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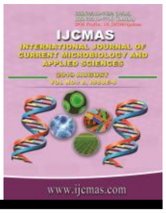

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Interspecific Hybridization in Genus *Abelmoschus* Medikus

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ABSTRACT

Keywords

Abelmoschus, Okra, Interspecific hybridization, Wild species, Crossability, seed set, Fruit set, Pollen viability

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Interspecific hybridization in okra is of immense value to exploit the diversity of species in the genus *Abelmsochus* for developing male sterile lines and/or advance breeding lines possessing resistance to YVMV and ELCV diseases. The present investigation was carried out during the year 2015-16 to study the pattern of interspecific hybridization in genus *Ablemoschus* involving ten wild species *viz*., *A. angulosus var. angulosus*, *A. angulosus var. grandiflorus*, *A. caillei*, *A. ficulneus*, *A. manihot ssp. tetraphyllus*, *A. moschatus*, *A. tetraphyllus var. pungense*, *A. tetraphyllus var. tetraphyllus*, *A. tuberculatus* and new taxa IC 0433556 with eight genotypes of cultivated species (*Abelmoschus esculentus*). Hand pollination was undertaken; fruit set, seed set, seed germination and pollen viability per cent were calculated. From the present investigation, it was found that the cultivated *A. esculentus* genotypes were compatible as male parents with *A. caillei*, *A. manihot ssp. tetraphyllus* and *A. tetraphyllus var. tetraphyllus*, *A. tuberculatus*. Interestingly, there was no compatibility when *A. tetraphyllus var. pungense* and new taxa IC 0433556 crossed with cultivated okra genotypes (IIHR-285 and 10-11-594). However, there was limited fruit set observed in *A. angulosus var. angulosus*, *A. angulosus var. grandiflorus*, *A. moschatus* and *A. ficulneus*. The F_1 seeds thus obtained were failed to germinate due to non-viable seeds. The significant difference ($p<0.01$) was found among the interspecific hybrids for pollen viability per cent. Germination per cent was higher in wild and cultivated parents than that of interspecific hybrids. Crossability index per cent was ranged from zero to hundred per cent (0-100%) among the selected cross combinations.

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is an economical and traditional vegetable belongs to Malvaceae family which is widely grown in both the tropical and sub-tropical regions of the world (Eshiet and Brisibe, 2015). It has both culinary and medicinal properties and hence it has a potential role in healthy diet in human life (Gemede *et al.*, 2014, Ohr, 2004 and Gosslau and Chen, 2004). In okra production, India occupies top position in the world. Its cultivated area, production and productivity are 0.51 million ha, 6.2 million tones and12.2 t/ha respectively (Indiastat, 2018). The major causes for low productivity in okra are limited breeding efforts to develop high yielding cultivars and lack of resistant sources to biotic and abiotic stresses. Major biotic factors causing yield losses in okra are YVMV, ELCV, fusarium wilt and powdery mildew, shoot and fruit borer, hoppers, aphids and jassids. There is limited genetic variability and limited resistant sources availability in cultivated *Abelmoschus esculentus* are the major lacunae to overcome these diseases and pests.

In okra, only marginal improvement in yield was achieved through traditional hybridization combined with selection. Though okra is often cross pollinated crop, high level of heterosis has been reported for yield and its components. But, the commercial exploitation of this situation is realised only if the hybrid seeds produced economically *i.e*., by utilizing male sterility system which will circumvent time consuming and laborious hand emasculation.

Further, presence of convincible reports on heterosis for yield in okra, developing cytoplasmic male sterility (CMS) system in okra using the potential wild donors can facilitate the production of hybrid varieties with higher yield, increased resistance to biotic and abiotic stresses. The presence of male sterility in agricultural and horticultural crops and its importance in developing F_1 hybrids has lead to superabundant research work pertaining to manipulations in extranuclear genome (Yarrow, 1993).

The introgression of nucleus of one species into the cytoplasmic background of the alien species through backcrossing has been commercially exploited in many crops. A number of different male sterility systems are now available in vegetable crops like cole crops, brinjal, chilli, capsicum and commercial crops like cotton, sunflower and safflower *etc*. In cole crops, male sterility system was obtained by alloplasmic substitution of the cytoplasm from other species of genus *Brassica* and its wild leatives (Yamagishi and Bhatt, 2014).

Apart from creation of male sterility, inter specific hybridization enables transfer of specific disease and pest resistance traits from wild and/or related species to cultivated species. Some of the wild okra species are reported to have desirable genes like disease and pest resistance (Singh *et al*., 2007). For the first time, male sterility in okra has been induced by gamma radiation and it is reported to be conditioned by single recessive gene (ms_1) (Dutta, 1976). In the present study, by employing interspecific hybridization, attempt was done for finding male sterility-inducing cytoplasm among wild species of the genus *Abelmoschus* with a view to develop and exploit CGMS system owing to the problems associated with the currently used GMS (existence of 50% pollen shedders in seed parent block and thus need to rogue out male fertile plants) in the development of commercial okra hybrids (Pitchaimuthu *et al*., 2012).

The genus *Abelmsochus* in India consists of about 12 species, out of which three are cultivated and the rest are wild species (Joseph *et al*., 2017). Differential ploidy level and often genotype specific variation in chromosome number has been noticed in okra as well as some of its wild relatives (Keisham *et al*., 2014). The crop is facing challenges of YVMV and ELCV which require search for resistance in the wild related taxa and their incorporation in cultivated okra. Attempts to develop hybrids of okra with different wild species were ruined due to sterility of the F_1 hybrid. The Crosses between cultivated okra genotypes and wild okra species *viz*., *A. angulosus* var. *grandiflorus*, *A. caillei*, *A. tuberculatus*, A. *tetraphyllus* and *A. mizonagensis* sp. nov. (Mizoram), *A. moschatus* subsp. *rugosus* and Guinean okra with *A. esculentus, A. angulosus* var. *grandiflorus* and *A. mizonagensis* sp. nov. (Mizoram) were raised but could not be advanced to next generation as the interspecific hybrid failed to produce viable seeds upon selfing and back cross.

In general, okra wild species had many desirable traits like dark green colour, high mucilage, extended bearing, perennation tendency, high branching, reduced fruit length, drought resistance, high temperature tolerance and YVMV resistance to be incorporated from the wild gene pool. Kuwada (1966) has developed an amphi-diploid of okra with *Abelmoschus tuberculatus* and described it as *Abelmoschus x tuberculatus*. Further, F_1 hybrids of *A. tuberculatus* with *A. manihot* were also attempted (Kuwada, 1974). Pal *et al.*, (1952) attempted wide hybridization between cultivated okra and its closest progenitor, *A. tuberculatus*. Akhond *et al.*, (2000) and Samarjeeva (2003) described the success of wide hybridization attempt involving okra with *A. moschatus* and *A. angulosus*, respectively.

Wide hybridization was attempted between various *Abelmoschus* species primarily for establishing the genetic relationship based on F_1 fertility and secondarily to derive useful new combinations (Joseph *et al.*, 2013). The developed material could be of use for YVMV and Enation Leaf Curl Virus resistance apart from cytoplasmic male sterility in cultivated okra.

Materials and Methods

Ten taxa of *Abelmoschus viz*., *A. angulosus* var. *angulosus, A. angulosus* var. *grandiflorus, A. caillei, A. esculentus, A. ficulneus, A. manihot var. tetraphyllus, A. moschatus ssp. moschatus, A. tetraphyllus* var. *pungens, A. tetraphyllus* var. *tetraphyllus* and *A. tuberculatus* were raised in the vegetable block of ICAR-IIHR, Bengaluru during the *kharif* season of year 2015. Emasculation of mature flower buds was performed by removing the perianth and shaving off the anthers in the previous evening before anthesis and covered with butter paper cover. Ready to open flower buds were also covered at the same time with butter paper cover to collect pollen. Pollen grains from male parent were collected and dusted on the receptive stigmas of emasculated flowers between 8.00 AM and 10.30 AM and again covered with butter paper cover and tagged. Upon maturity, capsules were harvested, dried and hybrid seeds stored for 30-45 days in a cool place. Such seeds were physically scarified using sand-paper and soaked overnight in distilled water before sowing. Seedlings were raised in protrays. The 2-4 true leaf aged seedlings were transplanted to pots and allowed to grow under optimal conditions.

The list of wild species and cultivated genotypes used for crossability study was mentioned in Table 1.

Results and Discussion

Cross compatibility studies [explaining number of crosses attempted (NCA), number of fruit set (NFS), fruit set per cent (FSP), seed set per cent (SSP), crossability index per cent (CI %)] between okra wild relatives and cultivated genotypes were mentioned in Table 2-14; among the wild relatives was mentioned in Table 15. The germination per cent of F_1 seeds and pollen viability (%) of interspecific hybrids mentioned in Table 16.

There was no fruit set obtained when *A. angulosus* var. *angulosus* flowers pollinated with pollen from IIHR 294, IIHR 296, IIHR 299, IIHR 10-11-551, IIHR 10-11-875 and IIHR G 10. But good fruit set was noticed with IIHR 285(33.33%) and with IIHR 10-11-594 (69.23%). The highest crossability index percent (38.10%) was recorded in the cross A. *angulous* var. *angulosus* X IIHR 285 followed by A. *angulous* var. *angulosus* X IIHR 594 (11.11%) (Table 2). The highest crossability index per cent (15.24%) was recorded in the cross *A. angulosus* var. *grandiflorus* IC 203832 X IIHR 294 followed by *A. angulosus* var. *grandiflorus* IC 203832 X IIHR 285 (Table 3). In the present investigation, there was no fruit set when *A. angulosus* var. *grandiflorus*-1 crossed with IIHR 294, IIHR 296, IIHR 299, IIHR 551, IIHR 875 and IIHR G 10 whereas the appreciable fruit set was found only when *A. angulosus* var. *grandiflorus*-1 crossed with IIHR 285 and IIHR 594 (Table 4). But the seeds produced in these crosses were shriveled and non-viable. This suggests the existence of post-zygotic barriers during interspecific hybridization. The crosses between *A. esculentus* cultivars and *A. angulosus* were found successful by Prabu and Warade (2013) only when cultivated okra was used as female parent. When *A.angulosus* was used as the female parent incompatibility was observed resulting in failure of embryo formation by Samarajeewa *et al.*, 1999. He opined that embryo rescue was the only alternative to raise viable hybrids. He found that when the cultivated type was used as female parent, progeny plants were produced without incompatibility difficulties.

The successful F_1s were obtained in both direct and reciprocal crosses between *A. tetraphyllus* var. *tetraphyllus* and *A. esculentus* cultivars by earlier workers [Jambhale (1980, Sheela (1986, 1994)]. The seed setting per cent was highest when crossed with IIHR 296 (100%). But there was no fruit and seed set when *A. tetraphyllus* var. *tetraphyllus* crossed with *A. esculentus* lines IIHR 294, IIHR 299, IIHR 551 and IIHR 875. The present work is in conformity with previous findings in respect of successful crossing between *A. tetraphyllus* var. *tetraphyllus* and *A. esculentus* (Table 10) by Jambhale 1980. There was no fruit set and seed set observed when *A. tetraphyllus* var. *pungense* crossed with *A. esculentus* IIHR 285 and IIHR 10-11-594.

The results obtained in crosses between *A. tuberculatus* and *A. escuelntus* (Table 11) in the present study were in line with the findings of Kuwada (1966). The cross between *A. tuberculatus* and *A. esculetnus* genotype IIHR 10-11-594 recorded the highest fruit set (100%) and seed set (99.02%) and crossability index per cent (100%) followed by *A. tuberculatus* X *A. esculentus* IIHR 10-11-875.

Abelmoschus ficulneus was found compatible when crossed to IIHR 285, IIHR 294, IIHR 299, IIHR 594 and G 10. The highest fruit set was found in the cross between *A. ficulneus* and IIHR 594 (69.23%) followed by IIHR 285 (21.88%) whereas the highest seed set was found in the cross between *A. ficulneus* and IIHR 294 (88.24%) followed by G10 (82.61%). The highest crossability index per cent was found in the cross between *A. ficulneus* and IIHR 594 (76.92%) followed by 285 (25.00%). But, *A. ficulneus* was found incompatible when *A. esculentus* line IIHR 296, IIHR 551 and IIHR 875 as pollen parents (Table 6). The main reason of hybrid inviability might be due to presence of irreconcilable parental chromosomes, negative cytoplasmic genic interactions and incongruous embryo and the surrounding tissue (Stebbins, 1958).

There was no fruit set when *A. moschatus* crossed with IIHR 294, IIHR 296, IIHR 299, IIHR 551, IIHR 875 and IIHR G 10 whereas the appreciable fruit set was found only when *A. moschatus* crossed with IIHR 285 and IIHR 594 (Table 10) in the present investigation.

But the seeds obtained were shriveled and non-viable. In this type of incompatibility, Allard (1990) opined that zygote formation might be prevented by ineffective growth of pollen or failure of fertilization. However, the viable hybrids of this species with *A. esculentus* through embryo culture technique were obtained by Gadwal *et al.*, (1968). This indicates that *A. moschatus* is reproductively less related to other okra species as opined by Hamon and Charrier (1983) and Pushaparajan (1986).

Table.1 The list of wild species and cultivated genotypes used for crossability study

Sl. No.	Wild species	Sl. No.	Cultivated species
1	*A. angulosus* var. *anglulosus*	1	*Abelmoschus esculentus* IIHR 285
2	*A. angulosus* var. *grandiflorus* IC 203832	2	*Abelmoschus esculentus* IIHR 294
3	*A. angulosus* var. *grandiflorus* -1	3	*Abelmoschus esculentus* IIHR 296
4	*A. caillei*	4	*Abelmoschus esculentus* IIHR 299
5	*A. ficulneus*	5	*Abelmoschus esculentus* IIHR 10-11-551
6	*A. manihot* var. *tetraphyllus*	6	*Abelmoschus esculentus* IIHR 10-11-875
7	*A. manihot* var. *tetraphyllus* IC 203833	7	*Abelmoschus esculentus* IIHR 10-11-594
8	*A. manihot* var. *tetraphyllus* IC 90339	8	*Abelmoschus esculentus* IIHR G 10
9	*A. mizoramensis*		
10	*A. moschatus*		
11	*A. tetraphyllus* var. *pungense*		
12	*A. tetraphyllus* var. *tetraphyllus*		
13	*A. tuberculatus*		
14	New taxa IC 0433556		

Table.2 Cross compatibility studies between *A.angulosus var. angulosus* and *A. esculentus* genotypes

Cross combination			**NCA**	**NFS**	**FSP**	**SSP**	**CI %**
A.angulosus var. angulosus	X	IIHR 285	12	4	33.33	22.35	38.10
A.angulosus var. angulosus	X	IIHR 294	10	0	0.00	0.00	0.00
A.angulosus var. angulosus	X	IIHR 296	10	0	0.00	0.00	0.00
A.angulosus var. angulosus	X	IIHR 299	10	0	0.00	0.00	0.00
A.angulosus var. angulosus	X	IIHR 10-11-551	10	0	0.00	0.00	0.00
A.angulosus var. angulosus	X	IIHR 10-11-594	10	1	10.00	69.23	11.11
A.angulosus var. angulosus	X	IIHR 10-11-875	15	0	0.00	0.00	0.00
A.angulosus var. angulosus	X	IIHR G 10	15	0	0.00	0.00	0.00

Note: NCA = Number of Crosses Attempted, NFS = Number of Fruit Set, FSP= Fruit Set Per cent, SSP= Seed Set Per cent (SSP), CI % = Crossability Index Per cent

Table.3 Cross compatibility studies between *A.angulosus var. grandiflorus* IC 203832 and *A. esculentus* genotypes

Cross combination			**NCA**	**NFS**	**FSP**	**SSP**	**CI %**
A.angulosus var. grandiflorus IC 203832	X	IIHR 285	15	2	13.33	42.31	14.81
A.angulosus var. grandiflorus IC 203832	X	IIHR 294	15	2	13.33	36.36	15.24
A.angulosus var. grandiflorus IC 203832	X	IIHR 296	10	0	0.00	0.00	0.00
A.angulosus var. grandiflorus IC 203832	X	IIHR 299	10	0	0.00	0.00	0.00
A.angulosus var. grandiflorus IC 203832	X	IIHR 10-11-551	15	0	0.00	0.00	0.00
A.angulosus var. grandiflorus IC 203832	X	IIHR 10-11-594	10	0	0.00	0.00	0.00
A.angulosus var. grandiflorus IC 203832	X	IIHR 10-11-875	10	0	0.00	0.00	0.00
A.angulosus var. grandiflorus IC 203832	X	IIHR G 10	10	0	0.00	0.00	0.00

Table.4 Cross compatibility studies between *A.angulosus var. grandiflorus*-1 and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
***A.angulosus var. grandiflorus* -1**	X	IIHR 285	81	14	17.28	48.33	19.75
***A.angulosus var. grandiflorus* -1**	X	IIHR 294	26	0	0.00	0.00	0.00
***A.angulosus var. grandiflorus* -1**	X	IIHR 296	30	0	0.00	97.30	0.00
***A.angulosus var. grandiflorus* -1**	X	IIHR 299	18	0	0.00	0.00	0.00
***A.angulosus var. grandiflorus* -1**	X	IIHR 10-11-551	10	0	0.00	0.00	0.00
***A.angulosus var. grandiflorus* -1**	X	IIHR 10-11-594	63	7	11.11	87.15	12.35
***A.angulosus var. grandiflorus* -1**	X	IIHR 10-11-875	10	0	0.00	0.00	0.00
***A.angulosus var. grandiflorus* -1**	X	IIHR G 10	10	0	0.00	0.00	0.00

Table.5 Cross compatibility studies between *A.caillei* and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
A. caillei	X	IIHR 285	19	9	47.37	99.60	48.58
A. caillei	X	IIHR 296	10	6	60.00	100.00	63.16
A. caillei	X	IIHR 299	10	8	80.00	100.00	84.21
A. caillei	X	IIHR 10-11-594	18	11	61.11	97.39	61.11
A. caillei	X	IIHR G 10	12	8	66.67	100.00	66.67

Table.6 Cross compatibility studies between *A. ficulneus* and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
A. ficulneus	X	IIHR 285	32	7	21.88	53.40	25.00
A. ficulneus	X	IIHR 294	13	1	7.69	88.24	9.05
A. ficulneus	X	IIHR 296	11	0	0.00	0.00	0.00
A. ficulneus	X	IIHR 299	12	1	8.33	50.00	9.80
A. ficulneus	X	IIHR 10-11-551	15	0	0.00	0.00	0.00
A. ficulneus	X	IIHR 10-11-594	13	9	69.23	64.53	76.92
A. ficulneus	X	IIHR 10-11-875	10	0	0.00	0.00	0.00
A. ficulneus	X	IIHR G 10	12	1	8.33	82.61	9.26

Table.7 Cross compatibility studies between *A manihot ssp. tetraphyllus* and *A. esculentus* genotypes

Cross combination			**NCA**	**NFS**	**FSP**	**SSP**	**CI %**
A. manihot ssp. tetraphyllus	X	IIHR 285	18	5	27.78	93.33	29.24
A. manihot ssp. tetraphyllus	X	IIHR 294	10	1	10.00	95.00	10.81
A. manihot ssp. tetraphyllus	X	IIHR 296	10	3	30.00	94.74	32.43
A. manihot ssp. tetraphyllus	X	IIHR 299	10	1	10.00	66.67	10.81
A. manihot ssp. tetraphyllus	X	IIHR 10-11-551	10	2	20.00	93.94	21.62
A. manihot ssp. tetraphyllus	X	IIHR 10-11-594	15	2	13.33	92.31	13.68
A. manihot ssp. tetraphyllus	X	IIHR 10-11-875	12	0	0.00	0.00	0.00
A. manihot ssp. tetraphyllus	X	IIHR G 10	15	1	6.67	64.00	6.84

Table.8 Cross compatibility studies between *A manihot ssp. tetraphyllus* IC 203833 and *A. esculentus* genotypes

Cross combination			**NCA**	**NFS**	**FSP**	**SSP**	**CI %**
***A. manihot ssp. tetraphyllus* IC 203833**	X	IIHR 285	10	1	10.00	84.21	10.81
***A. manihot ssp. tetraphyllus* IC 203833**	X	IIHR 294	10	2	20.00	90.16	22.22
***A. manihot ssp. tetraphyllus* IC 203833**	X	IIHR 296	12	0	0.00	0.00	0.00
***A. manihot ssp. tetraphyllus* IC 203833**	X	IIHR 299	10	0	0.00	64.10	0.00
***A. manihot ssp. tetraphyllus* IC 203833**	X	IIHR 10-11-551	10	0	0.00	67.74	0.00
***A. manihot ssp. tetraphyllus* IC 203833**	X	IIHR 10-11-594	15	2	13.33	86.67	14.04
***A. manihot ssp. tetraphyllus* IC 203833**	X	IIHR 10-11-875	12	0	0.00	0.00	0.00
***A. manihot ssp. tetraphyllus* IC 203833**	X	IIHR G 10	10	0	0.00	0.00	0.00

Table.9 Cross compatibility studies between *A manihot ssp. tetraphyllus* IC 90339 and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
***A. manihot ssp. tetraphyllus* IC 90339**	X	IIHR 285	10	4	40.00	89.19	43.24
***A. manihot ssp. tetraphyllus* IC 90339**	X	IIHR 294	10	0	0.00	0.00	12.04
***A. manihot ssp. tetraphyllus* IC 90339**	X	IIHR 296	12	0	0.00	0.00	0.00
***A. manihot ssp. tetraphyllus* IC 90339**	X	IIHR 299	10	0	0.00	0.00	0.00
***A. manihot ssp. tetraphyllus* IC 90339**	X	IIHR 10-11-551	10	0	0.00	0.00	0.00
***A. manihot ssp. tetraphyllus* IC 90339**	X	IIHR 10-11-594	10	4	40.00	86.90	42.11
***A. manihot ssp. tetraphyllus* IC 90339**	X	IIHR 10-11-875	10	0	0.00	0.00	0.00
***A. manihot ssp. tetraphyllus* IC 90339**	X	IIHR G 10	12	0	0.00	0.00	0.00

Table.10 Cross compatibility studies between *A moschatus* and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
A. moschatus	X	IIHR 285	36	18	50.00	73.36	51.81
A. moschatus	X	IIHR 294	20	2	0.00	0.00	0.00
A. moschatus	X	IIHR 296	15	4	0.00	0.00	0.00
A. moschatus	X	IIHR 299	20	3	0.00	0.00	0.00
A. moschatus	X	IIHR 10-11-551	15	0	0.00	0.00	0.00
A. moschatus	X	IIHR 10-11-594	37	18	48.65	75.61	49.14
A. moschatus	X	IIHR 10-11-875	10	2	0.00	0.00	0.00
A. moschatus	X	IIHR G 10	15	4	0.00	0.00	0.00

Table.11 Cross compatibility studies between *A tetraphyllus var. pungense* and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
A. tetraphyllus var. pungense	X	IIHR 285	18	0	0.00	0.00	0.00
A. tetraphyllus var. pungense	X	IIHR 10-11-594	12	0	0.00	0.00	0.00

Table.12 Cross compatibility studies between *A tetraphyllus var. tetraphyllus* and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
A. tetraphyllus var. tetraphyllus	X	IIHR 285	32	17	53.13	94.23	57.43
A. tetraphyllus var. tetraphyllus	X	IIHR 294	20	0	0.00	0.00	0.00
A. tetraphyllus var. tetraphyllus	X	IIHR 296	15	1	6.67	100.00	7.41
A. tetraphyllus var. tetraphyllus	X	IIHR 299	20	0	0.00	0.00	0.00
A. tetraphyllus var. tetraphyllus	X	IIHR 10-11-551	15	0	0.00	0.00	0.00
A. tetraphyllus var. tetraphyllus	X	IIHR 10-11-594	36	16	44.44	95.73	46.78
A. tetraphyllus var. tetraphyllus	X	IIHR 10-11-875	10	0	0.00	0.00	0.00
A. tetraphyllus var. tetraphyllus	X	IIHR G 10	12	1	8.33	0.00	8.77

Table.13 Cross compatibility studies between *A tuberculatus* and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
A. tuberculatus	X	IIHR 285	16	7	43.75	98.20	44.87
A. tuberculatus	X	IIHR 294	10	3	30.00	97.03	31.58
A. tuberculatus	X	IIHR 296	10	0	0.00	0.00	0.00
A. tuberculatus	X	IIHR 299	10	3	30.00	100.00	31.58
A. tuberculatus	X	IIHR 10-11-551	10	2	20.00	100.00	21.05
A. tuberculatus	X	IIHR 10-11-594	10	10	100.00	99.02	100.00
A. tuberculatus	X	IIHR 10-11-875	10	5	50.00	100.00	51.28
A. tuberculatus	X	IIHR G 10	10	3	30.00	86.57	30.00

Table.14 Cross compatibility studies between New taxa IC 0433556 and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
New taxa IC 0433556	X	IIHR 285	15	0	0.00	0.00	0.00
New taxa IC 0433556	X	IIHR 10-11-594	15	0	0.00	0.00	0.00

Table.15 Cross compatibility studies between wild species of and *A. esculentus* genotypes

Cross combination			NCA	NFS	FSP	SSP	CI %
A. caillei	X	*A. angulosus var. grandiflorus*	12	0	0.00	0.00	0.00
A. angulosus var. grandiflorus	X	*A. tetraphyllus ssp. tetraphyllus*	9	0	0.00	0.00	0.00
A. angulosus var. grandiflorus	X	*A. moshcatus*	14	0	0.00	0.00	0.00
A. moschatus	X	*A. tuberculatus*	10	1	10.00	85.00	10.10
A. moschatus	X	*A. angulosus var. grandiflorus*	12	2	16.67	75.00	18.73
A. angulosus var. grandiflorus	X	IIHR 10-11-875	10	0	0.00	0.00	0.00
A. angulosus var. grandiflorus	X	IIHR G 10	10	0	0.00	0.00	0.00

In the present study, there was cross compatibility between *A. caillei* and *A. esculentus* (Table 5). The results are in conformity with the findings of Hamon and Hamon (1991). The highest fruit and seed set were observed when *A. caillei* was crossed with IIHR 299 (80.00 % and 100%) followed by IIHR G 10 (66.67% and 100%). But, all the seeds obtained were not germinated due to lack of viable embryo. This may be resulted due to the differences in ploidy status of *A. caillei* as compared to *A. esculentus* which led to poor endosperm balance as per Kallo (1996). Though there was higher degree of crossability in the cross *A. caillei* x *A. esculentus*, Chacko *et al.*, (1996) noticed that the highest germination of the F_1s was observed only when *A. esculentus* was used as female parent. In contrast to this, Kousalya (2005) had reported maximum germination in the cross between *A. caillei* and *A.esculentus*.

The crosses attempted between *A. manihot* ssp. tetraphyllus IC 203833 and *A. esculentus* lines were successful when IIHR 285, IIHR 294 and IIHR 594 were used as the pollen parents but there was no fruit set when IIHR 296 and IIHR 299 used as the male parents (Table 8). The similar results were obtained when *A. manihot* ssp. *tetraphyllus* IC 90339 was used as the female parent (Table 9). Jambhale (1980) reported cross compatibility between *A. manihot* and *A. esculentus* but Teshima (1933) and Sujatha (1983) found that the cross was compatible only when *A. esculentus* was used as the female and *A. manihot* as the male parent.

From the present investigation, it was noted that higher values of fruit set per cent, number of seeds in crossed fruits, crossability index and germination per cent were recorded when *A. esculentus* lines used as the male parents while crossing with wild species *viz*., *A. caillei*, *A. manihot ssp. tetraphyllus*-1, *A. manihot ssp. tetraphyllus*-2 and *A. tuberculatus*. Whereas, the lowest values were recorded in crosses between *A. angulosus* var. *grandiflorus* -1, *A. angulosus* var. *grandiflorus* -2 and *A. angulosus* var. *grandiflorus* (IC 203832). This is in confirmation with Sheela (1994). The partial or complete failure of the endosperm to nurture the developing embryo due to the genetic imbalance might be the cause of the lowest seed set and recovery of shriveled seeds in the crossed fruits as observed by Allard, 1990. Whereas, Sindhu (1993) opined that lower fruit set was attributed to the chromosome number variation among the selected wild species. In the present study, seed germination was found maximum in crosses between cultivated okra species and *Abelmoschus tetraphyllus*. The obtained interspecific hybrids can be evaluated for identifying male sterile lines in the subsequent generations.

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