	-5.40	27.21**	46.70**	23.84	-3.40	28.03**	44.66**
PS × BN-364	14.51	5.22**	6.45**	22.75**	21.32	10.18**	14.50**	29.36**
PS × P-1343-17-5-3	11.84	-14.14	-13.13	0.16	17.06	-11.83	-8.37	3.51**
PS × MVSR 6711-14-2	12.42	-9.93	-8.87	5.07**	17.47	-9.71	-6.17	6.00**
PS × MSBN 3621-9-3-1	14.41	-2.50	5.72**	21.91**	19.96	-10.21	7.19**	21.11**
PS × B-10-224-3	14.67	-12.52	7.63**	24.11**	20.51	-13.20	10.15**	24.45**
PS × MBN 6242-3-1	15.24	8.16**	11.81**	28.93**	22.39	6.97**	20.24**	35.86**
PS × CFR 2211-2	14.78	0.48	8.43**	25.04**	21.19	3.46**	13.80**	28.58**
BUMOV 41212-3-1 × BN-364	14.29	-22.04	4.84**	20.89**	20.17	-18.27	8.32**	22.39**
BUMOV 41212-3-1 × P-1343-17-5-3	16.11	-12.11	18.19**	36.29**	22.67	-8.14	21.75**	37.56**
BUMOV 41212-3-1 × MVSR 6711-14-2	13.53	-26.18	-0.73	14.46**	20.10	-18.55	7.94**	21.96**
BUMOV 41212-3-1 × MSBN 3621-9-3-1	15.32	-16.42	12.39**	29.61**	21.46	-13.04	15.25**	30.21**
BUMOV 41212-3-1 × B-10-224-3	18.64	1.69**	36.75**	57.69**	25.46	3.16**	36.73**	54.49**
BUMOV 41212-3-1 × MBN 6242-3-1	17.56	-4.20	28.83**	48.56**	25.72	4.21**	38.13**	56.06**
BUMOV 41212-3-1 × CFR 2211-2	16.01	-12.65	17.46**	35.44**	22.17	-10.17	19.06**	34.52**
BN-364 × P-1343-17-5-3	12.58	-4.55	-7.70	6.42**	17.27	-6.24	-7.25	4.79**
BN-364 × MVSR 6711-14-2	12.42	-5.76	-8.87	5.07**	18.68	-1.89	0.32	13.34**
BN-364 × MSBN 3621-9-3-1	14.04	-5.00	3.00**	18.78**	19.46	-12.46	4.51**	18.08**
BN-364 × B-10-224-3	14.14	-15.68	3.74**	19.62**	19.01	-19.55	2.09**	15.35**

F_1 Hybrid	Leaf length (cm)				Leaf width (cm)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × MBN 6242-3-1	14.50	2.90**	6.38**	22.67**	20.98	0.23	12.67**	27.30**
BN-364 × CFR 2211-2	14.06	-4.41	3.15**	18.95**	19.81	-3.27	6.39**	20.20**
P-1343-17-5-3 × MVSR 6711-14-2	12.33	0.98	-9.53	4.31**	18.00	-5.46	-3.32	9.22**
P-1343-17-5-3 × MSBN 3621-9-3-1	13.41	-9.26	-1.61	13.45**	18.01	-18.98	-3.27	9.28**
P-1343-17-5-3 × B-10-224-3	14.21	-15.26	4.25**	20.21**	19.41	-17.85	4.24**	17.77**
P-1343-17-5-3 × MBN 6242-3-1	13.66	-3.05	0.22	15.56**	20.52	-1.95	10.20**	24.51**
P-1343-17-5-3 × CFR 2211-2	15.14	2.92**	11.07*	28.08**	21.89	6.88**	17.56**	32.82**
MVSR 6711-14-2 × MSBN 3621-9-3-1	13.28	-10.14	-2.56	12.35**	19.62	-11.74	5.37**	19.05**
MVSR 6711-14-2 × B-10-224-3	14.70	-12.34	7.85**	24.36**	20.46	-13.41	9.88**	24.15**
MVSR 6711-14-2 × MBN 6242-3-1	13.62	-3.33	-0.07	15.22**	20.18	-3.58	8.37**	22.45**
MVSR 6711-14-2 × CFR 2211-2	12.78	-13.12	-6.23	8.12**	18.47	-9.81	-0.80	12.07**
MSBN 3621-9-3-1 × B-10-224-3	14.81	-11.68	0.65	25.29**	19.99	-15.40	7.35**	21.29**
MSBN 3621-9-3-1 × MBN 6242-3-1	14.53	3.12**	6.60**	22.92**	21.16	-4.81	13.64**	28.39**
MSBN 3621-9-3-1 × CFR 2211-2	15.24	3.11**	11.81**	28.93**	21.72	-2.29	16.64**	31.79**
B-10-224-3 × MBN 6242-3-1	17.19	2.50**	26.11**	45.43**	23.81	0.76	27.87**	44.47**
B-10-224-3 × CFR 2211-2	16.82	89.74**	23.40**	42.30**	23.39	-1.01	25.61**	41.92**
MBN 6242-3-1 × CFR 2211-2	17.39	18.21**	27.58**	47.12**	24.33	16.24**	30.66**	47.63**
CD at 5%	1.19	1.18			1.74	1.72		
CD at 1%	1.56	1.57			2.28	2.28		

*, ** Significant at 5% and 1% level, respectively.

economic heterosis over PPH-1 and PPH-2 for leaf width. The maximum economic heterosis for this trait over both checks was shown by BUMOV 41212-3-1 × MBN 6242-3-1 (38.13 and 56.06%, respectively), followed by BUMOV 41212-3-1 × B-10-224-3 (36.73 and 54.49%, respectively) and MBN 6242-3-1 × CFR 2211-2 (30.66 and 47.63%, respectively) (Table 4.5.2). MBN 6242-3-1 × CFR 2211-2 was a hybrid between bushy and BN parent and its very high heterosis for leaf width provided a scope for development of hybrids with more vegetative growth. High heterosis for greater leaf width was also reported by El-Tahawey *et al* (2015) in pumpkin.

4.5.5 Petiole length (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for petiole length ranged from -6.74 to 55.58%, 1.71 to 69.75% and -7.02 to 55.15%, respectively. Only one cross-combination i.e. BN-364 × CFR 2211-2 (-6.74%) had significantly desirable heterobeltiosis (negative); no hybrids had significantly desirable economic heterosis (negative) over PPH-1, while two hybrids i.e. MVSR 6711-14-2 × MSBN 3621-9-3-1(-7.02%) and BN-364 × MVSR 6711-14-2 (-6.98%) exhibited significantly desirable economic heterosis over PPH-2 for this trait (Table 4.5.3). Both these hybrids were cross between bushy and BN parent and their very high heterosis (-ve) for petiole length provided a scope for development of hybrids with concentrated leaf bearing on bushy vines.

4.5.6 Number of primary branches

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for number of primary branches ranged from -23.46 to 42.64%, -20.75 to 18.75% and 6.07 to 67.84%, respectively. MVSR 6711-14-2 × B-10-224-3 (42.64%) followed by MSBN 3621-9-3-1 × MBN 6242-3-1 (27.66%) and BN-364 × MBN 6242-3-1 (22.33%) had maximum heterobeltiosis out of 22 significantly desirable cross-combinations. Only one hybrids i.e. MVSR 6711-14-2 × B-10-224-3 (18.75%) exhibited significantly desirable commercial heterosis over PPH-1, while All the 36 hybrids exhibited significantly desirable economic heterosis over PPH-2 for number of primary branches. The maximum economic heterosis for this trait over PPH-2 was shown by MVSR 6711-14-2 × B-10-224-3 (67.84%), followed by PS × P-1343-17-5-3 (41.34%), P-1343-17-5-3 × MVSR 6711-14-2 (41.34%), P-1343-17-5-3 × MBN 6242-3-1 (41.34%), PS × CFR 2211-2 (35.33%) and MSBN 3621-9-3-1 × MBN 6242-3-1 (35.33%) (Table 4.5.3). Out of these best hybrids, MSBN 3621-9-3-1 × MBN 6242-3- was a hybrid between bushy and BN parents and its very high heterosis for number of primary branches provided a scope for development of bushy and BN hybrids with more vegetative growth. The results of heterosis for more number of primary branches were substantiated with the findings of Hussien and Hamed (2015) in pumpkin, Narasannavar *et al* (2014) in ridge gourd and Janaranjani *et al* (2016) in bottle gourd.

Table 4.5.3: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for petiole length (cm) and number of primary branches

F_1 Hybrid	Petiole length (cm)				Number of primary branches			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	29.84	23.61	50.93	37.95	3.33	11**	-16.75	17.66**
PS × BN-364	24.82	7.30	25.54	14.74	3.42	14**	-14.5	20.84**
PS × P-1343-17-5-3	23.68	13.95	19.77	9.47	4	2.04**	0	41.34**
PS × MVSR 6711-14-2	23.78	35.42	20.28	9.93	3.58	7.5**	-10.5	26.5**
PS × MSBN 3621-9-3-1	25.84	29.39	30.70	19.46	3	0	-25	6.007**
PS × B-10-224-3	25.41	5.26	28.52	17.47	3	0	-25	6.007**
PS × MBN 6242-3-1	29.76	23.28	50.53	37.58	3.42	14**	-14.5	20.84**
PS × CFR 2211-2	26.40	10.09	33.53	22.05	3.83	17.84**	-4.25	35.33**
BUMOV 41212-3-1 × BN-364	27.87	20.49	40.97	28.84	3.25	8.33**	-18.75	14.84**
BUMOV 41212-3-1 × P-1343-17-5-3	29.29	40.95	48.15	35.41	3	-23.46	-25	6.007**
BUMOV 41212-3-1 × MVSR 6711-14-2	26.97	53.58	36.41	24.68	3.58	7.5**	-10.5	26.5**
BUMOV 41212-3-1 × MSBN 3621-9-3-1	31.07	55.58	57.15	43.64	3.58	19.33**	-10.5	26.5**
BUMOV 41212-3-1 × B-10-224-3	32.56	21.71	64.69	50.53	3.33	11**	-16.75	17.66**
BUMOV 41212-3-1 × MBN 6242-3-1	32.83	4.82	66.05	51.77	3.17	5.66**	-20.75	12.01**
BUMOV 41212-3-1 × CFR 2211-2	27.30	13.84	38.08	26.21	3	-7.69	-25	6.007**
BN-364 × P-1343-17-5-3	23.13	11.30	16.99	6.93	3.75	-4.33	-6.25	32.5**
BN-364 × MVSR 6711-14-2	20.12	14.57	1.77	-6.98**	3	-9.9	-25	6.007**
BN-364 × MSBN 3621-9-3-1	22.56	12.96	14.11	4.29	3.5	16.66**	-12.5	23.67**
BN-364 × B-10-224-3	24.12	4.28	22.00	11.51	3.42	14**	-14.5	20.84**
BN-364 × MBN 6242-3-1	25.19	8.90	27.41	16.45	3.67	22.33**	-8.25	29.68**

F_1 Hybrid	Petiole length (cm)				Number of primary branches			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × CFR 2211-2	21.57	-6.74**	9.10	-0.27	3	-7.69	-25	6.007**
P-1343-17-5-3 × MVSR 6711-14-2	23.99	36.61	21.34	10.91	4	2.04**	0	41.34**
P-1343-17-5-3 × MSBN 3621-9-3-1	21.42	7.26	8.34	-0.97	3	-23.46	-25	6.007**
P-1343-17-5-3 × B-10-224-3	26.50	27.52	34.04	22.51	3.58	-8.67	-10.5	26.5**
P-1343-17-5-3 × MBN 6242-3-1	28.90	39.07	46.18	33.61	4.00	2.04**	0	41.34**
P-1343-17-5-3 × CFR 2211-2	28.54	37.34	44.36	31.94	3.33	-15.05	-16.75	17.66**
MVSR 6711-14-2 × MSBN 3621-9-3-1	20.11	14.52	1.71	-7.02**	3.67	10.21**	-8.25	29.68**
MVSR 6711-14-2 × B-10-224-3	23.50	33.82	18.86	8.64	4.75	42.64**	18.75**	67.84**
MVSR 6711-14-2 × MBN 6242-3-1	26.18	49.08	32.42	21.03	3.58	7.5**	-10.5	26.5**
MVSR 6711-14-2 × CFR 2211-2	23.68	34.85	19.77	9.47	3.42	2.7**	-14.5	20.84**
MSBN 3621-9-3-1 × B-10-224-3	23.70	18.67	19.87	9.57	3.42	14**	-14.5	20.84**
MSBN 3621-9-3-1 × MBN 6242-3-1	24.81	24.23	25.49	14.70	3.83	27.66**	-4.25	35.33**
MSBN 3621-9-3-1 × CFR 2211-2	25.60	28.19	29.48	18.35	3.25	0	-18.75	14.84**
B-10-224-3 × MBN 6242-3-1	30.19	12.85	52.70	39.57	3.00	0	-25	6.007**
B-10-224-3 × CFR 2211-2	29.89	24.64	51.18	38.18	3.00	-7.69	-25	6.007**
MBN 6242-3-1 × CFR 2211-2	33.56	39.94	69.75	55.15	3.25	0	-18.75	14.84**
CD at 5%	2.58	2.57			0.32	0.31		
CD at 1%	3.39	3.41			0.42	0.42		

*, ** Significant at 5% and 1% level, respectively.

4.5.7 Earliest node to female flower

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for earliest node to female flower ranged from -47.78 to 420%, -20 to 420% and -31.5 to 279.45%, respectively. BN-364 × MVSR6711-14-2 (-47.78%) and BN-364 × CFR 2211-2 (-47.78%), followed by MVSR 6711-14-2 × MSBN 3621-9-3-1 (-43.75%), BUMOV 41212-3-1 × MVSR 6711-14-2(-43.4%) had maximum heterobeltiosis out of 16 significantly desirable cross-combinations, while 3 and 6 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for earliest node to female flower. The maximum economic heterosis for this trait over both checks was shown by BN-364 × MVSR 6711-14-2 (-20 and -31.5%, respectively), BN-364 × CFR 2211-2 (-20 and -31.5%, respectively) and MVSR 6711-14-2 × MSBN 3621-9-3-1 (-10 and -22.94%, respectively) (Table 4.5.4). All these were hybrids between bushy and BN parents, had very high heterosis for earliest node to female flower and provided a scope for development of bushy and BN hybrids with early female flowering. The result for this trait were affirmed with the reports of Hanchinamani and patil (2009) in cucumber, Thangamani and Pugalendhi (2013) in bitter gourd, Narasannavar *et al* (2014) in ridge gourd, Nisha and Veeraragavathatham (2014) and Hussien and Hamed (2015) in pumpkin.

4.5.8 Days to 50 % female flowering

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for days to 50 % female flowering ranged from -22.96 to 96.34%, -52.32 to -11.53% and -0.98 to 107.67%, respectively. B-10-224-3 × MBN 6242-3-1 (-22.96%) followed by BUMOV 41212-3-1 × MBN 6242-3-1 (-21.6%) and MSBN 3621-9-3-1 × MBN 6242-3-1 (-21.35%) had maximum heterobeltiosis out of 25 significantly desirable cross-combinations, while 35 and 10 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for days to 50% female flowering. The maximum economic heterosis for this trait over both checks was shown by MSBN 3621-9-3-1 × MBN 6242-3-1 (-52.32 and -11.53%, respectively), followed by BUMOV 41212-3-1 × MVSR 6711-14-2 (-51.81 and -10.58%, respectively) and BN-364 × B-10-224-3 (-51.29 and -9.63%, respectively) (Table 4.5.4). MSBN 3621-9-3-1 × MBN 6242-3-1 and BN-364 × B-10-224-3 were hybrids having bushy and BN parents and provided a scope for development of pumpkin hybrid with early female flowering.

Table 4.5.4: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for earliest node to first female flower and days to 50 % female flowering

F_1 Hybrid	Earliest node to female flower				Days to 50 % female flowering			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	9.33	273.2	273.2	219.52	46.33	-6.08**	-27.98**	33.63
PS × BN-364	2.75	10	10	-5.82**	32.67	-4.83**	-49.21**	-5.76**
PS × P-1343-17-5-3	9.17	266.8	266.8	214.04	72.00	96.34	11.92	107.67
PS × MVSR 6711-14-2	3.08	23.2	23.2	5.47	34.00	-12.82**	-47.14**	-1.93
PS × MSBN 3621-9-3-1	4.00	60	60	36.98	33.00	-15.38**	-48.7**	-4.81**
PS × B-10-224-3	13.00	420	420	345.2	46.33	-8.56**	-27.98**	33.63
PS × MBN 6242-3-1	11.00	340	340	276.71	45.00	-8.77**	-30.04**	29.79
PS × CFR 2211-2	8.50	240	240	191.09	38.33	-9.44**	-40.41**	10.55
BUMOV 41212-3-1 × BN-364	2.50	-34.72**	0	-14.38**	31.67	-7.74**	-50.76**	-8.65**
BUMOV 41212-3-1 × P-1343-17-5-3	7.08	-11.5**	183.2	142.46	36.33	-0.92	-43.52**	4.78
BUMOV 41212-3-1 × MVSR 6711-14-2	2.83	-43.4**	13.2	-3.08**	31.00	-20.51**	-51.81**	-10.58**
BUMOV 41212-3-1 × MSBN 3621-9-3-1	3.75	-6.25**	50	28.42	32.00	-17.94**	-50.25**	-7.7**
BUMOV 41212-3-1 × B-10-224-3	10.42	16.81	316.8	256.84	42.33	-14.19**	-34.19**	22.09
BUMOV 41212-3-1 × MBN 6242-3-1	9.42	5.6	276.8	222.6	38.67	-21.6**	-39.88**	11.53
BUMOV 41212-3-1 × CFR 2211-2	6.83	-47.17**	173.2	133.9	46.67	10.25	-27.45**	34.61
BN-364 × P-1343-17-5-3	3.58	-6.52**	43.2	22.6	33.00	-3.87*	-48.7**	-4.81**
BN-364 × MVSR 6711-14-2	2.00	-47.78**	-20**	-31.5**	33.33	-2.91	-48.18**	-3.86*
BN-364 × MSBN 3621-9-3-1	2.92	-23.75**	16.8	0	33.00	-3.87*	-48.7**	-4.81**
BN-364 × B-10-224-3	4.33	13.05	73.2	48.28	31.33	-8.73**	-51.29**	-9.63**

F_1 Hybrid	Earliest node to female flower				Days to 50 % female flowering			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × MBN 6242-3-1	4.42	15.4	76.8	51.36	33.67	-1.92	-47.66**	-2.88
BN-364 × CFR 2211-2	2.00	-47.78**	-20**	-31.5**	34.33	0	-46.63**	-0.98
P-1343-17-5-3 × MVSR 6711-14-2	10.00	100	300	242.46	37.00	0.89	-42.48**	6.72
P-1343-17-5-3 × MSBN 3621-9-3-1	4.33	8.25	73.2	48.28	35.00	-4.55**	-45.59**	0.95
P-1343-17-5-3 × B-10-224-3	9.67	20.87	286.8	231.16	35.67	-2.72	-44.55**	2.88
P-1343-17-5-3 × MBN 6242-3-1	7.08	-11.5**	183.2	142.46	36.00	-1.82	-44.03**	3.83
P-1343-17-5-3 × CFR 2211-2	6.42	-11.44**	156.8	119.86	37.00	0.89	-42.48**	6.72
MVSR 6711-14-2 × MSBN 3621-9-3-1	2.25	-43.75**	-10**	-22.94**	37.67	-3.41*	-41.44**	8.65
MVSR 6711-14-2 × B-10-224-3	4.67	-6.6**	86.8	59.93	33.67	-13.66**	-47.66**	-2.88
MVSR 6711-14-2 × MBN 6242-3-1	4.83	-3.4**	93.2	65.41	35.33	-9.41**	-45.08**	1.9
MVSR 6711-14-2 × CFR 2211-2	3.92	-21.6**	56.8	34.24	34.00	-12.82**	-47.14**	-1.93
MSBN 3621-9-3-1 × B-10-224-3	5.42	35.5	116.8	85.61	35.00	-10.25**	-45.59**	0.95
MSBN 3621-9-3-1 × MBN 6242-3-1	4.25	6.25	70	45.54	30.67	-21.35**	-52.32**	-11.53**
MSBN 3621-9-3-1 × CFR 2211-2	5.42	35.5	116.8	85.61	34.67	-11.1**	-46.1**	0
B-10-224-3 × MBN 6242-3-1	11.08	-5.7**	343.2	279.45	38.00	-22.96**	-40.92**	9.6
B-10-224-3 × CFR 2211-2	8.25	13.79	230	182.53	37.67	-11**	-41.44**	8.65
MBN 6242-3-1 × CFR 2211-2	9.83	35.58	293.2	236.64	42.67	0.8	-33.67**	23.07
CD at 55	1.16	1.14			3.20	3.20		
CD at 1%	1.53	1.52			4.22	4.26		

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

4.5.9 Earliest node to male flower

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for earliest node to male flower ranged from -35.32 to 33%, 0 to 58% and 0 to 58%, respectively. PS × BN-364 (-35.32), followed by BN-364 × MBN 6242-3-1 (-31.69%) and BUMOV 41212-3-1 × BN-364 (-31.64%) had maximum heterobeltiosis out of 13 significantly desirable cross-combinations, while no hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for earliest node to male flower (Table 4.5.5). However, many hybrids viz BN-364 × P-1343-17-5-3, BN-364 × MVSR 6711-14-2, BN-364 × MSBN 3621-9-3-1, BN-364 × CFR 2211-2, MVSR 6711-14-2 × MBN 6242-3-1, MSBN 3621-9-3-1 × MBN 6242-3-1 and MSBN 3621-9-3-1 × CFR 2211-2 involving bushy and BN parent were at par with the check hybrids providing a scope for development of bushy and BN hybrids with early node to male flowering. The results could be substantiated with the findings of Janaranjani *et al* (2016) for node at which first male flower appears in bottle gourd.

4.5.10 Days to 50% male flowering

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for earliest 50% male flowering ranged from -19.56 to 122.21%, -1.87 to 161.64% and -3.66 to 156.89%, respectively. MSBN 3621-9-3-1 × MBN 6242-3-1 (-19.56%) followed by BUMOV 41212-3-1 × MSBN 3621-9-3-1(-19.42%) and BN-364 × B-10-224-3 (-18.04%) had maximum heterobeltiosis out of 34 significantly desirable cross-combinations. Only one hybrid i.e. PS × BN-364 (-3.66%) was earliest for 50% male flowering over PPH-2, while PS × BN-364(-1.87%) hybrid exhibited non-significantly desirable economic heterosis over PPH-1 (Table 4.5.5). This cross involved bushy and BN parent and provided scope for development of pumpkin hybrids with early male flowering**.**

4.5.11 Node to first fruit

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for earliest node to fruit ranged from -44.23 to 34.63%, -20.44 to 187.11% and -6.52 to 237.33%, respectively. PS × BN-364 (-44.23%) followed by BN-364 × CFR 2211-2 (-38.94%) and BUMOV 41212-3-1 × MVSR 6711-14-2 (-37.71%) had maximum heterobeltiosis out of 23 significantly desirable cross-combinations, while 6 and 3 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for earliest node to fruit. The maximum economic heterosis for this trait over both checks was shown by PS × BN-364 (-20.44 and -6.52%), BUMOV 41212-3-1 × MVSR 6711-14-2 (-20.44 and -6.52%, respectively), followed by MVSR 6711-14-2 × CFR 2211-2 (-18.44 and -4.17%, respectively) (Table 4.5.6). PS × BN-364 was hybrid between bushy and BN parents, provided good scope for development of bushy and BN hybrids with earliest node to fruit.

Table 4.5.5: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for earliest node to male flower and days to 50 % male flowering

F_1 Hybrid	Earliest node to male flower				Days to 50 % male flowering			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	1.17	-25.94**	17	17	37.67	-4.22**	5.6	3.68
PS × BN-364	1.08	-35.32**	8	8	35.00	-11**	-1.87	-3.66**
PS × P-1343-17-5-3	1.42	6.76	42	42	36.67	-6.76**	2.8	0.93
PS × MVSR 6711-14-2	1.33	33	33	33	37.00	-5.92**	3.72	1.84
PS × MSBN 3621-9-3-1	1.08	8	8	8	36.00	-8.46**	0.92	-0.9
PS × B-10-224-3	1.42	0	42	42	37.67	-4.22**	5.6	3.68
PS × MBN 6242-3-1	1.58	-5.38**	58	58	37.33	-5.08**	4.65	2.75
PS × CFR 2211-2	1.00	0	0	0	37.33	-5.08**	4.65	2.75
BUMOV 41212-3-1 × BN-364	1.08	-31.64**	8	8	40.00	-13.66**	12.13	10.1
BUMOV 41212-3-1 × P-1343-17-5-3	1.08	-18.79**	8	8	37.33	-7.43**	4.65	2.75
BUMOV 41212-3-1 × MVSR 6711-14-2	1.00	0	0	0	40.67	-3.16**	14.01	11.94
BUMOV 41212-3-1 × MSBN 3621-9-3-1	1.00	0	0	0	37.33	-19.42**	4.65	2.75
BUMOV 41212-3-1 × B-10-224-3	1.08	-23.94**	8	8	40.00	-9.76**	12.13	10.1
BUMOV 41212-3-1 × MBN 6242-3-1	1.25	-20.88**	25	25	39.33	-14.5**	10.26	8.25
BUMOV 41212-3-1 × CFR 2211-2	1.00	0	0	0	38.67	-9.37**	8.41	6.44
BN-364 × P-1343-17-5-3	1.00	-24.81**	0	0	39.00	-3.29**	9.33	7.34
BN-364 × MVSR 6711-14-2	1.00	0	0	0	40.00	-4.76**	12.13	10.1
BN-364 × MSBN 3621-9-3-1	1.00	0	0	0	39.33	-16.31**	10.26	8.25
BN-364 × B-10-224-3	1.08	-23.94**	8	8	36.33	-18.04**	1.85	0
BN-364 × MBN 6242-3-1	1.25	-31.69**	25	25	40.00	-13.04**	12.13	10.1

F_1 Hybrid	Earliest node to male flower				Days to 50 % male flowering			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × CFR 2211-2	1.00	0	0	0	41.33	-3.14*	15.86	13.76
P-1343-17-5-3 × MVSR 6711-14-2	1.33	33	33	33	38.33	-4.95**	7.45	5.5
P-1343-17-5-3 × MSBN 3621-9-3-1	1.08	8	8	8	36.00	-10.73**	0.92	-0.9
P-1343-17-5-3 × B-10-224-3	1.17	-12.03**	17	17	37.67	-6.59**	5.6	3.68
P-1343-17-5-3 × MBN 6242-3-1	1.08	-18.79**	8	8	37.33	-7.43**	4.65	2.75
P-1343-17-5-3 × CFR 2211-2	1.00	0	0	0	39.33	-2.47*	10.26	8.25
MVSR 6711-14-2 × MSBN 3621-9-3-1	1.17	17	17	17	93.33	122.21	161.64	156.89
MVSR 6711-14-2 × B-10-224-3	1.00	0	0	0	38.33	-8.73**	7.45	5.5
MVSR 6711-14-2 × MBN 6242-3-1	1.00	0	0	0	41.33	-1.59	15.86	13.76
MVSR 6711-14-2 × CFR 2211-2	1.00	0	0	0	40.67	-3.16**	14.01	11.94
MSBN 3621-9-3-1 × B-10-224-3	1.33	33	33	33	37.33	-15.79**	4.65	2.75
MSBN 3621-9-3-1 × MBN 6242-3-1	1.00	0	0	0	37.00	-19.56**	3.72	1.84
MSBN 3621-9-3-1 × CFR 2211-2	1.00	0	0	0	40.33	-5.48**	13.06	11.01
B-10-224-3 × MBN 6242-3-1	1.17	-17.6**	17	17	40.67	-8.25**	14.01	11.94
B-10-224-3 × CFR 2211-2	1.00	0	0	0	39.33	-7.82**	10.26	2.97
MBN 6242-3-1 × CFR 2211-2	1.00	0	0	0	39.33	-7.82**	10.26	2.97
CD at 5%	0.26	0.27			2.38	2.37		
CD at 1%	0.34	0.36			3.13	3.15		

*, ** Significant at 5% and 1% level, respectively.

Table 4.5.6: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for node to first fruit and days to fruit maturity

F_1 Hybrid	Node to first fruit				Days to fruit maturity			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	11.00	17.89	144.44	187.2	58.00	-2.24**	47.47	49.98
PS × BN-364	3.58	-44.23**	-20.44**	-6.52**	39.00	-15.21**	-0.83	0.85
PS × P-1343-17-5-3	10.67	30.89	137.11	178.59	52.67	-2.46**	33.91	36.2
PS × MVSR 6711-14-2	4.92	-14.43**	9.33	28.45	41.00	-12.76**	4.24	6.02
PS × MSBN 3621-9-3-1	6.17	12.18	37.11	61.09	46.33	0.71	17.79	19.8
PS × B-10-224-3	12.92	6.16	187.11	237.33	56.67	-11.9**	44.08	46.54
PS × MBN 6242-3-1	11.33	-11.69**	151.77	195.82	57.67	-3.88**	46.63	49.13
PS × CFR 2211-2	8.58	1.9	90.66	124.02	56.33	0	43.22	45.66
BUMOV 41212-3-1 × BN-364	4.42	-31.15**	-1.77**	15.4	42.00	-8.69**	6.78	8.61
BUMOV 41212-3-1 × P-1343-17-5-3	7.92	-3.05**	76	106.78	54.00	0	37.29	39.64
BUMOV 41212-3-1 × MVSR 6711-14-2	3.58	-37.71**	-20.44**	-6.52**	44.33	-5.68**	12.71	14.63
BUMOV 41212-3-1 × MSBN 3621-9-3-1	5.17	-6**	14.88	34.98	43.33	-5.8**	10.17	12.05
BUMOV 41212-3-1 × B-10-224-3	11.17	19.72	148.22	191.64	56.00	-5.61**	42.38	44.81
BUMOV 41212-3-1 × MBN 6242-3-1	10.58	13.39	135.11	176.24	56.00	-5.61**	42.38	44.81
BUMOV 41212-3-1 × CFR 2211-2	7.75	-7.95**	72.22	102.34	52.67	-6.49**	33.91	36.2
BN-364 × P-1343-17-5-3	6.00	-6.54**	33.33	56.65	40.33	-12.32**	2.54	4.29
BN-364 × MVSR 6711-14-2	4.33	-24.69**	-3.77**	13.05	41.67	-9.41**	5.94	7.75
BN-364 × MSBN 3621-9-3-1	5.33	-3.09**	18.44	39.16	43.00	-6.52**	9.33	11.19
BN-364 × B-10-224-3	5.83	-9.19**	29.55	52.21	41.00	-10.86**	4.24	6.02

F1 Hybrid	Node to first fruit				Days to fruit maturity			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × MBN 6242-3-1	4.58	-28.66**	1.77	19.58	45.00	-2.17**	14.41	16.36
BN-364 × CFR 2211-2	3.92	-38.94**	-12.88**	2.34	44.67	-2.89**	13.57	15.51
P-1343-17-5-3 × MVSR 6711-14-2	4.50	-21.73**	0	17.49	45.00	-16.66**	14.41	16.36
P-1343-17-5-3 × MSBN 3621-9-3-1	5.33	-3.09**	18.44	39.16	45.00	-2.17**	14.41	16.36
P-1343-17-5-3 × B-10-224-3	11.00	34.63	144.44	187.2	47.67	-11.72**	21.2	23.27
P-1343-17-5-3 × MBN 6242-3-1	8.50	4.03	88.88	121.93	44.67	-17.27**	13.57	15.51
P-1343-17-5-3 × CFR 2211-2	8.00	-2.08**	77.77	108.87	45.67	-15.42**	16.12	18.1
MVSR 6711-14-2 × MSBN 3621-9-3-1	4.58	-16.72**	1.77	19.58	43.00	-6.52**	9.33	11.19
MVSR 6711-14-2 × B-10-224-3	5.50	-4.34**	22.22	43.6	45.00	-4.25**	14.41	16.36
MVSR 6711-14-2 × MBN 6242-3-1	5.67	-1.39**	26	48.04	44.00	-6.38**	11.87	13.78
MVSR 6711-14-2 × CFR 2211-2	3.67	-36.17**	-18.44**	-4.17**	42.67	-9.21**	8.49	10.34
MSBN 3621-9-3-1 × B-10-224-3	6.33	15.09	40.66	65.27	46.00	0	16.95	18.95
MSBN 3621-9-3-1 × MBN 6242-3-1	6.42	16.72	42.66	67.62	43.00	-6.52**	9.33	11.19
MSBN 3621-9-3-1 × CFR 2211-2	5.17	-6**	14.88	34.98	43.00	-6.52**	9.33	11.19
B-10-224-3 × MBN 6242-3-1	11.50	-5.5**	155.55	200.26	57.00	-5**	44.92	47.4
B-10-224-3 × CFR 2211-2	8.92	5.93	98.22	132.89	56.00	-0.53	42.38	44.81
MBN 6242-3-1 × CFR 2211-2	10.17	20.78	126	165.53	57.00	1.18	44.92	47.4
CD at 5%	0.95	0.95			1.18	1.16		
CD at 1%	1.25	1.26			1.54	1.55		

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

4.5.12 Days to fruit maturity

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for earliest node to fruit ranged from -17.27 to 1.18%, -0.83 to 47.47% and -0.85 to 49.13%, respectively. P-1343-17-5-3 × MBN 6242-3-1 (-17.27%) followed by P-1343-17-5-3 × MVSR 6711-14-2 (-16.66%), P-1343-17-5-3 × CFR 2211-2 (-15.42%) had maximum heterobeltiosis among 30 significantly desirable cross-combinations. PS × BN-364 hybrid with bushy and BN cross was at par with PPH-1, but no hybrid exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for days to fruit maturity (Table 4.5.6). Similar result was reported by Tamil Selvi and Jansirani (2016).

4.5.13 Peduncle length (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for peduncle length ranged from 3.22 to 191.07%, -38.85 to 116.77% and -37.79 to 120.51%, respectively. No hybrid had significantly desirable heterobeltiosis for this trait, while 13 and 12 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2, respectively. The maximum economic heterosis for this trait over both checks was shown by BN-364 × MVSR 6711-14-2 (-38.85 and-37.79%, respectively), followed by MVSR 6711-14-2 × CFR 2211-2 (-32.69 and -31.53%, respectively), BN-364 × CFR 2211-2 (-30.14 and -28.94%, respectively) and MVSR 6711-14-2 × MSBN 3621-9-3-1 (-29.29 and -28.07%, respectively) (Table 4.5.7). BN-364 × MVSR 6711-14-2, BN-364 × CFR 2211-2 and MVSR 6711-14-2 × MSBN 3621-9-3-1 involving bushy and BN parent along with high economic heterosis small peduncle provided good scope for development of hybrids with short peduncle length for concentrated fruit bearing in pumpkin.

4.5.14 Polar diameter (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for polar diameter ranged from -51.97 to 46.75%, -38.25 to 171.79% and -25.85 to 226.39%, respectively. BUMOV 41212-3-1 × P-1343-17-5-3(46.75%) followed by MSBN 3621-9-3-1 × MBN 6242-3-1(31.12%) and PS × BUMOV 41212-3-1(28.57%) had maximum heterobeltiosis out of 6 significantly desirable cross-combinations, while 25 and 30 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for polar diameter. The maximum economic heterosis for this trait over both checks was shown by MSBN 3621-9-3-1 × MBN 6242-3-1(171.79 and 226.39%, respectively), followed by BN-364 × MBN 6242-3-1(84.02 and 120.99%, respectively), BN-364 × MSBN 3621-9-3-1(45.01 and 74.14%, respectively) and MSBN 3621-9-3-1 × CFR 2211-2 (45.01 and 74.14%, respectively) (Table 4.5.8). All these are hybrids between bushy and BN parent had very high heterosis for this trait and provided good scope for development of hybrids with BN fruit shape. Similar results for fruit length were reported in bitter gourd by Thangamani and Pugalendhi (2013), in pumpkin by Hussien and Hamed (2015) and in ridge gourd by Narasannavar *et al* (2014).

Table 4.5.7: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for peduncle length (cm)

F_1 hybrid	Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2
PS × BUMOV 41212-3-1	6.79	8.64	44.16	46.65
PS × BN-364	4.67	64.43	-0.84*	0.86
PS × P-1343-17-5-3	7.00	12.00	48.61	53.18
PS × MVSR 6711-14-2	4.88	74.91	3.60	5.39
PS × MSBN 3621-9-3-1	4.96	65.33	5.30	7.12
PS × B-10-224-3	8.04	28.64	70.70	73.65
PS × MBN 6242-3-1	6.54	25.52	38.85	41.25
PS × CFR 2211-2	5.67	74.46	20.38	22.46
BUMOV 41212-3-1 × BN-364	4.29	51.05	-8.91**	-7.34**
BUMOV 41212-3-1 × P-1343-17-5-3	7.83	22.72	66.40	69.11
BUMOV 41212-3-1 × MVSR 6711-14-2	4.04	44.80	-14.22**	-12.74**
BUMOV 41212-3-1 × MSBN 3621-9-3-1	4.25	41.66	-9.76**	-8.20**
BUMOV 41212-3-1 × B-10-224-3	8.17	28.05	73.46	76.45
BUMOV 41212-3-1 × MBN 6242-3-1	6.50	24.76	38.00	40.38
BUMOV 41212-3-1 × CFR 2211-2	5.50	69.23	16.77	18.79
BN-364 × P-1343-17-5-3	5.88	107.04	24.84	26.99
BN-364 × MVSR 6711-14-2	2.88	3.22	-38.85**	-37.79**
BN-364 × MSBN 3621-9-3-1	3.38	19.01	-28.23**	-26.99**
BN-364 × B-10-224-3	4.88	71.83	3.60	5.39

F_1 hybrid	Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2
BN-364 × MBN 6242-3-1	3.88	36.61	-17.62**	-16.19**
BN-364 × CFR 2211-2	3.29	15.84	-30.14**	-28.94**
P-1343-17-5-3 × MVSR 6711-14-2	5.07	81.72	7.64	9.50
P-1343-17-5-3 × MSBN 3621-9-3-1	4.92	64.00	4.45	6.26
P-1343-17-5-3 × B-10-224-3	10.21	27.62	116.77	120.51
P-1343-17-5-3 × MBN 6242-3-1	7.67	47.21	62.84	65.65
P-1343-17-5-3 × CFR 2211-2	8.00	146.15	69.85	72.78
MVSR 6711-14-2 × MSBN 3621-9-3-1	3.33	19.35	-29.29**	-28.07**
MVSR 6711-14-2 × B-10-224-3	5.96	113.62	26.53	28.72
MVSR 6711-14-2 × MBN 6242-3-1	3.79	35.84	-19.53**	-18.14**
MVSR 6711-14-2 × CFR 2211-2	3.17	13.62	-32.69**	-31.53**
MSBN 3621-9-3-1 × B-10-224-3	4.75	58.33	0.84	2.59
MSBN 3621-9-3-1 × MBN 6242-3-1	4.04	34.66	-14.22**	-12.74**
MSBN 3621-9-3-1 × CFR 2211-2	3.83	27.66	-18.68**	-17.27**
B-10-224-3 × MBN 6242-3-1	8.92	71.20	89.38	92.65
B-10-224-3 × CFR 2211-2	9.46	191.07	100.84	104.31
MBN 6242-3-1 × CFR 2211-2	6.00	84.61	27.38	29.58
CD at 5%	0.81			
CD at 1%	1.07			

*, ** Significant at 5% and 1% level, respectively.

4.5.15 Equatorial diameter (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for equatorial diameter ranged from 3.67% to 80.87%, -37.89% to 59.25% and -25.77% to 90.32%, respectively. No hybrid had maximum heterobeltiosis out of 36 cross-combinations, while 22 and 8 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for equatorial diameter. The maximum economic heterosis for this trait over both checks was shown by BN-364 × MSBN 3621-9-3-1 (-37.89 and -25.77%, respectively), followed by MSBN 3621-9-3-1 × MBN 6242-3-1 (-35.03 and -22.35%, respectively) and BN-364 × MBN 6242-3-1 (-30.95 and -17.47%, respectively) (Table 4.5.8). All these are hybrids between bushy and BN parents of BN fruit shape provided good scope for development with less equatorial diameter or BN fruit shape. However, Thangamani and Pugalendhi (2013) in bitter gourd, Hussien and Hamed (2015) in pumpkin and Narasannavar *et al* (2014) in ridge gourd reported standard heterosis for greater diameter.

4.5.16 Fruit shape index

For 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for fruit shape index ranged from -22.42% to 180.35%, -36.26% to 316.48% and -35.55% to 321.11%, respectively. MVSR 6711-14-2 × MSBN 3621-9-3-1(180.35%), followed by MSBN 3621-9-3-1 × CFR 2211-2 (126.56%) and MSBN 3621-9-3-1 × B-10-224-3(113.63%) had maximum heterobeltiosis out of 23 significantly desirable cross-combinations, while 22 and 21 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for fruit shape index (Table 4.5.9). The maximum economic heterosis for this trait over both checks was shown by MSBN 3621-9-3-1 × MBN 6242-3-1(316.48 and 321.11%, respectively), followed by BN-364 × MBN 6242-3-1(165.93 and 168.88%) and BN-364 × MSBN 3621-9-3-1(132.96 and 135.55%). All these are hybrids between bushy and BN parent, had very high heterosis for this trait and provided good scope for development of bushy hybrids with BN fruit shape index.

4.5.17 Pulp thickness (cm)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for pulp thickness ranged from -32.89 to 45.39%, -44.62 to 34.52% and -17.07 to 101.46%, respectively. PS × BUMOV 41212-3-1 (45.39%), followed by BUMOV 41212-3-1 × P-1343-17-5-3 (35.77%) and BUMOV 41212-3-1 × MBN 6242-3-1 (33.62%) had maximum heterobeltiosis out of 10 significantly desirable cross-combinations, while 11 and 29 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for pulp thickness. The maximum economic heterosis for this trait over both checks was shown by P-1343-17-5-3 × CFR 2211-2 (34.52 and 101.46%, respectively), followed by PS × CFR 2211-2 (24.1 and 85.85%, respectively), PS × B-10-224-3 (16.61 and 74.63%, respectively)

Table 4.5.8: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for polar diameter (cm) and equatorial diameter (cm)

F_1 Hybrid	Polar diameter (cm)				Equatorial diameter (cm)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	16.20	28.57**	21.53**	45.94**	17.45	49.52	18.70	41.86
PS × BN-364	13.30	-31.44	-0.22	19.81**	12.41	26.76	-15.57**	0.89
PS × P-1343-17-5-3	13.43	6.58**	0.75**	20.99**	18.31	15.66	24.55	48.86
PS × MVSR 6711-14-2	8.70	-30.95	-34.73	-21.62	13.35	7.40	-9.18**	8.53
PS × MSBN 3621-9-3-1	16.23	-36.02	21.75**	46.21**	11.44	51.92	-22.17**	6.99
PS × B-10-224-3	16.43	-4.64	23.25**	48.01**	23.41	47.88	59.25	90.32
PS × MBN 6242-3-1	17.20	-37.74	29.03**	54.95**	17.51	57.60	19.11	42.35
PS × CFR 2211-2	15.27	21.19**	14.55**	37.56**	17.70	11.81	20.40	43.90
BUMOV 41212-3-1 × BN-364	13.23	-31.80	-0.75	19.18**	10.52	7.45	-28.43**	-14.47**
BUMOV 41212-3-1 × P-1343-17-5-3	18.30	46.75**	37.28**	64.86**	18.53	58.78	26.06	50.65
BUMOV 41212-3-1 × MVSR 6711-14-2	11.23	-9.94	-15.75	1.17**	12.53	7.36	-14.76**	1.86
BUMOV 41212-3-1 × MSBN 3621-9-3-1	16.53	-34.84	24.00**	48.91**	10.39	37.98	-29.31**	-15.52**
BUMOV 41212-3-1 × B-10-224-3	15.23	-11.60	14.25**	37.20**	18.25	56.38	24.14	48.37
BUMOV 41212-3-1 × MBN 6242-3-1	17.40	-37.02	30.53**	56.75**	14.13	27.18	-3.87**	14.87
BUMOV 41212-3-1 × CFR 2211-2	12.17	-2.40	-8.70	9.63**	14.49	24.16	-1.42**	17.80
BN-364 × P-1343-17-5-3	14.47	-25.41	8.55**	30.36**	13.31	35.95	-9.45**	8.21
BN-364 × MVSR 6711-14-2	10.43	-46.23	-21.75	-6.03	10.52	7.45	-2.84**	-14.83**
BN-364 × MSBN 3621-9-3-1	19.33	-23.80	45.01**	74.14**	9.13	21.24	-37.89**	-25.77**
BN-364 × B-10-224-3	15.23	-21.49	14.25**	37.20**	14.61	49.23	-0.61**	18.78
BN-364 × MBN 6242-3-1	24.53	-11.21	84.02**	120.99**	10.15	3.67	-30.95**	-17.47**

F_1 Hybrid	Polar diameter (cm)				Equatorial diameter (cm)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × CFR 2211-2	10.17	-47.57	-23.70	-8.37	12.71	29.82	-13.53**	3.33
P-1343-17-5-3 × MVSR 6711-14-2	10.43	-14.50	-21.75	-6.03	15.24	22.60	3.67	23.90
P-1343-17-5-3 × MSBN 3621-9-3-1	15.27	-39.81	14.55**	37.56**	11.17	48.33	-24.01**	-9.18**
P-1343-17-5-3 × B-10-224-3	15.20	-11.78	14.02**	36.93**	22.75	39.31	54.76	84.95
P-1343-17-5-3 × MBN 6242-3-1	19.13	-30.76	43.51**	72.34**	16.25	46.26	10.54	32.11
P-1343-17-5-3 × CFR 2211-2	15.23	24.83**	14.25**	37.20**	22.35	37.70	52.04	81.70
MVSR 6711-14-2 × MSBN 3621-9-3-1	18.23	-28.14	36.75**	64.23**	11.63	54.44	-20.88**	-5.44**
MVSR 6711-14-2 × B-10-224-3	10.27	-40.39	-22.95	-7.47	17.17	38.13	16.80	39.59
MVSR 6711-14-2 × MBN 6242-3-1	13.27	-51.97	-0.45	19.54**	12.59	13.32	-14.35**	2.35
MVSR 6711-14-2 × CFR 2211-2	8.23	-20.86	-38.25	-25.85	14.31	15.12	-2.65**	16.34
MSBN 3621-9-3-1 × B-10-224-3	19.17	-24.43	43.81**	72.70**	13.62	80.87	-7.34**	10.73
MSBN 3621-9-3-1 × MBN 6242-3-1	36.23	31.12**	171.79**	226.39**	9.55	26.82	-35.03**	-22.35**
MSBN 3621-9-3-1 × CFR 2211-2	19.33	-23.80	45.01**	74.14**	13.35	77.29	-9.18**	8.53
B-10-224-3 × MBN 6242-3-1	18.37	-33.51	37.80**	65.49**	18.38	65.43	-25.03**	49.43
B-10-224-3 × CFR 2211-2	15.10	-12.36	13.27**	36.03**	21.52	32.59	46.39	74.95
MBN 6242-3-1 × CFR 2211-2	14.43	-47.77	8.25**	30.00**	19.50	75.51	32.65	58.53
CD at 5%	0.27	0.27			0.25	0.21		
CD at 1%	0.35	0.36			0.33	0.28		

*, ** Significant at 5% and 1% level, respectively.

Table 4.5.9: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for fruit shape index and pulp thickness (cm)

F_1 Hybrid	Fruit shape index				Pulp thickness (cm)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	0.93	-13.08	2.19**	3.33**	3.21	45.39**	4.56**	56.58**
PS × BN-364	1.07	35.44**	17.58**	18.88**	2.04	-32.89	-33.55	-0.48
PS × P-1343-17-5-3	0.73	-7.59	-19.78	-18.88	3.17	4.27**	3.25**	54.63**
PS × MVSR 6711-14-2	0.65	-17.72	-28.57	-27.77	2.23	-26.64	-27.36	8.78**
PS × MSBN 3621-9-3-1	1.42	79.74**	56.04**	57.77**	2.09	-31.25	-31.92	1.95**
PS × B-10-224-3	0.70	-11.39	-23.07	-22.22	3.58	-3.5	16.61**	74.63**
PS × MBN 6242-3-1	0.98	24.05**	7.69**	8.88**	2.69	-11.51	-12.37	31.21**
PS × CFR 2211-2	0.86	8.86**	-5.49	-4.44	3.81	15.45**	24.1**	85.85**
BUMOV 41212-3-1 × BN-364	1.26	17.75**	38.46**	40.00**	1.71	-26.29	-44.29	-16.58
BUMOV 41212-3-1 × P-1343-17-5-3	0.99	-7.47	8.79**	10.00**	3.15	35.77**	2.6**	53.65**
BUMOV 41212-3-1 × MVSR 6711-14-2	0.90	-15.88	-1.09	0.00	2.00	-13.79	-34.85	-2.43
BUMOV 41212-3-1 × MSBN 3621-9-3-1	1.59	48.59**	74.72**	76.66**	1.70	-26.72	-44.62	-17.07
BUMOV 41212-3-1 × B-10-224-3	0.83	-22.42	-8.79	-7.77	2.51	-32.34	-18.24	22.43**
BUMOV 41212-3-1 × MBN 6242-3-1	1.23	14.95**	35.16**	36.66**	3.10	33.62**	0.97**	51.21**
BUMOV 41212-3-1 × CFR 2211-2	0.84	-21.49	-7.69	-6.66	2.60	-21.21	-15.3	26.82**
BN-364 × P-1343-17-5-3	1.09	45.33**	19.78**	21.11**	2.18	-5.62	-28.99	6.34**
BN-364 × MVSR 6711-14-2	0.99	76.78**	8.79**	10.00**	2.25	-1.31	-26.71	9.75**
BN-364 × MSBN 3621-9-3-1	2.12	7.07**	132.96**	135.55**	1.71	-0.58	-44.29	-16.58
BN-364 × B-10-224-3	1.04	57.57**	14.28**	15.55**	2.51	-32.34	-18.24	22.43**
BN-364 × MBN 6242-3-1	2.42	22.22**	165.93**	168.88**	1.70	-7.1	-44.62	-17.07

F$_1$ Hybrid	Fruit shape index				Pulp thickness (cm)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × CFR 2211-2	0.80	25.00**	-12.08	-11.11	2.25	-31.81	-26.71	9.75**
P-1343-17-5-3 × MVSR 6711-14-2	0.68	-9.33	-25.27	-24.44	2.80	21.21**	-8.79	36.58**
P-1343-17-5-3 × MSBN 3621-9-3-1	1.37	82.66**	50.54**	52.22**	2.24	-3.03	-27.03	9.26**
P-1343-17-5-3 × B-10-224-3	0.67	-10.66	-26.37	-25.55	3.22	-13.2	4.88**	57.07**
P-1343-17-5-3 × MBN 6242-3-1	1.18	57.33**	29.67**	31.11**	2.10	-9.09	-31.59	2.43**
P-1343-17-5-3 × CFR 2211-2	0.68	-9.33	-25.27	-24.44	4.13	25.15**	34.52**	101.46**
MVSR 6711-14-2 × MSBN 3621-9-3-1	1.57	180.35**	72.52**	74.44**	2.00	-12.28	-34.85	-2.43
MVSR 6711-14-2 × B-10-224-3	0.60	-9.09	-34.06	-33.33	2.70	-27.22	-12.05	31.7**
MVSR 6711-14-2 × MBN 6242-3-1	1.05	87.50**	15.38**	16.66**	2.38	4.38**	-22.47	16.09**
MVSR 6711-14-2 × CFR 2211-2	0.58	-9.37	-36.26	-35.55	2.50	-24.24	-18.56	21.95**
MSBN 3621-9-3-1 × B-10-224-3	1.41	113.63**	54.94**	56.66**	3.33	-10.24	8.46**	62.43**
MSBN 3621-9-3-1 × MBN 6242-3-1	3.79	52.20**	316.48**	321.11**	2.09	14.2**	-31.92	1.95**
MSBN 3621-9-3-1 × CFR 2211-2	1.45	126.56**	59.34**	61.11**	3.07	-6.96	0	49.75**
B-10-224-3 × MBN 6242-3-1	1.00	51.51**	9.89**	11.11**	2.70	-27.22	-12.05	31.7**
B-10-224-3 × CFR 2211-2	0.70	9.37**	-23.07	-22.22	3.38	-8.89	10.09**	64.87**
MBN 6242-3-1 × CFR 2211-2	0.74	15.62**	-18.68	-17.77	3.41	3.33**	11.07**	66.34**
CD at 5%	0.03	0.03			0.16	0.15		
CD at 1%	0.05	0.04			0.21	0.21		

*, ** Significant at 5% and 1% level, respectively.

and MBN 6242-3-1 × CFR 2211-2 (11.07 and 66.34%) (Table 4.5.9). MBN 6242-3-1 × CFR 2211-2 being hybrid between bushy and BN parents provided good scope for development of bushy and BN hybrids with thick pulped fruit. These results for fruit pulp thickness were substantiated with the findings of Narasannavar *et al* (2014) in ridge gourd, Nisha and Veeraragavathatham (2014) and Tamil Selvi and Jansirani (2016) in pumpkin and Janaranjani *et al* (2016) in bottle gourd.

4.5.18 Number of fruits per vine

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for number of fruits per vine ranged from -30.99 to 66.66%, -17.60 to 81.69% and -17.60 to 81.69%, respectively. BUMOV 41212-3-1 × MVSR 6711-14-2 (66.66%) and BUMOV 41212-3-1 × MBN 6242-3-1 (66.66%), followed by MVSR 6711-14-2 × CFR 2211-2 (66.4%) and B-10-224-3 × CFR 2211-2 (49.57%) had maximum heterobeltiosis among 16 significantly desirable cross-combinations, while 31 hybrids exhibited significantly desirable economic heterosis over both PPH-1 and PPH-2 for number of fruits per vine. The maximum economic heterosis for this trait was shown by PS × BUMOV 41212-3-1 (81.69% in each), BUMOV 41212-3-1 × BN-364 (81.69% in each), followed by PS × BN-364 (76.05% in each), BUMOV 41212-3-1 × MVSR 6711-14-2(76.05% in each), BUMOV 41212-3-1 × MSBN 3621-9-3-1(76.05% in each), BUMOV 41212-3-1 × MBN 6242-3-1(76.05% in each), MSBN 3621-9-3-1 × MBN 6242-3-1(70.42% in each) (Table 4.5.10). Out of these, BUMOV 41212-3-1 × BN-364, PS × BN-364, BUMOV 41212-3-1 × MSBN 3621-9-3-1, MSBN 3621-9-3-1 × MBN 6242-3-1 (70.42%) being hybrids between bushy and BN parent, provided good scope for development of bushy and BN hybrids with more number of fruits per vine. These results for number of fruits per vine were verified with the findings in Pumpkin (Nisha and Veeraragavathatham 2014, Hussien and Hamed 2015, Tamil Selvi and Jansirani 2016), cucumber (Hanchinamani and Patil 2009), bitter gourd (Thangamani and Pugalendhi 2013), ridge gourd (Narasannavar *et al* 2014) and bottle gourd (Janaranjani *et al* 2016).

4.5.19 Average fruit weight (kg)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for average fruit weight ranged from -77.52% to 103.96%, -58.11% to 134.18% and -47.31% to 228.87%, respectively. BN-364 × B-10-224-3 (-77.52), MVSR 6711-14-2 × B-10-224-3 (-74.08), MSBN 3621-9-3-1 × B-10-224-3 (-69.26) had maximum heterobeltiosis out of 10 significantly desirable cross-combinations, while 14 and 3 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for less average fruit weight. The maximum economic heterosis for this trait was shown by BUMOV 41212-3-1 ×

BN-364 (-58.11 and -47.31, respectively), BN-364 × MVSR 6711-14-2 (-56.41 and -45.16, respectively), BUMOV 41212-3-1 × MSBN 3621-9-3-1 (-55.55 and -44.08, respectively) (Table 4.5.11). All these crosses with significant heterosis for this trait provided good scope for development of bushy and BN hybrids with less average fruit weight. The maximum standard heterosis for high average fruit weight in cucumber, pumpkin and ridge gourd was reported by Hanchinamani and Patil (2009), Hussien and Hamed (2015) and Narasannavar *et al* (2014), respectively

4.5.20 Fruit yield per vine (kg)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for fruits yield per vine ranged from -69.87 to 144.96%, -42.68 to 260.36% and -28.78 to 347.72%, respectively. MBN 6242-3-1 × CFR 2211-2 (144.96%), followed by BUMOV 41212-3-1 × MBN 6242-3-1 (126.17%) and PS × B-10-224-3 (94.40%) had maximum heterobeltiosis out of 16 significantly desirable cross-combinations, while 20 and 27 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for fruits yield per vine. The maximum economic heterosis for this trait was shown by PS × B-10-224-3 (260.36 and 347.72%, respectively) followed by PS × CFR 2211-2 (204.87 and 278.78%), B-10-224-3 × MBN 6242-3-1 (201.21 and 274.24%), P-1343-17-5-3 × CFR 2211-1 (119.51 and 172.72%) (Table 4.5.11). However, bushy and BN crosses MBN 6242-3-1 × CFR 2211-2, BN-364 × P-1343-17-5-3 , PS × BN-364, BN-364 × B-10-224-3 MSBN 3621-9-3-1 × MBN 6242-3-1 had significant heterosis for yield and provided good scope for development of bushy and BN hybrids with more fruits yield per vine. Hanchinamani and Patil (2009), Thangamani and Pugalendhi (2013), Hussien and Hamed (2015) reported high heterosis for fruit yield per vine in cucumber, bitter gourd and in pumpkin.

4.5.21 TSS (ºBrix)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for TSS ranged from -61.02 to 174.26%, -66.52 to 42.67% and -83.84 to 96.73%, respectively. BN-364 × B-10-224-3 (174.26%), followed by P-1343-17-5-3 × B-10-224-3 (91.19%) and BN-364 × MBN 6242-3-1 (91.88%) had maximum heterobeltiosis out of 11 significantly desirable cross-combinations, while 12 and 19 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for TSS. The maximum economic heterosis for this trait was shown by BN-364 × B-10-224-3 (42.67 and 96.73%, respectively) followed by BN-364 × MBN 6242-3-1 (41.84 and 95.57%, respectively), BUMOV 41212-3-1 × MBN 6242-3-1 (13.38 and 56.34%, respectively) and P-1343-17-5-3 × B-10-224-3 (13.38 and 56.34%, respectively) (Table 4.5.12). Bushy and BN crosses BN-364 × B-10-224-3 and BN-364 × MBN 6242-3-1 provided good scope for development of bushy and BN hybrids with more TSS. Janaranjani *et al* (2016) reported high standard heterosis for TSS in bottle gourd.

Table 4.5.10: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for number of fruits per vine

F_1 Hybrid	Number of fruits per vine			
	Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2
PS × BUMOV 41212-3-1	2.58	6.61**	81.69**	81.69**
PS × BN-364	2.50	3.3**	76.05**	76.05**
PS × P-1343-17-5-3	2.08	-14.04	46.47**	46.47**
PS × MVSR 6711-14-2	2.17	-10.33	52.81**	52.81**
PS × MSBN 3621-9-3-1	2.42	0	70.42**	70.42**
PS × B-10-224-3	1.92	-20.66	35.21**	35.21**
PS × MBN 6242-3-1	2.08	-14.04	46.47**	46.47**
PS × CFR 2211-2	1.67	-30.99	17.60**	17.60**
BUMOV 41212-3-1 × BN-364	2.58	40.98**	81.69**	81.69**
BUMOV 41212-3-1 × P-1343-17-5-3	1.92	0	35.21**	35.21**
BUMOV 41212-3-1 × MVSR 6711-14-2	2.50	66.66**	76.05**	76.05**
BUMOV 41212-3-1 × MSBN 3621-9-3-1	2.50	11.12**	76.05**	76.05**
BUMOV 41212-3-1 × B-10-224-3	1.42	-5.33	0	0
BUMOV 41212-3-1 × MBN 6242-3-1	2.50	66.66**	76.05**	76.05**
BUMOV 41212-3-1 × CFR 2211-2	1.50	0	5.63**	5.63**
BN-364 × P-1343-17-5-3	1.92	0	35.21**	35.21**
BN-364 × MVSR 6711-14-2	2.17	18.57**	52.81**	52.81**
BN-364 × MSBN 3621-9-3-1	2.33	3.55**	64.08**	64.08**

F_1 Hybrid	Number of fruits per vine			
	Mean	**Heterobeltiosis**	**Economic heterosis**	
			PPH-1	**PPH-2**
BN-364 × B-10-224-3	1.58	-13.6	11.26**	11.26**
BN-364 × MBN 6242-3-1	1.58	-13.66	11.26**	11.26**
BN-364 × CFR 2211-2	1.33	-27.32	-6.33	-6.33
P-1343-17-5-3 × MVSR 6711-14-2	1.92	0	35.21**	35.21**
P-1343-17-5-3 × MSBN 3621-9-3-1	1.83	-18.66	28.87**	28.87**
P-1343-17-5-3 × B-10-224-3	1.58	-17.7	11.26**	11.26**
P-1343-17-5-3 × MBN 6242-3-1	2.08	8.33**	46.47**	46.47**
P-1343-17-5-3 × CFR 2211-2	1.42	-26.04	0	0
MVSR 6711-14-2 × MSBN 3621-9-3-1	2.08	-7.55	46.47**	46.47**
MVSR 6711-14-2 × B-10-224-3	1.33	6.4**	-6.33	-6.33
MVSR 6711-14-2 × MBN 6242-3-1	1.83	22**	28.87**	28.87**
MVSR 6711-14-2 × CFR 2211-2	2.08	66.4**	46.47**	46.47**
MSBN 3621-9-3-1 × B-10-224-3	1.67	-25.77	17.60**	17.60**
MSBN 3621-9-3-1 × MBN 6242-3-1	2.42	7.55**	70.42**	70.42**
MSBN 3621-9-3-1 × CFR 2211-2	1.17	-48	-17.60	-17.60
B-10-224-3 × MBN 6242-3-1	1.83	22**	28.87**	28.87**
B-10-224-3 × CFR 2211-2	1.75	49.57**	23.23**	23.23**
MBN 6242-3-1 × CFR 2211-2	1.75	16.66	0.23	0.23
CD at 5%	0.60	0.59		
CD at 1%	0.79	0.78		

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

Table 4.5.11: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for fruit yield per vine (kg) and average fruit weight (kg)

F_1 Hybrid	Fruit yield per vine (kg)				Average fruit weight (kg)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	3.93	29.27**	139.63**	197.72**	1.51	19.84**	29.05**	62.36**
PS × BN-364	2.88	-5.26	75.60**	118.18**	0.69	-45.23	-41.02	-25.80
PS × P-1343-17-5-3	1.51	-50.32	-7.92	14.39**	1.34	6.34**	14.52**	44.08**
PS × MVSR 6711-14-2	1.69	-44.40	3.04**	28.03**	0.70	-44.44	-40.17	-24.73
PS × MSBN 3621-9-3-1	5.18	70.39**	215.85**	292.42**	0.71	-43.65	-39.31	-23.65
PS × B-10-224-3	5.91	94.40**	260.36**	347.72**	2.67	-38.76	128.20**	187.09**
PS × MBN 6242-3-1	2.58	-15.13	57.31**	95.45**	1.87	48.41**	59.82**	101.07**
PS × CFR 2211-2	5.00	0.40	204.87**	278.78**	1.55	23.01**	32.47**	66.66**
BUMOV 41212-3-1 × BN-364	1.27	8.54**	-22.56	-3.78	0.49	-37.97	-58.11	-47.31
BUMOV 41212-3-1 × P-1343-17-5-3	1.40	19.65**	-14.63	6.06**	1.56	51.45**	33.33**	67.74**
BUMOV 41212-3-1 × MVSR 6711-14-2	1.77	26.42**	7.92**	34.09**	0.57	-27.84	-51.28	-38.70
BUMOV 41212-3-1 × MSBN 3621-9-3-1	1.29	10.25**	-21.34	-2.27	0.52	-34.17	-55.55	-44.08
BUMOV 41212-3-1 × B-10-224-3	3.38	-32.12	106.09**	156.06**	2.34	-46.33	100.00**	151.61**
BUMOV 41212-3-1 × MBN 6242-3-1	3.37	126.17**	105.48**	155.30**	1.38	35.29**	17.94**	48.38**
BUMOV 41212-3-1 × CFR 2211-2	2.95	49.74**	79.87**	123.48**	1.18	-3.27	0.85**	26.88**
BN-364 × P-1343-17-5-3	1.67	-15.22	1.82**	26.51**	0.87	-15.53	-25.64	-6.45
BN-364 × MVSR 6711-14-2	1.09	22.47**	-33.53	-17.42	0.51	-16.39	-56.41	-45.16
BN-364 × MSBN 3621-9-3-1	1.35	51.68**	-17.68	2.27*	0.64	28.00**	-45.29	-31.18
BN-364 × B-10-224-3	1.52	-69.47	-7.31	15.15**	0.98	-77.52	-16.23	5.37**
BN-364 × MBN 6242-3-1	0.94	-36.91	-42.68	-28.78	0.61	-40.19	-47.86	-34.40

F1 Hybrid	Fruit yield per vine (kg)				Average fruit weight (kg)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × CFR 2211-2	1.01	-27.85	-38.41	-23.48	0.75	-38.52	-35.89	-19.35
P-1343-17-5-3 × MVSR 6711-14-2	1.29	-34.51	-21.34	-2.27	0.68	-33.98	-41.88	-26.88
P-1343-17-5-3 × MSBN 3621-9-3-1	1.24	-37.05	-24.39	-6.06	0.67	-34.95	-42.73	-27.95
P-1343-17-5-3 × B-10-224-3	4.24	-14.85	158.53**	221.21**	2.64	-39.44	125.64**	183.87**
P-1343-17-5-3 × MBN 6242-3-1	2.77	40.60**	68.90**	109.84**	1.33	29.12**	13.67**	43.01**
P-1343-17-5-3 × CFR 2211-2	3.60	82.74**	119.51**	172.72**	2.44	100.00**	108.54**	162.36**
MVSR 6711-14-2 × MSBN 3621-9-3-1	1.30	47.72**	-20.73	-1.51	0.65	6.55**	-44.44	-30.10
MVSR 6711-14-2 × B-10-224-3	1.50	-69.87	-8.53	13.63**	1.13	-74.08	-3.41	21.50**
MVSR 6711-14-2 × MBN 6242-3-1	1.26	-15.43	-23.17	-4.54	0.69	-32.35	-41.02	-25.80
MVSR 6711-14-2 × CFR 2211-2	1.67	19.28**	1.82**	26.51**	0.82	-32.78	-29.91	-11.82
MSBN 3621-9-3-1 × B-10-224-3	2.25	-54.81	37.19**	70.45**	1.34	-69.26	14.52**	44.08**
MSBN 3621-9-3-1 × MBN 6242-3-1	1.47	-1.34	-10.36	11.36**	0.60	-41.17	-48.71	-35.48
MSBN 3621-9-3-1 × CFR 2211-2	1.39	-0.71	-15.24	5.30**	1.21	-0.81	3.41**	30.10**
B-10-224-3 × MBN 6242-3-1	4.94	-0.80	201.21**	274.24**	2.66	-38.99	127.35**	186.02**
B-10-224-3 × CFR 2211-2	4.85	-2.61	195.73**	267.42**	2.74	-37.15	134.18**	194.62**
MBN 6242-3-1 × CFR 2211-2	3.65	144.96**	122.56**	176.51**	2.10	72.13**	79.48**	125.80**
CD at 5%	1.11	1.10			0.40	0.39		
CD at 1%	1.46	1.47			0.52	0.52		

*, ** Significant at 5% and 1% level, respectively.

Table 4.5.12: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for TSS (° Brix) and total carotenoids (mg/100 g FW)

F_1 Hybrid	TSS (° Brix)				Total carotenoids (mg/100 g FW)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	5.50	-31.5	-23.29	5.76**	15.08	-23.45	187.23**	172.2**
PS × BN-364	3.30	-50.96	-53.97	-36.53	22.73	116.27**	332.95**	310.28**
PS × P-1343-17-5-3	5.50	-18.27	-23.29	5.76**	5.25	-50.04	0	-5.23
PS × MVSR 6711-14-2	2.40	-70.83	-66.52	-53.84	4.22	-68.27	-19.61	-23.82
PS × MSBN 3621-9-3-1	4.70	-30.16	-34.44	-96.15	7.75	-26.26	47.61**	39.89**
PS × B-10-224-3	5.57	-17.23	-22.31	7.11**	7.54	-28.25	43.61**	36.1**
PS × MBN 6242-3-1	5.17	-23.17	-27.89	-0.57	11.26	7.13**	114.47	103.24**
PS × CFR 2211-2	7.70	14.41**	7.39**	48.07**	9.67	-7.99	84.19**	74.54**
BUMOV 41212-3-1 × BN-364	7.47	-6.97	4.18**	43.65**	13.24	-32.79	152.19**	138.98**
BUMOV 41212-3-1 × P-1343-17-5-3	3.13	-61.02	-56.34	-39.8	6.61	-66.44	25.9**	19.31**
BUMOV 41212-3-1 × MVSR 6711-14-2	4.53	-44.95	-36.82	-12.88	4.69	-76.19	-10.66	-15.34
BUMOV 41212-3-1 × MSBN 3621-9-3-1	4.70	-41.46	-34.44	-9.61	8.51	-56.8	62.09**	53.61**
BUMOV 41212-3-1 × B-10-224-3	4.33	-46.07	-39.6	-16.73	17.82	-9.54	239.42**	221.66**
BUMOV 41212-3-1 × MBN 6242-3-1	8.13	1.24**	13.38**	56.34**	12.46	-36.75	137.33**	124.9**
BUMOV 41212-3-1 × CFR 2211-2	5.30	-33.99	-26.08	1.92**	13.27	-32.63	152.76**	139.53**
BN-364 × P-1343-17-5-3	7.43	75.65**	3.62**	42.88**	8.75	14.22**	66.66**	57.94**
BN-364 × MVSR 6711-14-2	4.17	-49.33	-41.84	-19.8	5.68	-57.29	8.19**	2.52**
BN-364 × MSBN 3621-9-3-1	4.63	-18.77	-35.42	-10.96	17.70	131.07**	237.14**	219.49**
BN-364 × B-10-224-3	10.23	174.26**	42.67**	96.73**	20.79	171.4**	296**	275.27**
BN-364 × MBN 6242-3-1	10.17	91.88**	41.84**	95.57**	17.64	88.66**	236**	218.41**

F_1 Hybrid	TSS (° Brix)				Total carotenoids (mg/100 g FW)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × CFR 2211-2	6.13	27.7**	-14.5	17.88**	5.07	-33.81	-3.42	-8.48
P-1343-17-5-3 × MVSR 6711-14-2	3.23	-60.75	-54.95	-37.88	5.29	-60.22	0.76**	-4.51
P-1343-17-5-3 × MSBN 3621-9-3-1	6.17	8.24**	-13.94	18.65**	6.39	19.66**	21.71**	15.34**
P-1343-17-5-3 × B-10-224-3	8.13	92.19**	13.38**	56.34**	14.27	99.85**	171.8**	157.58**
P-1343-17-5-3 × MBN 6242-3-1	7.23	36.41**	0.83**	39.03**	5.32	-43.1	1.33**	-3.97
P-1343-17-5-3 × CFR 2211-2	4.50	-6.25	-37.23	-13.46	3.74	14.72**	-28.76	-32.49
MVSR 6711-14-2 × MSBN 3621-9-3-1	7.75	-5.83	8.08**	49.03**	9.32	-29.92	77.52**	68.23**
MVSR 6711-14-2 × B-10-224-3	5.70	-30.74	-20.5	9.61**	6.11	-54.06	16.38**	10.28**
MVSR 6711-14-2 × MBN 6242-3-1	7.67	-6.8	6.97**	47.5**	4.46	-66.46	-15.04	-19.49
MVSR 6711-14-2 × CFR 2211-2	3.13	-61.96	-56.34	-39.8	10.66	-19.84	103.04**	92.41**
MSBN 3621-9-3-1 × B-10-224-3	5.63	-1.22	-21.47	8.26**	9.40	31.65**	79.04**	69.67**
MSBN 3621-9-3-1 × MBN 6242-3-1	7.43	30.35**	3.62**	42.88**	4.07	-56.47	-22.47	-26.53
MSBN 3621-9-3-1 × CFR 2211-2	4.20	-18.22	-41.42	-19.23	3.32	-37.82	-36.76	-40.07
B-10-224-3 × MBN 6242-3-1	4.37	-17.54	-39.05	-15.96	5.10	-45.45	-2.85	-7.94
B-10-224-3 × CFR 2211-2	6.30	31.25**	12.13**	-4.1	10.70	49.85**	103.8**	93.14**
MBN 6242-3-1 × CFR 2211-2	2.63	-40.94	-63.31	-49.42	5.36	-42.67	2.09**	-3.24
CD at 5%	0.28	0.27			0.24	0.21		
CD at 1%	0.37	0.36			0.32	0.28		

*, ** Significant at 5% and 1% level, respectively.

4.5.22 Total carotenoids (mg/100 g FW)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for total carotenoids ranged from -68.27 to 171.4%, -36.76 to 332.95% and -40.07 to 310.28%, respectively. BN-364 × B-10-224-3 (171.4%) followed by BN-364 × MSBN 3621-9-3-1(131.07%) and PS × BN-364 (116.27%) had maximum heterobeltiosis out of 11 significantly desirable cross-combinations, while 26 and 24 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for total carotenoids. The maximum economic heterosis for this trait was shown by PS × BN-364 (332.95 and 310.28%, respectively), followed by BN-364 × B-10-224-3 (296 and 275.27%, respectively) and BUMOV 41212-3-1 × B-10-224-3 (239.42 and 221.66%, respectively) (Table 4.5.12). Bushy and BN crosses PS × BN-364 and BN-364 × B-10-224-3 had significantly high heterosis for this trait and provided good scope for development of bushy and BN hybrids with more total caroteneoids. Jahan *et al* (2012) also reported significant heterosis over mid parent for total carotenoids content in sweet gourd.

4.5.23 Dry matter (%)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for dry matter ranged from -60.75 to 103.51%, -46.79 to 65.78% and -38.04 to 96.87%, respectively. BN-364 × B-10-224-3 (171.4%) followed by BN-364 × MBN 6242-3-1(103.51%), followed by BN-364 × B-10-224-3 (93.39%) and BN-364 × P-1343-17-5-3 (59.69%) had maximum heterobeltiosis out of 9 significantly desirable cross-combinations, while 13 and 21 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for dry matter. The maximum economic heterosis for this trait was shown by BN-364 × MBN 6242-3-1(65.78 and 96.87%), followed by BN-364 × B-10-224-3 (57.55 and 87.09%) and MSBN 3621-9-3-1 × B-10-224-3 (43.13 and 69.97%, respectively) (Table 4.5.13). All the bushy and BN crosses had significantly high heterosis for dry matter and provided good scope for development of bushy and BN hybrids with high dry matter that can improve the storage life of fruits**.**

4.5.24 Vitamin-C (mg/100 g FW)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2 for vitamin-C ranged from -75.1 to 87.75%, -24.97 to 277.65% and 0 to 403.37%, respectively. BN-364 × B-10-224-3 (87.75%) followed by P-1343-17-5-3 × B-10-224-3 (62.85%) and P-1343-17-5-3 × MSBN 3621-9-3-1(50.36%) had maximum heterobeltiosis out of 13 significantly desirable cross-combinations, while 34 and 35 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for vitamin-C (Table 4.5.13). The maximum economic heterosis for this trait was shown by BN-364 × B-10-224-3 (277.65 and 403.37%) followed by P-1343-17-5-3 × B-10-224-3 (227.57 and 336.62%,

Table 4.5.13: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for dry matter (%) and Vitamin-C (mg/100 g FW)

F_1 Hybrid	Dry matter (%)				Vitamin-C (mg/100 g FW)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
PS × BUMOV 41212-3-1	8.81	-43.3	0.8**	19.7**	55.32	-7.09	75.34**	133.71**
PS × BN-364	8.27	-10.78	-5.37	12.36**	63.33	14.41**	100.72**	167.55**
PS × P-1343-17-5-3	6.68	-27.93	-23.56	-9.23	63.39	14.52**	100.91**	167.8**
PS × MVSR 6711-14-2	6.67	-42.59	-23.68	-9.37	23.67	-70.17	-24.97	0
PS × MSBN 3621-9-3-1	5.69	-38.61	-34.89	-22.69	47.40	-14.36	50.23**	100.25**
PS × B-10-224-3	7.17	-22.65	-17.96	-2.58	55.35	-12.77	75.43**	133.84**
PS × MBN 6242-3-1	6.53	-29.55	-25.28	-11.27	71.37	28.87**	126.21**	201.52**
PS × CFR 2211-2	10.13	9.27**	15.9**	37.63**	71.34	28.88**	126.11**	201.39**
BUMOV 41212-3-1 × BN-364	9.73	-37.38	11.32**	32.2**	62.99	-66.92	99.65**	166.11**
BUMOV 41212-3-1 × P-1343-17-5-3	9.26	-40.41	5.94**	25.81**	79.32	-58.34	151.41**	235.1**
BUMOV 41212-3-1 × MVSR 6711-14-2	6.57	-57.72	-24.82	-10.73	47.40	-75.1	50.23**	100.25**
BUMOV 41212-3-1 × MSBN 3621-9-3-1	6.45	-58.49	-26.2	-12.36	63.46	-66.67	101.14**	168.1**
BUMOV 41212-3-1 × B-10-224-3	6.25	-59.78	-28.48	-15.08	63.19	-66.81	100.28**	166.96**
BUMOV 41212-3-1 × MBN 6242-3-1	9.30	-40.15	6.4**	26.35**	55.32	-70.94	75.11**	133.71**
BUMOV 41212-3-1 × CFR 2211-2	7.40	-52.38	-15.33	0.54**	63.29	-66.76	100.6**	167.38**
BN-364 × P-1343-17-5-3	11.61	59.69**	32.83**	57.74**	39.49	-16.68	25.16**	66.83**
BN-364 × MVSR 6711-14-2	4.56	-60.75	-47.82	-38.04	55.42	-30.15	75.65**	134.13**
BN-364 × MSBN 3621-9-3-1	8.64	-5.57	-1.14	17.39**	55.32	16.7**	75.34**	133.71**
BN-364 × B-10-224-3	13.77	93.39**	57.55**	87.09**	119.15	87.75**	277.65**	403.37**

F_1 Hybrid	Dry matter (%)				Vitamin-C (mg/100 g FW)			
	Mean	Heterobeltiosis	Economic heterosis		Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2			PPH-1	PPH-2
BN-364 × MBN 6242-3-1	14.49	103.51**	65.78**	96.87**	71.34	28.81**	126.11**	201.39**
BN-364 × CFR 2211-2	7.59	5.56**	-13.15	3.12**	55.32	16.21**	75.34**	133.71**
P-1343-17-5-3 × MVSR 6711-14-2	6.23	-46.38	28.71**	-15.35	55.38	-30.2	75.53**	133.96**
P-1343-17-5-3 × MSBN 3621-9-3-1	5.72	-37.48	-34.55	-22.28	47.44	50.36**	50.36**	100.42**
P-1343-17-5-3 × B-10-224-3	10.67	46.76**	22.08**	44.97**	103.35	62.85**	227.57**	336.62**
P-1343-17-5-3 × MBN 6242-3-1	6.67	-8.25	-23.68	-9.37	47.44	-14.33	50.36**	100.42**
P-1343-17-5-3 × CFR 2211-2	5.81	-20.08	-33.52	-21.05	71.27	49.72**	125.89**	201.09**
MVSR 6711-14-2 × MSBN 3621-9-3-1	7.58	-34.76	-13.27	2.98**	31.56	-60.22	0.03	33.33**
MVSR 6711-14-2 × B-10-224-3	7.65	-34.16	-12.47	3.94**	47.40	-40.26	50.23**	100.25**
MVSR 6711-14-2 × MBN 6242-3-1	8.41	-27.62	-3.77	14.26**	39.49	-50.23	25.16**	66.83**
MVSR 6711-14-2 × CFR 2211-2	10.73	-7.65	22.76**	45.78**	47.57	-40.05	50.77**	100.97**
MSBN 3621-9-3-1 × B-10-224-3	12.51	36.72**	43.13**	69.97**	39.53	-37.7	25.29**	67**
MSBN 3621-9-3-1 × MBN 6242-3-1	11.31	23.6**	29.4**	53.66**	47.47	-14.28	50.45**	100.54**
MSBN 3621-9-3-1 × CFR 2211-2	8.74	-4.48	0	18.75**	39.53	16.95**	25.29**	67**
B-10-224-3 × MBN 6242-3-1	4.65	-16.06	-46.79	-36.82	39.56	-37.66	25.38**	67.13**
B-10-224-3 × CFR 2211-2	8.69	20.86**	-0.57	18.07**	63.36	-0.15	100.82**	167.68**
MBN 6242-3-1 × CFR 2211-2	5.53	-23.08	-36.72	-24.86	71.31	28.76**	126.02**	201.26**
CD at 5%	0.26	0.27			0.24	0.21		
CD at 1%	0.35	0.36			0.32	0.28		

*, ** Significant at 5% and 1% level, respectively.

respectively) and BUMOV 41212-3-1 × P-1343-17-5-3 (151.41 and 235.1%, respectively). BN-364 × B-10-224-3 as bushy and BN cross provided good scope for development of bushy and BN hybrids with high vitamin-C that can improve the quality of fruits. Thangamani and Pugalendhi (2013) also found significantly high heterosis for ascorbic acid in five hybrids of bitter gourd.

4.5.25 Total sugar (mg/100g DW.)

Among 36 crosses, the magnitude of heterobeltiosis, economic heterosis over PPH-1 and PPH-2for total sugar ranged from -44.35 to 66.03%, -5.76 to 71.79% and -39.68 to 4.28%, respectively. MVSR 6711-14-2 × MSBN 3621-9-3-1 (66.03%) followed by MVSR 6711-14-2 × CFR 2211-2 (63.05%) and BUMOV 41212-3-1 × MBN 6242-3-1 (23.18%) had maximum heterobeltiosis out of 8 significantly desirable cross-combinations, while 32 and 10 hybrids exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for total sugar (Table 4.5.14). The maximum economic heterosis for this trait was shown by PS × MSBN 3621-9-3-1 (71.79 and 4.28%), followed by BUMOV 41212-3-1 × B-10-224-3 (71.15 and 3.89%, respectively), MVSR 6711-14-2 × MSBN 3621-9-3-1 (69.23 and 2.72%) and MVSR 6711-14-2 × B-10-224-3(69.23 and 2.72%, respectively). PS × MSBN 3621-9-3-1, MVSR 6711-14-2 × B-10-224-3 and MVSR 6711-14-2 × MSBN 3621-9-3-1 as bushy and BN crosses provided good scope for development of bushy and BN hybrids with high total sugar that can improve the quality of fruits.

4.6 *Per se* performance of best bushy and butternut hybrids

The *per se* performance of best hybrid combinations selected on the basis of involvement of bushy and BN parents as well as their per hectare yield performance were presented in Table 4.6. On the basis of yield per hectare performance, the best hybrids were PS × MSBN 3621-9-3-1(40.96 t/ha), PS × BN-364 (40.13 t/ha), BN-364 × P-1343-17-5-3 (39.50 t/ha), BN-364 × B-10-224-3 (36.02 t/ha), MSBN 3621-9-3-1 × MBN 6242-3-1 (34.76 t/ha), MSBN 3621-9-3-1 × CFR 2211-2 (33.02 t/ha), BN-364 × MSBN 3621-9-3-1 (32.07 t/ha), MVSR 6711-14-2 × MSBN 3621-9-3-1(30.81t/ha), BUMOV 41212-3-1 × MSBN 3621-9-3-1 (30.41t/ha) and BUMOV 41212-3-1 × BN-364 (30.10 t/ha).

Both the parents of hybrid PS × MSBN 3621-9-3-1 were poor combiner for yield per hectare, but revealed significant and desirable economic heterosis over check PPH-2 and it was bushy and BN hybrid with early maturity (46 days approx.), economical fruit size (710 gm) and good pulp thickness (2.09 cm). MSBN 3621-9-3-1 × MBN 6242-3-1 was bushy

MBN 6242-3-1 × CFR 2211-2

PS × BN-364

MSBN 3621-9-3-1 × CFR 2211-2

Photographs of some bushy and high yielding hybrids

Table 4.5.14: Heterobeltiosis (%) and economic heterosis (%) of F_1 hybrids for total sugar (mg/100g DW.)

F_1 Hybrid	Total sugar (mg/100g DW.)			
	Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2
PS × BUMOV 41212-3-1	1.94	-24.51	24.35**	-24.51
PS × BN-364	2.49	-3.11	59.61**	-3.11
PS × P-1343-17-5-3	2.63	-1.12	68.58**	2.33**
PS × MVSR 6711-14-2	2.28	-11.28	46.15**	-11.28
PS × MSBN 3621-9-3-1	2.68	4.28**	71.79**	4.28**
PS × B-10-224-3	1.58	-39.92	1.28**	-38.52
PS × MBN 6242-3-1	2.25	-12.45	44.23**	-12.45
PS × CFR 2211-2	2.66	3.5**	70.51**	3.5**
BUMOV 41212-3-1 × BN-364	1.58	-36.29	1.28**	-38.52
BUMOV 41212-3-1 × P-1343-17-5-3	2.61	-1.87	67.3**	1.55**
BUMOV 41212-3-1 × MVSR 6711-14-2	1.59	-23.18	1.92**	-38.13
BUMOV 41212-3-1 × MSBN 3621-9-3-1	1.59	-23.18	1.92**	-38.13
BUMOV 41212-3-1 × B-10-224-3	2.67	1.52**	71.15**	3.89**
BUMOV 41212-3-1 × MBN 6242-3-1	2.55	23.18**	63.46**	-0.77
BUMOV 41212-3-1 × CFR 2211-2	1.55	-25.12	-0.64	-39.68
BN-364 × P-1343-17-5-3	1.58	-40.6	1.28**	-38.52
BN-364 × MVSR 6711-14-2	1.58	-36.29	1.28**	-38.52
BN-364 × MSBN 3621-9-3-1	1.47	-40.72	-5.76	-42.8
BN-364 × B-10-224-3	2.59	-1.52	66.02**	0.77**
BN-364 × MBN 6242-3-1	1.38	-44.35	-11.53	-46.3

F_1 Hybrid	Total sugar (mg/100g DW.)			
	Mean	Heterobeltiosis	Economic heterosis	
			PPH-1	PPH-2
BN-364 × CFR 2211-2	1.59	-35.88	1.92**	-38.13
P-1343-17-5-3 × MVSR 6711-14-2	2.50	-6.01	60.25**	-2.72
P-1343-17-5-3 × MSBN 3621-9-3-1	1.59	-40.22	1.92**	-38.13
P-1343-17-5-3 × B-10-224-3	2.60	-2.25	66.66**	1.16**
P-1343-17-5-3 × MBN 6242-3-1	2.61	-1.87	67.3**	1.55**
P-1343-17-5-3 × CFR 2211-2	2.29	-13.9	46.79**	-10.89
MVSR 6711-14-2 × MSBN 3621-9-3-1	2.64	66.03**	69.23**	2.72**
MVSR 6711-14-2 × B-10-224-3	2.64	0.38**	69.23**	2.72**
MVSR 6711-14-2 × MBN 6242-3-1	1.57	1.94**	0.64**	-38.91
MVSR 6711-14-2 × CFR 2211-2	2.56	63.05**	64.1**	-0.38
MSBN 3621-9-3-1 × B-10-224-3	1.58	-39.92	1.28**	-38.52
MSBN 3621-9-3-1 × MBN 6242-3-1	1.55	-2.51	-0.64	-39.68
MSBN 3621-9-3-1 × CFR 2211-2	1.59	0	1.92**	-38.13
B-10-224-3 × MBN 6242-3-1	1.96	-25.47	25.64**	-23.73
B-10-224-3 × CFR 2211-2	2.52	-4.18	61.53**	-1.94
MBN 6242-3-1 × CFR 2211-2	2.38	-9.5	52.56**	-7.39
CD at 5%	0.27	0.27		
CD at 1%	0.29	0.36		

*, ** Significant at 5% and 1% level, respectively.

Table 4.6: *Per se* performance of best hybrids on the basis of high yield, bushy growth habit and butternut fruit type

Yield per ha (t/ha)							*Per se* performance						
S.NO.	Hybrid	*Per se* performnance	GCA of parents	SCA of hybrids	Heterosis over checks (%)		Vine length (cm)	Internodal length (cm)	Earliest node to female flower	Pulp thickness (cm)	Days to maturity	Average fruit weight (kg)	Fruit shape index
					PPH-1	PPH-2							
1	PS × MSBN 3621-9-3-1	40.96	P × P	3.11	5.18	30.61**	73.11	3.00	4.00	2.09	46.33	0.71	1.42
2	PS × BN-364	40.13	P × P	-7.26	3.05	27.96*	77.44	2.72	2.75	2.04	39.00	0.69	1.07
3	BN-364 × P-1343-17-5-3	39.50	P × P	1.17	1.43	25.95*	59.78	2.67	3.58	2.18	40.33	0.87	1.09
4	BN-364 × B-10-224-3	36.02	P × G	19.72**	-7.49	14.85	55.44	3.22	4.33	2.51	41.00	0.98	1.04
5	MSBN 3621-9-3-1 × MBN 6242-3-1	34.76	P × G	-20.49**	-10.73	10.84	53.22	2.31	4.25	2.09	43.00	0.60	3.79
6	MSBN 3621-9-3-1 × CFR 2211-2	33.02	P × A	-3.65	-15.20	5.29	44.11	2.22	5.42	3.07	43.00	1.21	1.45
7	BN-364 × MSBN 3621-9-3-1	32.07	P × P	-3.70	-17.64	2.26	40.33	1.80	2.92	1.71	43.00	0.64	2.12
8	MVSR 6711-14-2 × MSBN 3621-9-3-1	30.81	P × P	-3.20	-20.87*	-1.75	38.44	1.98	2.25	2.00	43.00	0.65	1.57
9	BUMOV 41212-3-1 × MSBN 3621-9-3-1	30.41	A × P	31.58**	-21.90	-3.02	39.00	2.67	3.75	1.70	43.33	0.52	1.59
10	BUMOV 41212-3-1 × BN-364	30.10	A × P	-14.73*	-22.70	-4.01	52.00	2.30	2.50	1.71	42.00	0.49	1.26
11	PPH-1	38.94	-	-	-	-	83.67	2.34	2.50	3.07	39.33	1.17	0.91
12	PPH-2	31.36	-	-	-	-	64.89	2.83	2.92	2.05	38.67	0.93	0.90

P = Poor GCA, G = Good GCA, A = Average GCA hybrid with BN fruits and good pulp thickness. It is combination of one poor and one good combiner for yield. Therefore the emphasis should be given for improvement through recurrent selection involving bushy growth habit, BN fruit size with good pulp thickness and high yield potential. MSBN 3621-9-3-1 × CFR 2211-2 was also bushy hybrid with BN fruits having more pulp thickness and less average fruit weight. It is a combination of one poor and one average combiner for yield. Therefore, the emphasis should be given for improvement through recurrent selection involving bushy growth habit, BN fruit size with good pulp thickness, less average fruit weight and high yield potential.

4.7 Correlation analysis

4.7.1 Association of vine length with other vegetative characters –

In the present investigation, the correlation studies of various vegetative and flowering characters unveiled higher genotypic correlation as compared to the corresponding phenotypic correlation (Table 4.7.1). The association of vine length with all these characters indicated that vine length is positively correlated with internodal length, leaf length, leaf width, petiole length, earliest node to first female flower, days to 50% female flowering, earliest node to first male flower. However the internodal length (0.85) and earliest node to female flower (0.85) exerted maximum influence on the vine length, followed by days to 50% female flowering, petiole length, earliest node to male flower. The genotypic and phenotypic correlation values indicated that the environment did not manipulate the expressions of these traits. Similar result was also reported by Nandpuri *et al* (1973).Therefore, the selection for these characters would be effective in single environment. For selecting bushy vines in pumpkin, the emphasis must be given to the small internodal length, lower node to female flower, less number of days to 50% female flowering, short petiole length and lower node to first male flower. The earlier studies indicated that vine length can be modified by making selections on the bases of these vegetative characters (Faruk Hossain *et al* 2010).

Table 4.7.1: Genotypic and phenotypic correlation for vine length other vegetative and flowering characters -

Characters		NPB	IL	LL	LW	PL	ENFF	DFF	ENMF	DFM
IL	G	-0.001								
	P	-0.01								
LL	G	-0.43**	0.13							
	P	-0.30**	0.14							
LW	G	-0.38**	0.07	0.96**						
	P	-0.24*	0.09	0.94**						
PL	G	-0.23*	0.31**	0.83**	0.86**					
	P	-0.17	0.28**	0.75**	0.78**					
ENFF	G	-0.10	0.68**	0.54**	0.52**	0.61**				
	P	-0.05	0.62**	0.46**	0.44**	0.54**				
DFF	G	0.01	0.49**	0.09	0.08	0.18	0.59**			
	P	0.06	0.44**	0.06	0.07	0.15	0.57**			
ENMF	G	0.10	0.47**	-0.13	-0.09	0.001	0.61**	0.64**		
	P	0.01	0.33**	-0.06	-0.07	0.03	0.36**	0.34**		
DFM	G	-0.04	-0.36**	0.03	0.12	-0.11	-0.20*	-0.12	-0.25**	
	P	-0.08	-0.30**	-0.01	0.06	-0.10	-0.17	-0.08	-0.17	
VL	G	-0.19*	0.85**	0.45**	0.44**	0.57**	0.85**	0.60**	0.53**	-0.23*
	P	-0.16	0.80**	0.41**	0.39**	0.51**	0.82**	0.58**	0.38**	-0.18

*, ** Significant at 5% and 1% level, respectively.

NPB= Number of primary branches, IL = Internodal length, LL = Leaf length, LW = Leaf width, PL = Petiole length, ENFF = Earliest node to female flower, DFF = Days to 50%female flowering, ENMF = Earliest node to male flower, DFM = Days to 50%male flowering, VL = Vine length

4.7.2 Association of fruit yield per vine with other fruit characters –

Correlation studies of yield per plant with other associated characters in pumpkin revealed that genotypic correlation was higher than the corresponding phenotypic correlation (Table 4.7.3). Therefore, the role of environment in the expression of these characters was insignificant. Similar result was also reported by Nandpuri *et al* (1973). From the Table 4.7.2, it was observed that fruit yield per vine had positive and significant genotypic and phenotypic association with earliest node to first fruit, peduncle length, equatorial diameter, pulp thickness, average fruit weight, number days to first fruit harvest and vine length, whereas fruit shape index had negative and significant genotypic and phenotypic association with fruit yield per vine and number of fruits per vine had only negative and significant genotypic association. Polar diameter had positive but non-significant association with fruit yield per vine. However the average fruit weight (1.00), node to first fruit (0.98), vine length (0.97), peduncle length (0.95) and equatorial diameter (0.91) exerted maximum influence on the fruit yield. The present investigation included bushy and butternut hybrids. According to the results obtained from association of yield and related characters, the selection for bushy vines and high fruit shape index (butternut fruits) might decrease the yield potential. Vine length had positive and significant genotypic and phenotypic association with earliest node to first fruit, peduncle length, equatorial diameter, pulp thickness, average fruit weight, days to fruit maturity, however negatively and significantly associated with fruit shape index but non-significantly associated with number of fruits per vine. The node to first fruit (0.92), peduncle length (0.88) and average fruit weight (0.86) exerted maximum influence on the vine length. According to the results obtained the selection for lower node to first fruit less peduncle length, less fruit weight, high fruit shape index and more number of fruits per vine might indirectly favour the selection of bushy vines with butternut fruit types. Similar results was found by Resmi and Sreelathakumary (2012), Janaranjani and Kanthaswamy (2015), Potekar *et al* (2014), Faruk Hossain *et al* (2010), Arunkumar *et al* (2011).

Table 4.7.2: Genotypic and phenotypic correlation for fruit yield per vine other fruit characters

Characters		NFF	PD	PDF	EDF	FSI	PT	NFV	AFW	DFM	VL
PD	G	0.83**									
	P	0.79**									
PDF	G	0.18	0.04								
	P	0.18	0.03								
EDF	G	0.76**	0.87**	-0.17							
	P	0.74**	0.84**	-0.17							
FSI	G	-0.24**	-0.39**	0.86**	-0.60**						
	P	-0.23*	-0.38**	0.86**	-0.60**						
PT	G	0.62**	0.60**	-0.08	0.82**	-0.46**					
	P	0.60**	0.58**	-0.08	0.81**	-0.46**					
NFV	G	-0.12	-0.27**	0.13	-0.48**	0.33**	-0.50**				
	P	-0.09	-0.17	0.07	-0.31**	0.21*	-0.33**				
AFW	G	0.90**	0.94**	0.06	0.91**	-0.40**	0.73**	-0.37**			
	P	0.64**	0.68**	0.04	0.68**	-0.29**	0.55**	-0.22*			
DFM	G	0.87**	0.66**	0.07	0.66**	-0.29**	0.62**	-0.13	0.78**		
	P	0.84**	0.63**	0.07	0.65**	-0.29**	0.60**	-0.07	0.57**		
VL	G	0.92**	0.88**	0.08	0.82**	-0.33**	0.59**	-0.01	0.86**	0.75**	
	P	0.88**	0.85**	0.08	0.81**	-0.33**	0.57**	-0.01	0.64**	0.73**	
FYV	G	0.98**	0.95**	0.09	0.91**	-0.38**	0.73**	-0.27**	1.00**	0.85**	0.97**
	P	0.78**	0.77**	0.07	0.77**	-0.32**	0.60**	0.10	0.71**	0.71**	0.82**

*, ** Significant at 5% and 1% level, respectively.

NFF = Node to first fruit, PD = Peduncle length, PDF = Polar diameter of fruit, EDF = Equatorial diameter of fruit, FSI = Fruit shape index, PT = Pulp thickness, NFV = Number of fruits per vine, AFW = Average fruit weight, DFM = Days to fruit maturity, VL = Vine length, FYV = Fruit yield per vine

4.7.2 Association of average fruit weight with quality characters -

The association of fruit weight with the different quality characters was presented in Table 4.7.3. From significant and positive genotypic as well as phenotypic association of average fruit weight with vitamin-C and total sugar indicated that with the reduction in fruit size there would be decrease in the level of these quality traits. However, the negative and non-significant genotypic and phenotypic association with dry matter, TSS and total carotenoids highlighted that these traits might remain unchanged with the decrease or increase in average fruit weight. Among quality characters, total sugar (0.34) and vitamin-C (0.31) displayed maximum influence on the quality of fruit while selecting for low or high average fruit weight. So, in present investigation the selection for smaller fruit may reduce the level of quality characters such as total sugar and vitamin-C. On the other hand TSS, total carotenoids and dry matter remain unaffected or may increase insignificantly.

Table 4.7.3: Genotypic and phenotypic correlation for fruit yield per vine with other quality characters

Characters		TSS	Total Caroteneoids	Dry matter	Vitamin-C	Total sugar
Total Caroteneoids	G	0.30**				
	P	0.30**				
Dry matter	G	0.62**	0.47**			
	P	0.62**	0.47**			
Vitamin-C	G	0.31**	0.50**	0.31**		
	P	0.31**	0.50**	0.31**		
Total sugar	G	-0.10	0.12	-0.12	0.29**	
	P	-0.09	0.11	-0.11	0.27**	
Average fruit weight	G	-0.07	-0.001	-0.16	0.31**	0.34**
	P	-0.07	-0.001	-0.15	0.29**	0.31**

*, ** Significant at 5% and 1% level, respectively.

CHAPTER- V

SUMMARY

The present investigation entitled "Heterosis and combining ability studies on yield, quality and storage traits involving bush and butternut type genotypes in pumpkin (*Cucurbita moschata* Duch. ex Poir.)" was planned with the objectives to find out general combining ability and specific combining ability effects for growth, earliness, yield and quality traits, to assess gene action governing these traits and to estimate the extent of heterosis for these traits in F_1 hybrids.

The experiment was conducted at Vegetable Research Farm and Biochemistry Laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana during summer season of 2015 and 2016. Pumpkin inbreds (Punjab Samrat, BUMOV 41212-3-1, BN-364, P-1343-17-5-3, MVSR 6711-14-2, MSBN 3621-9-3-1, CFR 2211-2, B-10-224-3, MBN 6242-3-1) having variation in vegetative growth, earliness, yield and quality traits were crossed in diallel fashion excluding reciprocals. Nine parents, 36 F_1 hybrids and two checks (PPH-1 and PPH-2) were evaluated in a Randomized Block Design (RBD) for vegetative growth, yield, quality and storage traits. Data were compiled and statistically analyzed as per RBD using BMM and MVM softwares. Analysis of variance for experimental design for various characters as well as combining ability highlighted considerable amount of variation due to highly significant GCA and SCA indicating involvement of both additive and non-additive gene effects in all the traits. However, higher σ^2SCA than σ^2GCA suggested greater role of non-additive gene effects in the inheritance of all the characters studied in present investigation.

The general combining ability estimates of parents revealed that MSBN 3621-9-3-1 as bushy and BN type was the best combiner for vine length (-47.83), internodal length (-0.80), petiole length (-1.84), earliest node to female flower (-1.78) and male flower (-0.07), peduncle length (-1.28), equatorial diameter (2.29), fruit shape index (0.26), node to first fruit (-1.66), days to maturity (-3.59), less average fruit weight (-0.40) and good general combiner for number of primary branches (0.07), days to 50% female flowering (-2.39), polar diameter (0.43), number of fruits per vine(0.13), TSS (0.17); CFR 2211-2 being bush type was the best combiner for number of primary branches (0.14), days to 50% female flowering (-3.18), polar diameter (1.22), TSS (0.39) and dry matter (1.20) and good general combiner for vine length (-22.85), earliest node to male flower (-0.06), days to 50% male flowering (-1.33), fruit shape index (0.12), pulp thickness (0.21), total carotenoids (0.29); MBN 6242-3-1 as BN type was the best combiner for leaf length (0.71) and width (0.99), pulp thickness (0.44) and fruit yield per vine (0.63) and good general combiner for Vitamin-C (1.52); MVSR 6711-14-2 as bush type

was the best general combiner for days to 50% male flowering (-1.36) and Vitamin-C (4.43) and good general combiner for number of primary branches (0.09), petiole length (-1.41) days to 50% female flowering (-1.75), earliest node to male flower (-0.06), node to first fruit (-1.06) and days to maturity (-3.53); BN-364 as bushy and BN type was best general combiner for number of fruits per vine (0.22) and total carotenoids (0.89) and good general combiner for leaf length (0.44) and width (0.56), earliest node to female flower (-0.47), equatorial diameter (-0.98), less average fruit weight (-0.19) and Vitamin-C content (1.44).

The highest estimates of SCA involving bushy and BN parents for number of primary branches (MSBN 3621-9-3-1 × B-10-224-3), internodal length (PS × MSBN 3621-9-3-1), petiole length(PS × BN-364), earliest node to female flower (BUMOV 41212-3-1 × CFR 2211-2), days to 50% female flowering (BUMOV 41212-3-1 × CFR 2211-2), earliest node to male flower (BN-364 × MSBN 3621-9-3-1), days to 50% male flowering (MVSR 6711-14-2 × MSBN 3621-9-3-1), fruit shape index (B-10-224-3 × MBN 6242-3-1), node to first fruit (BUMOV 41212-3-1 × CFR 2211-2), days to fruit maturity (BUMOV 41212-3-1 × CFR 2211-2), fruit yield per vine (MVSR 6711-14-2 × B-10-224-3), TSS (P-1343-17-5-3 × MBN 6242-3-1) and dry matter (P-1343-17-5-3 × MBN 6242-3-1) and Vitamin-C content (MVSR 6711-14-2 × B-10-224-3) revealed the occurrence of both additive as well as non-additive genetic effects that can further be utilized through heterosis breeding or recurrent selection for high SCA particularly in these crosses for specific traits.

Bushy and BN crosses with high SCA effects for leaf length and width (BN-364 × B-10-224-3), peduncle length (PS × BN-364), polar diameter (B-10-224-3 × MBN 6242-3-1), pulp thickness (MVSR 6711-14-2 × CFR 2211-2), total carotenoids (BUMOV 41212-3-1 × CFR 2211-2) and total sugar (PS × MVSR 6711-14-2) highlighted the predominance of additive and additive × additive genetic variance in particular crosses that can be further exploited in hybridization and pedigree selection to increase the gene frequencies for the enlisted traits. However, the bushy and BN crosses for short vine (BUMOV 41212-3-1 × MBN 6242-3-1), equatorial diameter (B-10-224-3 × MBN 6242-3-1), number of fruits per vine (B-10-224-3 ×MBN 6242-3-1) and less average fruit weight (B-10-224-3 × MBN 6242-3-1) depicted non-additive genetic effects that can be exploited through heterosis breeding.

Heterosis can be exploited for the development of bushy and BN hybrids with more number of fruit, less fruit weight and high fruit yield per vine. BUMOV 41212-3-1 × BN-364, PS × BN-364, BUMOV 41212-3-1 × MVSR 6711-14-2, BUMOV 41212-3-1 × MSBN 3621-9-3-1, MSBN 3621-9-3-1 × MBN 6242-3-1 were best hybrids for less fruit weight as well as more number of fruits per vine. However, bushy and BN crosses PS × CFR 2211-2 (204.87 and 278.78%, respectively), B-10-224-3 × MBN 6242-3-1 (201.21 and 274.24%, respectively), MBN 6242-3-1 × CFR 2211-2 (122.56 and 176.51%, respectively), P-1343-17-5-3 × CFR 2211-1 (119.51 and 172.72%, respectively), PS × BN-364 (75.60 and 118.18%, respectively), BN-364 × P-1343-17-5-3 (1.82 and 26.51%, respectively) , BN-364 × B-10-224-3 (15.15% over PPH-2), MSBN 3621-9-3-1 × MBN 6242-3-1 (11.36% over PPH-2) had significant heterosis for yield and provided good scope for development of bushy and BN hybrids with more fruits yield per vine.

In present investigation, no hybrid exhibited significantly desirable economic heterosis over PPH-1 and PPH-2 for early days to fruit maturity. MVSR 6711-14-2 × MSBN 3621-9-3-1, BN-364 × MBN 6242-3-1, MSBN 3621-9-3-1 × MBN 6242-3-1, BN-364 × MSBN 3621-9-3-1 and MSBN 3621-9-3-1 × CFR 2211-2 were best BN hybrids with bushy growth habit and earliness in flowering. Only MSBN 3621-9-3-1 × CFR 2211-2 bearing BN fruits had significant heterosis for pulp thickness over PPH-2.

BN-364 × B-10-224-3 revealed high economic heterosis over both checks for total carotenoids (332.95, 310.28%, respectively), dry matter (57.55 and 87.09%) and Vitamin-C (277.65 and 403.37%), while PS × BN-364 was best hybrid for TSS (332.95%, 310.28%, respectively); BN-364 × MBN 6242-3-1 (65.78 and 96.87%, respectively) and PS × MSBN 3621-9-3-1 (71.79 and 4.28%, respectively) for dry matter; MVSR 6711-14-2 × MSBN 3621-9-3-1 (69.23 and 2.72%, respectively) and MVSR 6711-14-2 × B-10-224-3 (69.23 and 2.72%, respectively) were good hybrids for total sugar.

On the basis of yield per hectare performance, the best hybrids were PS × MSBN 3621-9-3-1(40.96 t/ha), PS × BN-364 (40.13 t/ha), BN-364 × P-1343-17-5-3 (39.50 t/ha), BN-364 × B-10-224-3 (36.02 t/ha), MSBN 3621-9-3-1 × MBN 6242-3-1 (34.76 t/ha), MSBN 3621-9-3-1 × CFR 2211-2 (33.02 t/ha), BN-364 × MSBN 3621-9-3-1 (32.07 t/ha), MVSR 6711-14-2 × MSBN 3621-9-3-1(30.81t/ha), BUMOV 41212-3-1 × MSBN 3621-9-3-1 (30.41t/ha) and BUMOV 41212-3-1 × BN-364 (30.10 t/ha).

The association of vegetative and flowering characters for vine length revealed the maximum influence of internodal length (0.85) and earliest node to female flower (0.85), followed by days to 50% female flowering, petiole length, earliest node to male flower. The fruit yield per vine was highly associated with average fruit weight (1.00), followed by node to first fruit (0.98), vine length (0.97), peduncle length (0.95) and equatorial diameter (0.91). Total sugar (0.34) and Vitamin-C (0.31) displayed maximum and positive correlation with average fruit weight.

It can be concluded that most of the characters were governed by additive and non additive gene effects, but analysis of variance indicated the predominance of non-additive gene effects for all the characters. Therefore, heterosis breeding and recurrent selection for high SCA would facilitate simultaneous exploitation of both genetic components in future breeding programmes of pumpkin. However, the predominance of additive and additive × additive genetic variance in particular crosses of some traits can be further exploited through hybridization and selection for increasing the gene frequencies. Hybrids performing better than commercial checks can be further tested in multilocation trials to confirm their potential and to identify the best hybrid combination(s) for commercialization.

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APPENDIX I: Average performance of parents for vegetative, flowering and fruit earliness traits

Parents	Vine length (cm)	Number of primary branches	Internodal length (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Node to 1st female flower	Days to 50% female flowering	Node to 1st male flower	Days to 50% male flowering	Node to 1st fruit	Days to fruit maturity
Punjab Samrat	215.67	3.00	5.20	13.79	19.34	24.14	2.50	63.33	1.67	39.33	13.92	65.67
BUMOV 41212-3-1	76.78	3.00	2.43	18.33	24.68	31.68	8.92	49.33	1.58	46.33	9.33	59.33
BN-364	44.33	3.00	1.26	13.18	18.42	23.13	3.83	34.33	1.83	47.00	6.42	46.00
P-1343-17-5-3	139.33	3.92	5.32	10.87	15.70	20.78	8.00	36.67	1.33	40.33	8.17	54.00
MVSR 6711-14-2	36.89	3.33	2.14	12.21	19.04	17.56	5.00	39.00	1.00	42.00	5.75	47.00
MSBN 3621-9-3-1	43.67	1.92	2.06	14.78	22.23	19.97	4.00	39.00	1.00	47.67	5.50	46.00
B-10-224-3	325.44	3.00	8.33	16.77	23.63	26.74	14.25	50.67	1.42	44.33	12.17	64.33
MBN 6242-3-1	176.33	3.00	2.91	14.09	20.93	31.32	11.75	49.33	2.17	46.00	12.83	60.00
CFR 2211-2	57.27	3.25	1.61	14.71	20.48	23.98	7.25	42.33	1.00	42.67	8.42	56.33

APPENDIX II: Average performance of parents for fruit, yield and quality traits

Genotypes	Peduncle length (cm)	Polar diameter (cm)	Equator diameter (cm)	Fruit shape index	Pulp thickness (cm)	Average fruit weight (kg)	No. of fruits per vine	Fruit yield/ vine (kg)	Fruit yield per ha (tonnes)	TSS (°Brix)	Total carotenoids (mg/100g FW)	Dry matter (%)	Vitamin-C (mg/100g FW)	Total sugar (mg/100g DW)
Punjab Samrat	6.24	12.60	15.83	0.80	3.04	1.26	2.42	2.31	27.01	6.73	10.51	9.27	55.35	2.57
BUMOV 41212-3-1	6.38	12.47	11.67	1.07	2.32	0.79	1.50	1.15	29.83	8.03	19.70	15.54	190.42	2.07
BN-364	2.83	19.40	9.79	1.98	1.72	0.50	1.83	0.90	21.09	3.73	7.66	7.12	47.40	2.48
P-1343-17-5-3	8.00	12.20	16.33	0.75	2.31	1.03	1.92	1.94	34.96	4.23	2.68	7.27	23.67	2.66
MVSR 6711-14-2	2.79	7.00	12.43	0.56	2.28	0.61	1.25	0.82	18.17	8.23	13.30	11.62	79.35	1.32
MSBN 3621-9-3-1	3.00	25.37	7.53	3.37	1.40	0.40	2.25	0.68	20.93	5.70	5.34	9.15	31.55	1.59
B-10-224-3	10.88	17.23	26.13	0.66	3.71	4.36	1.17	4.67	44.23	3.20	7.14	5.54	63.46	2.63
MBN 6242-3-1	5.21	27.63	11.11	2.49	1.83	1.01	1.50	1.37	13.27	5.30	9.35	4.63	55.38	1.54
CFR 2211-2	3.25	10.40	16.23	0.64	3.30	1.22	1.17	1.40	33.10	4.80	3.26	7.19	47.60	1.57

APPENDIX III: Average performance of F_1 hybrids for vegetative, flowering and fruit earliness traits

F_1 hybrids	Vine length (cm)	Number of primary branches	Internodal length (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Node to 1st female flower	Days to 50% female flowering	Node to 1st male flower	Days to 50% male flowering	Node to 1st fruit	Days to fruit maturity
PS × BUMOV 41212-3-1	223.67	3.33	3.38	17.34	23.84	29.84	9.33	46.33	1.17	37.67	11.00	58.00
PS × BN-364	73.78	3.42	2.72	14.51	21.32	24.82	2.75	32.67	1.08	35.00	3.58	39.00
PS × P-1343-17-5-3	77.44	4.00	6.04	11.84	17.06	23.68	9.17	72.00	1.42	36.67	10.67	52.67
PS × MVSR 6711-14-2	224.33	3.58	3.33	12.42	17.47	23.78	3.08	34.00	1.33	37.00	4.92	41.00
PS × MSBN 3621-9-3-1	179.22	3.00	3.00	14.41	19.96	25.84	4.00	33.00	1.08	36.00	6.17	46.33
PS × B-10-224-3	70.89	3.00	6.40	14.67	20.51	25.41	13.00	46.33	1.42	37.67	12.92	56.67
PS × MBN 6242-3-1	73.11	3.42	3.43	15.24	22.39	29.76	11.00	45.00	1.58	37.33	11.33	57.67
PS × CFR 2211-2	287.22	3.83	2.99	14.78	21.19	26.40	8.50	38.33	1.00	37.33	8.58	56.33
BUMOV 41212-3-1 × BN-364	52.00	3.25	2.30	14.29	20.17	27.87	2.50	31.67	1.08	40.00	4.42	42.00
BUMOV 41212-3-1 × P-1343-17-5-3	70.44	3.00	4.31	16.11	22.67	29.29	7.08	36.33	1.08	37.33	7.92	54.00
BUMOV 41212-3-1 × MVSR 6711-14-2	171.89	3.58	2.96	13.53	20.10	26.97	2.83	31.00	1.00	40.67	3.58	44.33
BUMOV 41212-3-1 × MSBN 3621-9-3-1	39.00	3.58	2.67	15.32	21.46	31.07	3.75	32.00	1.00	37.33	5.17	43.33
BUMOV 41212-3-1 × B-10-224-3	174.00	3.33	4.50	18.64	25.46	32.56	10.42	42.33	1.08	40.00	11.17	56.00
BUMOV 41212-3-1 × MBN 6242-3-1	178.00	3.17	3.72	17.56	25.72	32.83	9.42	38.67	1.25	39.33	10.58	56.00
BUMOV 41212-3-1 × CFR 2211-2	45.00	3.00	2.42	16.01	22.17	27.30	6.83	46.67	1.00	38.67	7.75	52.67
BN-364 × P-1343-17-5-3	59.78	3.75	2.67	12.58	17.27	23.13	3.58	33.00	1.00	39.00	6.00	40.33
BN-364 × MVSR 6711-14-2	31.44	3.00	2.04	12.42	18.68	20.12	2.00	33.33	1.00	40.00	4.33	41.67
BN-364 × MSBN 3621-9-3-1	40.33	3.50	1.80	14.04	19.46	22.56	2.92	33.00	1.00	39.33	5.33	43.00
BN-364 × B-10-224-3	55.44	3.42	3.22	14.14	19.01	24.12	4.33	31.33	1.08	36.33	5.83	41.00

BN-364 × MBN 6242-3-1	66.89	3.67	1.73	14.50	20.98	25.19	4.42	33.67	1.25	40.00	4.58	45.00
BN-364 × CFR 2211-2	32.78	3.00	1.52	14.06	19.81	21.57	2.00	34.33	1.00	41.33	3.92	44.67
P-1343-17-5-3 × MVSR 6711-14-2	70.11	4.00	2.63	12.33	18.00	23.99	10.00	37.00	1.33	38.33	4.50	45.00
P-1343-17-5-3 × MSBN 3621-9-3-1	54.00	3.00	3.09	13.41	18.01	21.42	4.33	35.00	1.08	36.00	5.33	45.00
P-1343-17-5-3 × B-10-224-3	248.33	3.58	8.16	14.21	19.41	26.50	9.67	35.67	1.17	37.67	11.00	47.67
P-1343-17-5-3 × MBN 6242-3-1	166.56	4.00	4.57	13.66	20.52	28.90	7.08	36.00	1.08	37.33	8.50	44.67
P-1343-17-5-3 × CFR 2211-2	161.44	3.33	3.53	15.14	21.89	28.54	6.42	37.00	1.00	39.33	8.00	45.67
MVSR 6711-14-2 × MSBN 3621-9-3-1	38.44	3.67	1.98	13.28	19.62	20.11	2.25	37.67	1.17	93.33	4.58	43.00
MVSR 6711-14-2 × B-10-224-3	45.56	4.75	2.70	14.70	20.46	23.50	4.67	33.67	1.00	38.33	5.50	45.00
MVSR 6711-14-2 × MBN 6242-3-1	41.22	3.58	2.34	13.62	20.18	26.18	4.83	35.33	1.00	41.33	5.67	44.00
MVSR 6711-14-2 × CFR 2211-2	40.33	3.42	1.86	12.78	18.47	23.68	3.92	34.00	1.00	40.67	3.67	42.67
MSBN 3621-9-3-1 × B-10-224-3	41.78	3.42	2.89	14.81	19.99	23.70	5.42	35.00	1.33	37.33	6.33	46.00
MSBN 3621-9-3-1 × MBN 6242-3-1	53.22	3.83	2.31	14.53	21.16	24.81	4.25	30.67	1.00	37.00	6.42	43.00
MSBN 3621-9-3-1 × CFR 2211-2	44.11	3.25	2.22	15.24	21.72	25.60	5.42	34.67	1.00	40.33	5.17	43.00
B-10-224-3 × MBN 6242-3-1	194.67	3.00	3.80	17.19	23.81	30.19	11.08	38.00	1.17	40.67	11.50	57.00
B-10-224-3 × CFR 2211-2	184.78	3.00	4.03	16.82	23.39	29.89	8.25	37.67	1.00	39.33	8.92	56.00
MBN 6242-3-1 × CFR 2211-2	161.33	3.25	2.93	17.39	24.33	33.56	9.83	42.67	1.00	39.33	10.17	57.00
PPH-1	83.67	4.00	2.34	13.63	18.62	19.77	2.50	64.33	1.00	35.67	4.50	39.33
PPH-2	64.89	2.83	2.83	11.82	16.48	21.63	2.92	34.67	1.00	36.33	3.83	38.67

APPENDIX IV: Average performance of F_1 hybrids for fruit, yield and quality traits

F_1 hybrids	Peduncle length (cm)	Polar diameter (cm)	Equator diameter (cm)	Fruit shape index	Pulp thickness (cm)	No. of Fruits per vine	Fruit yield/ vine (kg)	Fruit yield/ ha (tones)	Average fruit weight (kg)	TSS (°Brix)	Total carotenoids (mg/100g FW)	Dry matter (%)	Vitamin-C (mg/100g FW)	Total sugar (mg/100g DW)
PS × BUMOV 41212-3-1	6.79	16.20	17.45	0.93	3.21	2.58	3.38	34.90	1.51	5.50	15.08	8.81	55.32	1.94
PS × BN-364	4.67	13.30	12.41	1.07	2.04	2.50	1.63	40.13	0.69	3.30	22.73	8.27	63.33	2.49
PS × P-1343-17-5-3	7.00	13.43	18.31	0.73	3.17	2.08	3.23	25.56	1.34	5.50	5.25	6.68	63.39	2.63
PS × MVSR 6711-14-2	4.88	8.70	13.35	0.65	2.23	2.17	1.66	35.86	0.70	2.40	4.22	6.67	23.67	2.28
PS × MSBN 3621-9-3-1	4.96	16.23	11.44	1.42	2.09	2.42	2.04	40.96	2.57	4.70	7.75	5.69	47.40	2.68
PS × B-10-224-3	8.04	16.43	23.41	0.70	3.58	1.92	4.67	44.44	2.67	5.57	7.54	7.17	55.35	1.58
PS × MBN 6242-3-1	6.54	17.20	17.51	0.98	2.69	2.08	3.69	68.55	1.87	5.17	11.26	6.53	71.37	2.25
PS × CFR 2211-2	5.67	15.27	17.70	0.86	3.81	1.67	2.46	61.07	1.55	7.70	9.67	10.13	71.34	2.66
BUMOV 41212-3-1 × BN-364	4.29	13.23	10.52	1.26	1.71	2.58	1.24	30.10	0.49	7.47	13.24	9.73	62.99	1.58
BUMOV 41212-3-1 × P-1343-17-5-3	7.83	18.30	18.53	0.99	3.15	1.92	3.53	52.49	1.56	3.13	6.61	9.26	79.32	2.61
BUMOV 41212-3-1 × MVSR 6711-14-2	4.04	11.23	12.53	0.90	2.00	2.50	1.25	33.02	0.57	4.53	4.69	6.57	47.40	1.59
BUMOV 41212-3-1 × MSBN 3621-9-3-1	4.25	16.53	10.39	1.59	1.70	2.50	1.26	30.41	0.52	4.70	8.51	6.45	63.46	1.59
BUMOV 41212-3-1 × B-10-224-3	8.17	15.23	18.25	0.83	2.51	1.42	3.71	60.20	2.34	4.33	17.82	6.25	63.19	2.67
BUMOV 41212-3-1 × MBN 6242-3-1	6.50	17.40	14.13	1.23	3.10	2.50	2.58	59.96	1.38	8.13	12.46	9.30	55.32	2.55
BUMOV 41212-3-1 × CFR 2211-2	5.50	12.17	14.49	0.84	2.60	1.50	1.69	42.03	1.18	5.30	13.27	7.40	63.29	1.55
BN-364 × P-1343-17-5-3	5.88	14.47	13.31	1.09	2.18	1.92	1.68	39.50	0.87	7.43	8.75	11.61	39.49	1.58
BN-364 × MVSR 6711-14-2	2.88	10.43	10.52	0.99	2.25	2.17	0.93	25.91	0.51	4.17	5.68	4.56	55.42	1.58
BN-364 × MSBN 3621-9-3-1	3.38	19.33	9.13	2.12	1.71	2.33	1.23	32.07	0.64	4.63	17.70	8.64	55.32	1.47

BN-364 × B-10-224-3	4.88	15.23	14.61	1.04	2.51	1.58	1.63	36.02	0.98	10.23	20.79	13.77	119.15	2.59
BN-364 × MBN 6242-3-1	3.88	24.53	10.15	2.42	1.70	1.58	1.07	22.44	0.61	10.17	17.64	14.49	71.34	1.38
BN-364 × CFR 2211-2	3.29	10.17	12.71	0.80	2.25	1.33	1.01	23.93	0.75	6.13	5.07	7.59	55.32	1.59
P-1343-17-5-3 × MVSR 6711-14-2	5.07	10.43	15.24	0.68	2.80	1.92	1.29	30.65	0.68	3.23	5.29	6.23	55.38	2.50
P-1343-17-5-3 × MSBN 3621-9-3-1	4.92	15.27	11.17	1.37	2.24	1.83	1.18	29.38	0.67	6.17	6.39	5.72	47.44	1.59
P-1343-17-5-3 × B-10-224-3	10.21	15.20	22.75	0.67	3.22	1.58	3.77	37.74	2.64	8.13	14.27	10.67	103.35	2.60
P-1343-17-5-3 × MBN 6242-3-1	7.67	19.13	16.25	1.18	2.10	2.08	2.00	49.35	1.33	7.23	5.32	6.67	47.44	2.61
P-1343-17-5-3 × CFR 2211-2	8.00	15.23	22.35	0.68	4.13	1.42	3.08	64.05	2.44	4.50	3.74	5.81	71.27	2.29
MVSR 6711-14-2 × MSBN 3621-9-3-1	3.33	18.23	11.63	1.57	2.00	2.08	1.13	30.81	0.65	7.75	9.32	7.58	31.56	2.64
MVSR 6711-14-2 × B-10-224-3	5.96	10.27	17.17	0.60	2.70	1.33	1.60	35.71	1.13	5.70	6.11	7.65	47.40	2.64
MVSR 6711-14-2 × MBN 6242-3-1	3.79	13.27	12.59	1.05	2.38	1.83	1.32	29.86	0.69	7.67	4.46	8.41	39.49	1.57
MVSR 6711-14-2 × CFR 2211-2	3.17	8.23	14.31	0.58	2.50	2.08	1.31	39.74	0.82	3.13	10.66	10.73	47.57	2.56
MSBN 3621-9-3-1 × B-10-224-3	4.75	19.17	13.62	1.41	3.33	1.67	1.52	53.33	1.34	5.63	9.40	12.51	39.53	1.58
MSBN 3621-9-3-1 × MBN 6242-3-1	4.04	36.23	9.55	3.79	2.09	2.42	1.58	34.76	0.60	7.43	4.07	11.31	47.47	1.55
MSBN 3621-9-3-1 × CFR 2211-2	3.83	19.33	13.35	1.45	3.07	1.17	1.27	33.02	1.21	4.20	3.32	8.74	39.53	1.59
B-10-224-3 × MBN 6242-3-1	8.92	18.37	18.38	1.00	2.70	1.83	4.27	87.87	2.66	4.37	5.10	4.65	39.56	1.96
B-10-224-3 × CFR 2211-2	9.46	15.10	21.52	0.70	3.38	1.75	3.71	86.15	2.74	6.30	10.70	8.69	63.36	2.52
MBN 6242-3-1 × CFR 2211-2	6.00	14.43	19.50	0.74	3.41	1.75	3.25	64.94	2.10	2.63	5.36	5.53	71.31	2.38
PPH-1 (Check)	4.71	13.33	14.70	0.91	3.07	1.42	1.58	38.94	1.17	7.17	5.25	8.74	31.55	1.56
PPH-2 (Check)	4.63	11.10	12.30	0.90	2.05	1.42	1.42	31.36	0.93	5.20	5.54	7.36	23.67	2.57

APPENDIX V: Phenotypic characterization of parents for growth and fruit traits

Parents	Growth habit	Leaf colour	Fruit shape	Fruit peel colour	Fruit peel hardiness	Pulp colour
Punjab Samrat	Vine	Dark Green	Flat round	Dark Green Mottled	Intermediate	Orange
BUMOV 41212-3-1	Vine	Light Green	Oval	Light Green Mottled	Hard	Yellow
BN-364	Bush	Light Green	Butternut	Cream	Hard	Dark Orange
P-1343-17-5-3	Vine	Dark Green	Flat round	Dark Green Mottled	Intermediate	Light orange
MVSR 6711-14-2	Bush	Dark Green	Flat round	Dark Green Mottled	Hard	Light orange
MSBN 3621-9-3-1	Bush	Dark Green	Butternut	Light Green Mottled	Intermediate	Yellow
B-10-224-3	Vine	Dark Green	Flat round	Dark Green Mottled	Intermediate	Light orange
MBN 6242-3-1	Vine	Dark Green	Butternut	Dark Green Mottled	Hard	Dark Orange
CFR 2211-2	Bush	Light Green	Flat round	Cream	Hard	Light orange

APPENDIX VI: Phenotypic characterization of F_1hybrids for growth and fruit traits

F_1hybrids	Growth habit	Leaf colour	Fruit shape	Fruit peel colour	Fruit peel hardiness	Pulp colour
PS × BUMOV 41212-3-1	Vine	Green	Round	Dark Green Mottled	Hard	Dark Orange
PS × P-1343-17-5-3	Vine	Dark Green	Flat round	Dark Green Mottled	Intermediate	Yellow
PS × MVSR 6711-14-2	Bush	Dark Green	Flat round	Dark Green Mottled	Hard	Light orange
PS × BN-364	Bush	Light Green	Oval	Light Green Mottled	Hard	Orange
PS × MBN 6242-3-1	Semi vine	Dark Green	Round	Dark Green Mottled	Hard	Orange
PS × MSBN 3621-9-3-1	Bush	Dark Green	Butternut	Dark Green Mottled	Intermediate	Light orange
PS × CFR 2211-2	Bush	Dark Green	Round	Dark Green Mottled	Hard	Light orange
PS × B-10-224-3	Vine	Dark Green	Flat round	Dark Green Mottled	Intermediate	Orange
BUMOV 41212-3-1 × BN-364	Bush	Green	Oblong	Cream	Hard	Orange
BUMOV 41212-3-1 × MVSR 6711-14-2	Bush	Light Green	Round	Light Green Mottled	Hard	Light orange
BUMOV 41212-3-1 × CFR 2211-2	Bush	Green	Flat round	Light Green Mottled	Hard	Light orange
BUMOV 41212-3-1 × MSBN 3621-9-3-1	Bush	Light Green	Butternut	Light Green Mottled	Hard	Dark Orange
BUMOV 41212-3-1 × B-10-224-3	Semi vine	Light Green	Flat round	Light Green Mottled	Hard	Orange
BUMOV 41212-3-1 × MBN 6242-3-1	Semi vine	Green	Oblong	Light Green Mottled	Hard	Dark Orange
BUMOV 41212-3-1 × P-1343-17-5-3	Semi vine	Dark Green	Round	Dark Green Mottled	Hard	Dark Orange
BN-364 × P-1343-17-5-3	Bush	Dark Green	Oval	Dark Green Mottled	Hard	Orange
BN-364 × MVSR 6711-14-2	Bush	Light Green	Round	Light Green Mottled	Hard	Dark Orange
BN-364 × MSBN 3621-9-3-1	Bush	Dark Green	Butternut	Cream	Intermediate	Orange
BN-364 × B-10-224-3	Bush	Green	Round	Light Green Mottled	Hard	Light orange
BN-364 × MBN 6242-3-1	Bush	Green	Butternut	Light Green Mottled	Hard	Orange

BN-364 × CFR 2211-2	Bush	Light Green	Flat round	Cream	Hard	Dark Orange
P-1343-17-5-3 × MVSR 6711-14-2	Bush	Dark Green	Flat round	Dark Green Mottled	Hard	Light orange
P-1343-17-5-3 × MSBN 3621-9-3-1	Bush	Dark Green	Oblong	Dark Green Mottled	Intermediate	Light orange
P-1343-17-5-3 × B-10-224-3	Vine	Dark Green	Flat round	Dark Green Mottled	Hard	Light Yellow
P-1343-17-5-3 × MBN 6242-3-1	Semi vine	Dark Green	Oblong	Dark Green Mottled	Hard	Dark Orange
P-1343-17-5-3 × CFR 2211-2	Semi vine	Green	Flat round	Dark Green Mottled	Hard	Light Orange
MVSR 6711-14-2 × MSBN 3621-9-3-1	Bush	Dark Green	Butternut	Dark Green Mottled	Hard	Orange
MVSR 6711-14-2 × B-10-224-3	bush	Dark Green	Flat round	Dark Green Mottled	Hard	Light orange
MVSR 6711-14-2 × MBN 6242-3-1	Bush	Dark Green	Round	Dark Green Mottled	Hard	Orange
MVSR 6711-14-2 × CFR 2211-2	Bush	Green	Flat round	Dark Green Mottled	Hard	Light orange
MSBN 3621-9-3-1 × B-10-224-3	Bush	Dark Green	Butternut	Light Green Mottled	Hard	Light orange
MSBN 3621-9-3-1 × MBN 6242-3-1	Bush	Dark Green	Butternut	Light Green Mottled	Intermediate	Light orange
MSBN 3621-9-3-1 × CFR 2211-2	Bush	Green	Butternut	Light Green Mottled	Hard	Light orange
B-10-224-3 × MBN 6242-3-1	Semi vine	Dark Green	Round	Dark Green Mottled	Hard	Light Yellow
B-10-224-3 × CFR 2211-2	Semi vine	Green	Flat round	Light Green Mottled	Intermediate	Light orange
MBN 6242-3-1 × CFR 2211-2	Semi vine	Light Green	Flat round	Light Green Mottled	Hard	Orange
PPH-1	Bush	Dark Green	Round	Light Green Mottled	Hard	Light orange
PPH-2	Bush	Green	Round	Cream	Hard	Orange

APPENDIX VII: Estimates of genetic parameters of pumpkin for vine length other vegetative and flowering characters -

Characters	hý (%)	% GA	PCV	GCV	CV
Number of primary branches	73.97	18.83	12.36	10.63	6.31
Internodal length (cm)	90.68	82.27	44.05	41.94	13.45
Leaf length (cm)	82.36	20.29	11.96	10.85	5.02
Leaf breadth (cm)	79.3	18.66	11.42	10.17	5.2
Petiole length (cm)	81.55	24.04	14.31	12.92	6.15
Earliest node to female flower	94.67	101.34	51.96	50.56	11.99
Days to 50% female flowering	93.09	39	20.34	19.62	5.34
Earliest node to male flower	40.86	14.72	17.49	11.18	13.45
Days to 50% male flowering	66.76	8.58	6.24	5.1	3.6
Vine length (cm)	97.28	143.58	71.65	70.67	11.82

Hy % = Heritability percentage, % GA = Percent genetic advance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, CV = Coefficient of variation

APPENDIX VIII: Estimates of genetic parameters of pumpkin for fruit yield per vine with other fruit characters –

Characters	hý (%)	% GA	PCV	GCV	CV
Node to first fruit	95.33	78.3	39.87	38.93	8.62
Peduncle length (cm)	93.68	67.67	35.07	33.94	8.81
Polar diameter of fruit (cm)	99.88	65.15	31.66	31.65	1.08
Equator diameter of fruit (cm)	99.84	53.98	26.25	26.23	1.06
Fruit shape index	99.85	110.85	53.89	53.85	2.07
Pulp thickness (cm)	97.44	49.34	24.58	24.26	3.94
Number of fruits per vine	41.07	22.36	26.43	16.94	20.29
Average fruit weight (kg)	56.23	79.2	68.38	51.27	45.24
Days to fruit maturity	98.6	26.4	13	12.91	1.54
Vine length (cm)	97.28	143.58	71.65	70.67	11.82
Fruit yield per vine (kg)	70.64	87.26	59.97	50.4	32.49

Hy % = Heritability percentage, % GA = Percent genetic advance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, CV = Coefficient of variation

APPENDIX IX: Estimates of genetic parameters of pumpkin for average fruit weight with fruit quality traits -

Characters	hý (%)	% GA	PCV	GCV	CV
TSS (ºBrix)	99.15	71.33	34.93	34.78	3.22
Total carotenoids (mg/100g FW)	99.92	113.31	55.05	55.03	1.54
Dry matter (%)	99.52	60.99	29.75	29.68	2.06
Vitamin-C (mg/100g FW)	99.99	65.50	31.8	31.8	0.29
Total sugar (mg/100 g DW.)	86.03	43.57	24.58	22.8	9.19
Average fruit weight (kg)	89.36	110.45	60.00	56.72	19.57

Hy % = Heritability percentage, % GA = Percent genetic advance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, CV = Coefficient of variation