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Study of heterosis over environments for fruit yield and its related traits in okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract
Okra, being an often cross-pollinated crop, responds well to heterosis breeding. Exploitation of heterosis is primarily dependent on the screening and selection of available germplasm that could be produced by better combinations of important agronomic characters. An experiment was carried out in *kharif* 2018 to estimate standard heterosis for yield and its contributing traits using 55 hybrids developed through line x tester design were evaluated at three different locations at Navsari Agricultural University, Navsari (Gujarat) with commercial check 'OH 102'. Appreciable heterosis was found over commercial check for all the traits studied in desirable direction. Among 55 hybirds, JOL-14-10 x Arka Abhay, JOL-14-10 x GJO-3, JOL-13-05 x GJI-03 at Navsari, Achhalia and Vyara, respectively exhibited higher but non-significant standard heterosis for fruit yield. The other crosses exhibited desirable but non-significant standard heterosis for fruit yield and other component traits suggested that there is no scope of exploiting heterosis commercially, but possibility of isolating desirable segregants among these hybrid combinations.

Keywords: Standard heterosis, Line x Tester analysis, okra [*Abelmoschus esculentus* (L.) Moench]

Introduction

Among the vegetable crops, okra (*Abelmoschus esculentus* (L.) Moench.) is a member of the *Malvaceae* family; an important annual vegetable crop grown throughout the country both as summer as well as rainy season crop for its green, tender and delicious fruits (Kochhar, 1986) [22]. It is thought to have been originated in India (Zeven and Zukovasky, 1975) [53]. Okra accounts for 60% of the value of exported fresh vegetables, excluding the root vegetables, potato, onion and garlic, the destinations being the Middle East, Western Europe and the USA. Okra is a largely self-pollinated annual plant (Fryxell, 1957) [12] with a high chromosome number of 2n = 130, which appears to have originated in Abyssinia (Darlington and Wylie, 1955) [6]. Amount of cross pollination ranges from 4 to 18 per cent (Purewal and Randhawa, 1947) [38] also observed in okra.

Hybridization has been the most successful approach in increasing the productivity in vegetable crops. Selection of genetically superior and suitable genotypes is the most important stage from the standpoint of hybridization of vegetable crops in order to develop new genotypes having desirable characters. To break the yield barriers in existing open-pollinated varieties of okra, a hybridization-based breeding strategy would be desirable. The phenomenon of heterosis has been a powerful force in the evolution of crop plants and has been exploited extensively in crop production (Birchler *et al*., 2003) [4]. Heterosis breeding has been the most successful approach in increasing the productivity in cross-pollinated vegetable crops (Medagam *et al.*, 2012) [27]. Heterosis for increased fruit size, fruit weight and fruits per plant in okra was first reported by Vijayaraghvan and Warriar (1946) [49]. Heterosis breeding is an important genetic tool that can facilitate yield enhancement from 30 to 400% and helps enrich many other desirable quantitative and qualitative traits in crops (Srivastava, 2000) [45]. Since then, heterosis for yield and its components were extensively studied. Several research workers have reported occurrence of heterosis in considerable quantities for fruit yield and its various components (Venkataramani, 1952; Joshi *et al*., 1958; Partap and Dhankar, 1980; Elangovan *et al*., 1981; Partap *et al*., 1981; Mehta *et al*., 2007; Weerasekara *et al*., 2007; Jindal *et al*., 2009) [47, 18, 33, 10, 34, 29, 51, 17]. The ease in emasculation and very high percentage of fruit setting indicates the possibilities of exploitation of hybrid vigour in okra.

The scope for utilization of heterosis largely depends on the direction and magnitude of heterosis. It expressed as relative heterosis, heterobeltiosis and standard heterosis, depending on the criteria used to compare the performance of a hybrid. The relative heterosis will only help to understand the genetic status of the characters (Moll and Stuber, 1974) [30]. However, from the practical point of view, standard heterosis is the most important of the 3 types of heterosis because it is aimed at developing desirable hybrids superior to the existing high yielding commercial varieties (Chaudhary, 1984) [5]. The ease in emasculation and very high percentage of fruit setting indicates the possibilities of exploitation of hybrid vigour in okra. The presence of sufficient hybrid vigour is an important prerequisite for successful production of hybrid varieties. Therefore, the heterotic studies can provide the basis for the exploitation of valuable hybrid combinations in the future breeding programmes and their commercial utilization.

The present investigation was undertaken with the objective of determining the mean performance and the heterotic pattern among line x tester crosses so as to identify the hybrids which possess superior hybrid vigour for yield and its components of okra.

Materials and methods

The experimental material consists of 55 F_1 hybrids developed from 11 lines (AOL-12-52, AOL-12-59, AOL-13-73, AOL-12-144, AOL-12-133, AOL-14-32, JOL-69-05, JOL-11-12, JOL-13-05, JOL-14-10 and JDNOL-11-12) and five testers (GJO-3, GAO-5, Parbhani Kranti, Arka Anamika and Arka Abhay) in a Line × Tester fashion. The 55F1 hybrids and their 16 parents were evaluated along with one commercial check (OH 102) in a randomized block design with three replications at three different locations *viz.*, College farm, N.M.College of Agriculture, Cotton Sub-Research Station, Achhalia and Regional Rice Research Station, Vyara, Navsari Agricultural University, Navsari (Gujrat) during *kharif* 2018. Each entry was sown in a single row plot of ten plants, spaced 60 x 30 cm. Observations on yield and yield attributes *viz*., days to 50% flowering, first flowering node, internodal length (cm), branches per plant, fruits per plant, plant height (cm), days to first picking, days to last picking, fruit length (cm), fruit diameter (mm), stalk length (cm), fruit weight (g), seeds per fruit, 100-seed weight (g), fruit yield per plant (g) and fiber content (%) were recorded from 16 parents and 55 F_1 hybrids. The data was subjected to Line×Tester analysis and magnitude of heterosis was calculated as per standard procedure and significance of heterosis was worked out using the formula suggested by Wynne *et al.* (1970) [52].

Result and discussion

The estimates of heterosis were worked out with respect to standard heterosis, which is really useful in replacing existing cultivars/hybrids with new ones. Therefore, standard heterosis was worked out by comparing F_1 with standard check hybrid 'OH-102' statistically. In the present investigation, standard heterosis in each individual location for fruits yield per plant ranged from -45.28 % (AOL-13-73 X Parbhani Kranti) to 2.23 % (JOL-14-10 X Arka Abhay), -45.00 % (JOL-13-05 X Parbhani Kranti) to 8.64 % (JOL-14-10 X GJO-3) and -48.77 % (AOL-12-133 X Parbhani Kranti) to 3.69 % (JOL-13-05 X GJO-3) at Navsari, Achhalia and Vyara, respectively. Similar result was reported by Medagam *et al*. (2012) [27], Medagam *et al*. (2013) [28], More *et al.* (2015) [31], Nama *et al*. (2017) [32] and Gavint *et al*. (2018) [14].

In okra, traits like fruits per plant, fruit length, fruit diameter and fruit weight are the important yield components. Higher heterotic response of these yield attributing traits would be useful for obtaining higher fruit yield, but in present investigation none of the top hybrid exhibited significant standard heterosis for yield contributing traits in each individual location (except Achhalia) and showed poor/low heterotic response. Similar results was reported by Hosamani *et al. (*2008) [15], Medagam *et al*. (2012) [27], Medagam *et al*. (2013) [28], Jethava (2014) [16], Patel (2015) [36], Tiwari *et al.* (2015) [46], Verma and Sood (2015) [48], Satish *et al*. (2017) [41] and Gavint *et al.* (2018) [14]. Among 55 hybrids, JOL-14-10 X Arka Abhay at Navsari; JOL-14-10 X GJO-3, JDNOL-11-12 X GAO-5 and AOL-12-52 X Arka Anamika at Achhalia and JOL-13-05 X GJO-3 and AOL-12-144 X GJO-3 at Vyara exhibited positive but non-significant standard heterosis. Similar result was reported for fruit yield per plant by Medagam *et al*. (2012) [27] and Medagam *et al*. (2013) [28].

The trait, fruit yield per plant is economically important, complex trait and multiplicative product of several basic components. Positive heterosis is due to differences in genetic background of lines used in hybridization and it is confirmed by the significant difference in parental variances for all the traits. Similar observations were reported by Kumar *et al.* (2013) [24], Akotkar *et al.* (2014) [1], Badiger *et al.* (2014) [2], Jethava (2014) [16], Katagi *et al.* (2015) [19], and Satish *et al*. (2017) [41]. Number of fruits per plant is also an important trait that determine yield of okra and for this trait, positive heterosis is desirable. The estimates of heterosis revealed that none of the hybrid reported significant and positive heterosis at Navsari and Vyara, while at Achhalia AOL-12-52 X Arka Anamika and JOL-14-10 X GJO-3 reported positive and significant heterosis. Non-significant heterosis for fruits per plant were reported by Solankey and Singh (2011), Medagam *et al*. (2012) [27], Medagam *et al*. (2013) [28], Tiwari *et al.* (2015) [46], Satish *et al*. (2017) [41] and Gavint *et al.* (2018) [14], while significant and positive heterosis for fruits per plant was reported by Sreeparvathy *et al*. (2010) [44], Ramya and Kumar (2010) [44], Patel and Patel (2016) [35], Nama *et al*. (2017) [32] and Kerure and Pitchaimuthu (2018) [20]. For the fruit length, significant and positive heterosis was recorded by five and two hybrids at Navsari and Vyara, while at Achhalia none of the hybrid exhibited significant and positive heterosis. The maximum standard heterosis for fruit length was recorded by AOL-14-32 X Arka Anamika and AOL-14-32 X Parbhani Kranti at Navsari and Vyara, respectively. Significant and positive standard heterosis for fruit length was reported by Medagam *et al*. (2012) [27], Patel and Patel (2016) [35], Gavint *et al*. (2018) [14] and Kerure and Pitchaimuthu (2018) [20], while non-significant standard heterosis was reported by Jethava (2014) [16] and Satish *et al*. (2017) [41].

For the fruit weight, none of the hybrid exhibited positive and significant standard heterosis at all locations. These findings were in agreement with Mehta *et al.* (2007) [29] and Gavint *et al.* (2018) [14]. For the fruit diameter, none of the hybrid reported significant and positive heterosis at Navsari and Vyara, while at Achhalia two hybrids, AOL-12-144 X Arka Anamika and AOL-14-32 X Arka Abhay reported positive and significant heterosis. For fruit diameter Non-significant heterosis was reported by Wammanda *et al*. (2010) [50], Verma and Sood (2015) [48] and significant heterosis was reported by Reddy *et al.* (2013) [40], Patel and Patel (2016) [35], Nama *et al*. (2017) [32], Satish *et al*. (2017) [41] and Gavint *et al*. (2018) [14].

The branches are an important growth parameter contributing to productivity in which significant and positive heterosis was recorded by one, 12 and four hybrids at Navsari, Achhalia and Vyara, respectively. Among them the maximum and significant standard heterosis for branches per plant was recorded by AOL-12-144 X Arka Abhay, AOL-14-32 X Arka Anamika and AOL-12-133 X GAO-5 at Navsari, Achhalia and Vyara, respectively. Similar results was reported by Medagam *et al*. (2013) [28], Kumar *et al*. (2015) [25], Nama *et al*. (2017) [32], Paul *et al*. (2017), Satish *et al*. (2017) [41] and Kerure and Pitchaimuthu (2018) [20].

Plant height and shorter internodal length at fully matured stages is one of the important ideotype in okra for higher yield. Out of 55 hybrids, none of the hybrid recorded significant and positive heterosis over check at Navsari and Vyara, while at Achhalia only one hybrid AOL-12-133 X GAO-5 exhibited significant and positive heterosis for plant height. Result indicated that majority of the crosses showed non-significant heterosis for plant height and similar findings were in agreement with Khatik *et al*. (2012) [21], Medagam *et al*. (2012) [27], Medagam *et al*. (2013) [28], Jethava (2014) [16], Bhatt *et al.* (2016) [3] and Satish *et al*. (2017) [41], while significant heterosis was reported by Reddy *et al.* (2013) [40], Patel and Patel (2016) [35], Nama *et al*. (2017) [32] and Kerure and Pitchaimuthu (2018) [20]. For internodal length, significant and negative heterosis was recorded by three and one hybrid at Navsari and Achhalia, while none of the hybrid at Vyara exhibited significant and negative heterosis. Desirable standard heterosis for internodal length was reported by AOL-12-59 X Arka Anamika and JDNOL-11-12 X Parbhani Kranti at Navsari and Achhalia, respectively. Significant and negative heterosis for internodal length was reported by Verma and Sood (2015) [48], Bhatt *et al.* (2016) [3], Patel and Patel (2016) [35] and Nama *et al.* (2017) [32], while non-significant heterosis was reported by Solankey and Singh (2011), Medagam *et al*. (2012) [27], Medagam *et al*. (2013) [28], Jethava (2014) [16] and Tiwari *et al.* (2015) [46]. As okra bears fruit at each node, shorter distance between the nodes, will ultimately lead to higher production. Joshi *et al.* (1958) [18] have stressed the importance of shorter internodes for increased yield in okra.

For days last to picking, two and 20 hybrids at Navsari and Achhalia exhibited significant and positive standard heterosis, while at Vyara none of the hybrid exhibited positive and significant heterosis. Maximum standard heterosis for days to last picking was reported by JOL-69-05 X Parbhani Kranti and JOL-14-10 X GJO-3 at Navsari and Achhalia. Similar result for days to last picking was reported by Verma and Sood (2015) [48] and Satish *et al*. (2017) [41].

In present investigation, top hybrids for fruit yield per plant exhibited positive but non-significant response with yield contributing traits like fruits per plant (except Achhalia), branches per plant, plant height and days to last picking (except Achhalia) in each individual location. Hybrids that were non-heterotic may be ascribed to the cancellation of positive and negative effect shown by the parents involved in a cross combinations and can also happen when the dominance is not unidirectional (Gardner and Eberhart, 1966; Mather and Jinks, 1982) [13, 26].

Early picking is a desirable trait in crop plants in general. Seven hybrids exhibited significant and negative standard heterosis at Navsari while at Achhalia and Vyara, none of the hybrid exhibited significant and negative standard heterosis for days to 50 % flowering. Significant and negative heterosis for days to 50% flowering was recorded by Tiwari *et al.* (2015) [46], Bhatt *et al*. (2016) [3], Patel and Patel (2016) [35], Nama *et al*. (2017) [32], Satish *et al*. (2017) [41], Gavint *et al.* (2018) [14] and Kerure and Pitchaimuthu (2018) [20], while non-significant and positive heterosis for days to 50% flowering was recorded by Solankey and Singh (2011), Reddy *et al.* (2013) [40] and Jethava (2014) [16]. For the first flowering node, significant and negative heterosis was recorded by six, one and twenty five hybrids at Navsari, Achhalia and Vyara, respectively. Minimum standard heterosis for first flowering node was reported by JOL-11-12 X GAO-5; JOL-13-05 X GJO-3 and JOL-14-10 X Arka Abhay at Navsari, Achhalia and Vyara, respectively. Similar finding was confirmed by Medagam *et al*. (2013) [28], Jethava (2014) [16], Tiwari *et al.* (2015) [46] and Verma and Sood (2015) [48]. Significant and negative heterosis for days to first picking was recorded by seven hybrids at Navsari while none of the hybrid at Achhalia and Vyara. Standard heterosis for days to first picking was reported by AOL-14-32 X Parbhani Kranti at Navsari. Similar results were reported by Tiwari *et al.* (2015) [46], Verma and Sood (2015) [48] and Nama *et al.* (2017) [32] for days to first picking. In present investigation, it is observed that none of the top heterotic hybrids for fruit yield exhibited earliness in picking on basis of earliness traits like days 50% flowering, days to first flowering and days to first fruit picking. Similar results were reported by Dhankhar *et al.* (1998) [8], Dhankhar and Dhankhar (2001) [7], Solankey and Singh (2011).

Seed related traits *viz*; seeds per fruit and 100 seed weight are important parameters as far as okra breeding is concerned. For seeds per fruit, 31 hybrids at Achhalia exhibited significant and negative standard heterosis while none of the hybrid at Navsari and Vyara. For 100 seed weight, none of the hybrids reported significant and negative standard heterosis in each individual location. Non significant heterosis for seeds per fruit and 100 seed weight was reported by Jethava (2014) [16] and Patel and Patel (2016) [35] while significant heterosis in desirable direction for seeds per fruit was reported by More *et al.* (2015) [31] and Satish *et al.* (2017) [41]. Very few workers have worked on heterosis for quality traits in okra. Okra fruit with shorter stalk length and lower fiber content are considered as good in quality, for stalk length out of 55 hybrids, 35, four and two hybrids exhibited significant and negative standard heterosis at Navsari, Achhalia and Vyara, respectively, which was in confirmation with Tiwari *et al.* (2015) [46]. For fiber content, the significant and negative heterosis was recorded by 13, 12 and six hybrids at Navsari, Achhalia and Vyara, respectively, which was in confirmation with More *et al.* (2015) [31].

In present investigation, it was observed that all yield contributing traits were not equally contributed towards heterosis for fruit yield per plant. This was because the component traits competed for the sum total of metabolic substances produced by the plant and the conditions which favored the development of one component could have adversely affected the other one. Therefore, to obtain maximum yield in a selection programme desired levels of each component need to be known (More, 2015 and Satish *et al*., 2017) [31, 41]. In the present study, the significance of the heterotic performance was may be highly affected by the genetic background of parental genotypes. Similar results were reported by Medagam *et al.* (2013) [28], Solankey *et al.* (2013), Tiwari *et al.* (2015) [46], Verma and Sood (2015) [48], Satish *et al.* (2017) [41] and Kerure and Pitchaimuthu (2018) [20]. The manifestation of negative heterosis observed in some of the hybrids for different traits may be due to the combination of the unfavorable genes of the parents (Medagam *et al*., 2013) [28]. Manifestation of heterosis for all the traits in single cross may not be possible but, the exploitation of hybrid vigor in one or more yield-attributing traits will significantly improve the crop performance over existing hybrid or variety (Hosamani *et al.*, 2008) [15]. While formulating suitable breeding methodology for the improvement in this crop, attention must be paid for the improvement of visual appearance as well as the biochemical qualitative aspects too, besides the productivity.

It is clear from the above discussion that none of the common hybrid exhibited significant and positive standard heterosis for all traits in each individual location. Non-significant and lower magnitude of desirable heterosis over standard check for fruit yield and its component traits suggested that there is no scope of exploiting heterosis commercially, but possibility of isolating desirable segregants among these hybrid combinations. It is also clear thatnon additive gene action for all the component traits observed in the present study indicated that improvement of yield and yield component traits go for biparental mating, recurrent selection or diallel selective mating than conventional pedigree or backcross breeding techniques, which would leave the unfixable components of genetic variances unexploited for yield and its components.

Table 1: Top three performing hybrid for various traits in okra over different environments

Traits	**Location**		
	E_1 Navsari	**E_2 Achhalia**	**E_3 Vyara**
Days to 50% flowering	AOL-14-32 X Parbhani Kranti, AOL-14-32 X Arka Abhay, JOL-14-10 X Parbhani Kranti and JOL-14-10 X Arka Anamika (-11.03*)	AOL-14-32 X GAO-5 (-5.47)	AOL-13-73 X Parbhani Kranti (-9.15)
	JOL-69-05 X GAO-5 and JOL-13-05 X GJO-3 (-10.29*)	AOL-13-73 X Arka Abhay and AOL-13-73 X GAO-5 (-3.91)	AOL-12-59 X GJO-3 and JOL-11-12 X Parbhani Kranti (-8.45)
	AOL-12-59 X Arka Abhay (-9.56*)	JOL-14-10 X Parbhani Kranti (-3.13)	AOL-12-59 X GAO-5, AOL-13-73 X Arka Anamika, AOL-12-144 X GJO-3 and JOL-13-05 X GJO-3 (-7.75)
First flowering node	JOL-11-12 X GAO-5 (-30.88**)	JOL-13-05 X GJO-3 (-31.34**)	JOL-14-10 X Arka Abhay (-36.92**)
	AOL-12-144 X GAO-5 (-29.41**)	AOL-12-144 X GJO-3 (-23.88)	AOL-12-133 X GJO-3 and AOL-14-32 X GAO-5 (-35.38**)
	JOL-14-10 X GAO-5 (-27.21*)	JOL-69-05 X Parbhani Kranti and JDNOL-11-12 X GAO-5 (-20.90)	JDNOL-11-12 X Arka Anamika (-32.31**)
Inter nodal length (cm)	AOL-14-32 X Arka Anamika (-17.02**)	AOL-14-32 X Arka Anamika (-15.94*)	AOL-12-52 X Arka Anamika and AOL-12-59 X GAO-5 (-4.25)
	AOL-12-133 X Parbhani Kranti (13.48*)	AOL-14-32 X Parbhani Kranti (-13.77)	AOL-12-144 X GJO-3 and JDNOL-11-12 X GJO-3 (-2.82)
	AOL-12-59 X Parbhani Kranti (12.06*)	AOL-12-133 X Arka Abhay (-11.59)	AOL-13-73 X Arka Anamika and JOL-13-05 X GJO-3 (-2.11)
Branches per plant	AOL-12-144 X Arka Abhay, (34.15**)	AOL-14-32 X Arka Anamika (35.14**)	AOL-12-133 X GAO-5 and JOL-69-05 X Parbhani Kranti (39.29**)
	AOL-12-133 X Arka Anamika (24.39)	AOL-13-73 X GJO-3 and AOL-13-73 X GAO-5 (33.78**)	JOL-69-05 X GJO-3 (35.71*)
	AOL-12-133 X GAO-5, AOL-14-32 X GJO-3, JOL-69-05 X Parbhani Kranti and JOL-69-05 X Arka Anamika (19.51)	AOL-12-59 X Parbhani Kranti, AOL-12-144 X Parbhani Kranti and AOL-12-144 X Arka Abhay (32.43**)	AOL-12-144 X Arka Abhay (32.14*)
Fruits per plant	AOL-12-144 X Arka Abhay (13.50)	AOL-12-52 X Arka Anamika (13.98)	JDNOL-11-12 X GJO-3 (4.71)
	AOL-12-52 X GAO-5 (12.86)	JOL-14-10 X GJO-3 (13.35)	AOL-12-144 X GJO-3 (3.53)
	AOL-12-52 X Arka Anamika (9.97)	JDNOL-11-12 X GJO-3 (9.94)	JOL-69-05 X Arka Anamika (2.94)
plant height (cm)	AOL-12-52 X GAO-5 (19.64)	AOL-12-133 X GAO-5 (13.90*)	AOL-12-144 X GJO-3 (10.60)
	AOL-12-133 X GAO-5 (16.24)	AOL-14-32 X GJO-3 (7.04)	AOL-12-52 X GAO-5 (10.45)
	AOL-12-133 X Parbhani Kranti (14.31)	AOL-14-32 X GAO-5 (6.86)	JDNOL-11-12 X GAO-5 (8.94)
Days to first picking	AOL-14-32 X Parbhani Kranti (10.27*)	AOL-13-73 X Arka Abhay (-4.65)	AOL-13-73 X Parbhani Kranti (-7.69)
	JOL-14-10 X Parbhani Kranti (-982*)	AOL-14-32 X GAO-5 (-3.42)	JOL-11-12 X Parbhani Kranti (-7.44)
	JOL-14-10 X Arka Anamika and JOL-69-05 X GAO-5 (-930*)	AOL-13-73 X GAO-5 and JOL-14-10 X Parbhani Kranti (-3.15)	AOL-12-59 X GJO-3 (-6.95)
Traits	E_1 Navsari	E_2 Achhalia	E_3 Vyara

Days to last picking	JOL-69-05 X Arka Anamika (-4.14)	AOL-14-32 X Arka Anamika (-2.76)	AOL-14-32 X Parbhani Kranti (-9.84**)
	JOL-13-05 X Arka Abhay (-3.54)	AOL-12-59 X Parbhani Kranti (0.41)	JOL-69-05 X GAO-5 (-9.58**)
	AOL-12-144 X Arka Anamika (-3.28)	JDNOL-11-12 X GAO-5 (0.00)	JOL-11-12 X Arka Abhay (-8.07*)
Fruit length (cm)	JDNOL-11-12 X GJO-3 (-19.31**)	AOL-12-144 X GJO-3 (-31.31**)	AOL-12-144 X Arka Anamika (-29.72**)
	JOL-13-05 X GAO-5 (-16.54**)	AOL-12-144 X Arka Anamika (-27.41**)	JDNOL-11-12 X Arka Abhay (-27.71**)
	AOL-12-52 X GAO-5 (-15.94**)	AOL-14-32 X Arka Anamika (-26.81**)	AOL-13-73 X Arka Abhay (25.73**)
Fruit diameter (cm)	JOL-69-05 X GAO-5 (7.66)	AOL-12-144 X Arka Anamika (13.79**)	JOL-14-10 X Arka Abhay (10.47)
	AOL-12-59 X GJO-3 (7.00)	AOL-14-32 X Arka Abhay (13.35**)	JOL-13-05 X GAO-5 (8.76)
	AOL-13-73 X Parbhani Kranti, JOL-13-05 X GJO-3 and JOL-14-10 X Arka Abhay (6.56)	JOL-69-05 X Arka Abhay (8.53)	AOL-12-133 X Arka Abhay (7.69)
Stalk length (cm)	AOL-12-59 X Parbhani Kranti (-14.75**)	JDNOL-11-12 X GJO-3 (-7.66*)	JOL-14-10 X Arka Abhay (-7.78**)
	AOL-13-73 X Arka Anamika (-13.64**)	JOL-11-12 X Arka Abhay (-6.73*)	JOL-11-12 X GJO-3 (-5.34*)
	AOL-12-59 X Arka Anamika (-12.01**)	JDNOL-11-12 X GAO-5 (-6.61*)	JDNOL-11-12 X Arka Anamika (-4.30)
Fruit weight (g)	AOL-12-133 X Arka Abhay (16.77)	AOL-12-59 X Arka Anamika (9.36)	AOL-14-32 X GAO-5 (17.09)
	AOL-12-133 X GAO-5 (16.02)	AOL-12-133 X Arka Abhay (8.94)	AOL-14-32 X Arka Abhay (13.71)
	AOL-14-32 X GAO-5 (15.66)	AOL-14-32 X GAO-5 (8.42)	JOL-11-12 X GJO-3 (12.21)
Seeds per fruit	AOL-12-59 X GJO-3 (-2.06)	AOL-12-52 X GAO-5 (-28.26**)	AOL-12-59 X GJO-3 (-5.31)
	JOL-13-05 X Parbhani Kranti (-0.86)	AOL-12-133 X GAO-5 (-27.99**)	JOL-11-12 X GAO-5 (-4.98)
	AOL-13-73 X Arka Anamika (0.51)	JDNOL-11-12 X GJO-3 (-27.73**)	AOL-13-73 X Arka Anamika (-2.82)
100 seed weight (g)	AOL-12-133 X Arka Abhay (-2.47)	JDNOL-11-12 X Arka Abhay (-8.19)	JOL-11-12 X GJO-3 (-5.03)
	AOL-13-73 X Arka Anamika (-0.16)	AOL-13-73 X Arka Anamika (-8.05)	AOL-12-59 X Arka Anamika (-3.46)
	AOL-12-52 X Parbhani Kranti (2.31)	JOL-11-12 X Arka Anamika (-7.20)	AOL-12-133 X Arka Anamika (-2.23)
Fruit yield per plant (g)	JOL-14-10 X Arka Abhay (2.23)	JOL-14-10 X GJO-3 (8.64)	JOL-13-05 X GJO-3 (3.69)
	AOL-12-52 X Arka Anamika (-0.02)	JDNOL-11-12 X GAO-5 (3.70)	AOL-12-144 X GJO-3 (0.84)
	JDNOL-11-12 X GAO-5 (-0.42)	AOL-12-52 X Arka Anamika (0.42)	JOL-14-10 X GJO-3 (-0.67)
Fiber content (%)	JOL-13-05 X Parbhani Kranti (-25.33**)	AOL-12-59 X GAO-5 (-24.60**)	JOL-11-12 X Parbhani Kranti (-18.91**)
	AOL-13-73 X Arka Abhay (-24.28**)	JOL-11-12 X Parbhani Kranti (-23.52**)	AOL-12-52 X GAO-5 (-17.75**)
	JOL-11-12 X Parbhani Kranti (-22.50**)	AOL-12-144 X GJO-3 (-14.76**)	AOL-13-73 X Arka Abhay (-16.74**)

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