EFFECT OF PHYTOHORMONES IN OVERCOMING THE CROSS INCOMPATIBILITY BARRIER OF *Corchorus capsularis* AND *Corchorus olitorius* Hybrids

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BY

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This is to certify that thesis entitled "Effect of phytohormones in overcoming the cross incompatibility barrier of *Corchorus capsularis* and *Corchorus olitorius* Hybrids" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN DEPARTMENT OF GENETICS AND PLANT BREEDING,** embodies the result of a piece of bona fide research work carried out by Md. Mostafa Bin Afzal Registration No. 18-09319 under my direct supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: December, 2020

Place: Dhaka, Bangladesh

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(Prof. Dr. Jamilur Rahman)

Supervisor

DEDICATED TO

MY HONORABLE PROFESSOR

DR. JAMILUR RAHMAN AND MY FAMILY MEMBERS WHO LAID THE FOUNDATION OF MY SUCCESS

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The Author

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LIST OF ABBREVIATED TERMS

Abbreviation	Full Words
DAS	Days after sowing
IAA	Indole-Acetic-Acid
GA_3	Gibberellic Acid
NAA	α-Naphthalene Acetic-Acid
hrs	Hours
%	Percentage
cm	Centimeter
DMRT	Duncan’s Multiple Range Test
RCBD	Randomized Complete Block Design
g	gram
cm^2	Square Centimeter
BBS	Bangladesh Bureau of Statistics
et al	et alu = other people
mg/L	Milligram per liter
cv	Cultivar
i.e.	ed est (That is)
e.g.	Exampli grantia (by way of example)

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ABSTRACT

This research work was carried out for producing inter-species putative hybrids of two cultivated jute species *Corchorus capsularis* and *Corchorus olitorius* by applying phytohormones and evaluating hybrid performance. This study was organized and executed in two seasons, first season for producing inter-species putative hybrids through applying phytohormones and the second season the performances the of the putative hybrids were evaluated. Five varieties of *C. capsularis* and six varieties of *C. olitorius* were used for inter-species hybridization programme. The eleven parents and their fourteen inter-species putative hybrids were used for estimation of heterosis and character association study. Two hormone treatments, IAA and mixed hormones (GA_3+NAA+Kinetin) were used to increase better embryo development and seed setting. Results showed that hormone treatments affected in fruit and seed setting. IAA gave better performance in seed setting and mixed hormones gave better performance in fruit setting. In case of the fruit setting, it was 41.21% in IAA and 46.0% in mixed hormones. While in case of seed setting, 13.80% in IAA and 7.33% in mixed hormones. The analysis of variance showed that there were significant variations among the performance of the parents and putative hybrids for the all the traits except base diameter and dry fiber weight. In case of hybrids, the higher heterosis value for plant height, base diameter, petiole length, root length, root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight and dry fiber weight were 65.381% (OM-1 X CC-45), 36.065% (O-9897 X BJRI-2142), 34.444% (O-3820 X CVE-3), 48.995%(JRO-524 XCVL-1), 174.04% (O-9897 X BJRI-2142), 352.380% (O-72 X BJRI-2197), 347.27% (O-72 X BJRI-2197), 275.04%(O-9897 X BJRI-2142) and 175.46% (JRO-524 XCVL-1) over better parent values respectively. In the correlation coefficient study, almost same result was observed in parents and inter-species putative hybrids at phenotypic levels. Correlation coefficient of the parents and inter-species hybrids clearly indicated that plant height, base diameter, petiole length, root length, root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight and dry fiber weight, characters have very high degree of positive relationships in all cases. Taking together, IAA hormones had more effect in overcoming the cross incompatibility barrier between two cultivated jute species. Again, considering all characters the highest mean performance and heterosis value was in found in O-72 X BJRI-2197 cross combination indicating this combination would give transgressive segregants in later generations.

CHAPTER I

INTRODUCTION

Jute (*Corchorus* spp.) is one of the world's important sources of natural fiber. The genus '*Corchorus'* has more than 100 species, however, only two of them e.g. White jute (*C. capsularis*) and Tossa jute (*C. olitorius*) are commercially cultivated (Zhang *et al.,* 2019). These two plant species are exploited for natural bast or stem fiber and are second only to cotton in volume of global fiber production (Saha *et al.,* 2017). The jute (2x= 2n= 14) fiber is obtained from the secondary phloem of two cultivated species of '*Corchorus'*. Being a natural bast fiber jute occupies important place in environmental aspects due to biodegradable characteristics (Samanta *et al.,* 2011).
Jute (2x=2n=14) is self-pollinated extensively cultivated in tropical and sub-tropical region. Jute is a dicotyledonous fiber yielding annual plants. Jute fibers are composed primarily of the plant materials cellulose (major component of plant fiber) and lignin (major components of wood fiber). The lignin content of a mature *C. olitorius* stem is about 29% (Tanmoy *et al.,* 2015). Jute fiber is totally biodegradable and compostable and therefore an extremely attractive renewable resource.

India, Bangladesh, China and Thailand are the leading producers of jute. India is the largest producer of jute goods in the world, while Bangladesh is the largest cultivar of raw jute (Ghosh and Jethi, 2013). Worldwide total amount of jute production is 339.3 million tons, where Bangladesh alone produced 145.2 million tons, which is 41.9% of total (FAOSTAT, 2014). In Bangladesh total 737770 hector land cultivated for jute and yield per hector is 11.178 bales and total production is 8246797 bales (BBS, 2017).

Jute sector has huge potentials for economic development. Without any doubt, Bangladesh is still the major exporter of jute and jute goods all over the worlds, whereas India is acting as number one exporter and importer. Export promotion Bureau (EPB) data shows, Bangladesh exported jute and jute goods worth nearly $920 million in fiscal year 2015-2016. Although India is importing jute, her production cost of jute is 25 percent less than Bangladesh, signifying a higher productivity (EPB, 2016).

The productivity of the current varieties of jute in Bangladesh is not as high as expected. The existing varieties are not resistant to root rot, root knot, anthracnose, seedling blight, nematodes and viruses. *C. olitorius* produces fibers of superior quality with better tensile strength, but is susceptible to flooding and water logging. On the other hand, the varieties of *C. capsularis* are known as tolerant to water logging and flooding, however, the fiber quality of *C. capsularis* jute varieties are not internationally standared. Therefore, a genetic combination between the two species of *C. olitorius and C. capsularis* is highly desirable from the point of breeding aspect.

In crop improvement programmes, inter-specific hybridization is a tool for creating variation and use for development of new species. It is resorted to when plant breeders have exhausted the variability in a species, or as they are looking for some characters not present in one and can be brought from other. Hybridization between two cultivated species of jute, which has equal number of chromosomes, might lead to generation of variation related to adaptability, immunity to diseases, pests and strong white fiber. Although a number of desirable varieties of jute have been released from time to time in Bangladesh, however, none does have the combination of the desired characters from the two cultivated jute species. Hence, the breeders are desperately looking for combinations of the two cultivated jute species. It is important to have flood tolerant varieties with the fiber quality of 'Tossa'. Though inter-specific hybridization in jute is very difficult, due to hybrid sterility and other genetical, cytoplasmic and physiological factors, breeders are continuously trying to overcome the cross incompatibility barrier to get inter-specific hybrids for incorporation of the desirable characters of the two cultivated jute species. The necessity for the hybridization between the two cultivated species *C. capsularis* and *C. olitorius* was realized by jute breeders since the early part of this century.

Generally, several pre- or post-zygotic barriers are known to limit the production of hybrids between many distantly related species (Brar and Khush, 1986). The pre-fertilization barriers include all the factors that hinder effective fertilization, for example, (i) failure of pollen tube germination (ii) slow pollen tube growth. Post fertilization barriers usually hinder or related to the development of the zygote after fertilization and normal development of seed. This kind of abnormality may be due to (i) chromosome elimination (ii) apomixes (induction of egg cell to a parthenocarpic fruit development) (iii) hybrid inviability or weakness and (iv) hybrid sterility.

In case of jute, the rate of pollen tube growth of *C. capsularis* (pollinated) was found to be slower than that the selfed ones and only a few tubes reached the embryo sac of pollinated flower buds of *C. olitorius* (Patel and Datta, 1960). These authors concluded that the main barrier in obtaining viable F_1 hybrid seeds could be the ineffectiveness of most of the pollen tubes to grow rapidly enough and fertilize the majority of the ovules. Most of the F_1 hybrids reported, so far showed material inheritance either in F_1 or skewed in F_2 generations. The possibility of parthenogenetic seed development in jute hybridization has been suggested by Iyer *et al.,* (1961) and Arangzeb and Khatun (1982, 1983). Unilateral chromosome elimination is another possible explanation for obtaining material type of hybrid plants where it is only possible to obtain F_1 hybrids with one maternal (*C. olitorius)* genome suggested by Khatun (1993).

A number of researchers reported hybridization between the two cultivated species of jute e.g. *C. capsularis* and *C. olitorius* to be successful (Finlow, 1917, 1921, 1923; Howard, 1924; Banerjee & Datta, 1960; Datta *et al* 1960). Many, Islalm and Rashid (1960); Swaminathan *et al.,* (1961); Choudhuri and Mia, 1962; Mia and Shaikh, 1967; however, have claimed to have succeeded in producing parents in F_1 and F_2 generations.

Several techniques have been used to arrest the early abortion of hybrid embryos. Using *C. olitorius* as a female parent, Islam and Rashid (1960), and Swaminathan *et al.,* (1961) obtained hybrids, the former by smearing the pedicel of the pollinated flowers with high concentration of Indole-3-Acetic Acid (IAA) and the later by grafting the two parental species reciprocally prior to crossing. Swaminathan *et al.,* (1961) reported that application of pollen irradiated with 2000r X-rays maked it possible to get F_1 viable seeds. Through hormone application and embryo culture, Isalm (1964) was able to obtain a single reciprocal hybrid which died before flowering. Based on these points, these studies were planned with following objectives:

i) To determine the effect of phytohormones in overcoming the inter-specific cross incompatibility barrier between *C. capsularis* and *C. olitorius*.
ii) To compare the performance of the parental lines of the two species of jute and their putative F_1 hybrid lines.
iii) To estimate heterosis of inter-specific putative hybrids over mid-parent and better-parent.
iv) To find out the correlation coefficients among the different characters of parental and inter-specific putative hybrid lines.

CHAPTER II

REVIEW OF LITERATURE

Jute is the most important fiber crop of Bangladesh. The crop has received much attention by a large number of researchers on various aspects of its production, utilization and development. It is a long history of more than fifty years that inter-species hybridization between the two cultivated species of *Corchorus* has been tried by many workers. Development of inter-species hybrids and its related literature of the world have been reviewed in this chapter.

2.1 Cross compatibility between *Corchorus caplularis* and *C. olitorius*

Finlow (1917, 1921, 1923) first attempted to get a hybrid between *Corchorus caplularis* and *C. olitorius* at diploid level, but failed to get any viable seed. Later on Patel, Ghose and Dasgupta (1929) carried out hybridization of the two cultivated jute species, but they could not produce any hybrid using seven different methods. While Bhaduri (1948) claimed to have obtained viable inter-species hybrids between *Corchorus caplularis* and *C. olitorius* by implanting self pollinated style of *Corchorus caplularis* into decapitated style of *C. olitorius.* But he observed no apparent segregation of characters in the F_2. The F_1 hybrids apparently showed maternal inheritance with reference to fruit characters.

Frost and Bose (1966) obtained few F_1 hybrid plants by applying IAA in emasculated *C. olitorius* flowers after pollination. All these hybrid plants showed strong resemblance to the female parent. Following biochemical tests, no difference were found between suspected hybrid and female parent. They concluded that no hybridization had taken place or what was less likely a masking effect due to complete dominance of one of the parents (*C. olitorius)* had taken place.

Naik (1982) at IARI got some viable seeds on both the reciprocal crosses in the species of *Corchorus.* For the quantitative characters, F_2 generation of these suspected hybrids were skewed toward the maternal parent.

Datta *et al.,* (1960) tried to produce inter-species hybrids between *Corchorus caplularis* and *C. olitorius* at tetraploid level. They found pot setting in one direction only (4n *C. olitorius* x *C. capsularis*) but seeds obtained did not germinate. In reciprocal crosses, pods were found to set but most of the pods could not attain maturity and dropped at the time of development. While Iyer *et al.* (1961) observed parthenocarpic development of fruits, while hybridization was done by grafting of the two species *C. caplularis* and *C. olitorius*

At BJRI (1979) (Bangladesh Jute Research Institute), hybridization was made between autotraploids, *C. caplularis* and *C. olitorius* for the production of amphidiploids. *C. olitorius* was used as a pistillate parent and growth hormone (GA) was used. The percentage of fruit setting was 40. The fruits were morphologically same as the female parent. Only two apparently normal seeds germinated and appeared like female parent and no F_2 segregations were noted.

Das (1968) made inter-species hybridization reciprocally between *C. capsularis* and *C. olitorius* in the conventional way and also by grafting. In the conventional way, no fruit setting was observed. Fruit setting was higher in grafted *C. olitorius* x *C. capsularis*. A low percentage of fertile seeds were produced in either direction.

A number of workers reported to have produced successfully hybrids of the *C. capsularis* and *C. olitorius* (Islam and Rashid, 1961, Swaminathan *et al.* 1961, Choudhuri and Mia, 1962, Mia and Shaikh 1967, Bhaduri and Bairagi, 1968). Most of them used reciprocal grafting, pollen irradiation and the hormone application method to overcome the incompatibility barriers, Islam and Rashid (1961) and Swaminathan *et al.* (1961) observed skewed distribution of recombination types towards the female parent in the F_2 and the F_1 generations.

Raut and Naik (1983) obtained F_1 and F_2 generations from the cross between the two cultivated jute species by applying reciprocal grafting hormone treatment, pollen irradiation and ovary culture. Most of the F_1 plants from different cross combination were not found with any combination of characters. Only the rare ones with some characters from the male parent were kept as suspected hybrids and carried to F_2.

Islam and Rashid (1961) obtained a hybrid between *C. capsularis* and *C. olitorius* which were weak, slow growing and they showed dominance of female parent. In the reciprocal crosses they did not get any hybrid.

Swaminathan and Iyer (1961) examined F_2 generation of two hybrids of *C. olitorius* x *C. capsularis.* The F_2 progenies of these two hybrids contained more than 40% of non-viable seedlings. On the other hand, Bhaduri and Bairagi (1968) obtained hybrids between the two *Corchorus* species by normal crossing but F_1 and F_2 plants showed maternal appearance.

Crossing were made by Arangazeb and Khatun (1983) in a wide range of combinations in between cultivated and wild *olitorius* with cultivated and wild *capsularis* types with and without the application of growth hormone. Most developed seed germinated and appeared like female parents. It was assumed that GA and IAA induced apomixis enhanced by pollination.

Wilson and Menzel (1967) succeeded in obtaining F_1 hybrids between *Hibiscus canabinus* (2n=36) and *H. subdariffa* (2n=72). Their subsequent study showed that two fertile plants obtained were allohexaploid. A few lines of F_2 and F_3 showed moderate resistance to root-knot nematode (Wilson and Adamson, 1970).

Inter-species among *H. acetosella* (2n=72) x *H. cannabinus* (2n=36) and *H. radiatus* (2n=72) x *H. cannabinus* (2n=36) were made in India and a hybrid MT-1676 obtained through the later cross. It has proved to be a high yielder. Hybrids of *H. cannabinus* and *H. subdariffa* were also reported from USA (FAO, 1983).

2.2 Reasons for incompatibility

Srinath and Kundu (1962) studied the causes for the failure of getting viable seeds in crosses of the two jute species and observed normal growth of the pollen tubes in the style of the female parent in the reciprocal crosses. Their conclusion was that incompatibility was not due to the retardation of growth of pollen tubes in either case, and the shortness of style offered no advantage in overcoming inter-species incompatibility.

According to Patel and Datta (1960) in the successful hybridization of *C. olitorius* and *C. capsularis* and their reciprocal, the main barriers are firstly the effectiveness of majority of the pollen tubes to grow rapidly enough and fertilize the majority of ovules, and secondly the failure to germinate of even a few seeds obtained. A kind of imbalance may prevail either directly between endosperm and embryo or of anyone or both of them with the surrounding maternal tissue. As a result, degeneration of the fertilized ovules occurs during their varying period of growth.

Iyer, *et al.,* (1961) studied inter-species hybridization of jute. They observed normal development of embryo and endosperm up to about 10 days, but mature fruit contained only shrunken seeds, when *C. olitorius* was used as a female parent. when *C. capsularis* was used as a female parent normal fertilization occurs, but the flowers abscissed within three days. They concluded that nutritional difficulties resulting from nuclear cytoplasmic disharmony may be responsible for the failure of seed development.

In the case of cotton, Beasley (1940) found that certain inter-species hybridization failed because only a few seeds were produced in each boll, too few to prevent its abscission. To induce boll retention, he pollinated first with 6 to 12 grains of the female species. Then an excess amount of pollen of the male species was applied. The bolls adhered, and among the normal seeds were some small ones that produced hybrids.

2.3 Cross compatibility of two cultivated species at diploid and tetraploid level

Kundu *et. al.* (1950) reported that hybridization of both cultivated and wild *C. olitorius* (2n=28) with diploid *C. capsularis* gave good pods and seed setting (4n, *C. olitorius x* 4n, *C. capsularis*) but seeds did not germinate. In another report by Datta *et. al. (1960)*, at tetraploid level, got fruits and seeds in only one direction (4n, *C. olitorius x* 4n, *C. capsularis*) but seeds did not germinate. Again, Datta (1961) tried to amphidiploids between included tetraploid of the two jute species reciprocally. Fruit setting was observed but most of the pods dropped before maturity.

Hybridization was attempted by Arangeb and Khatun (1983) at BJRI between autotraploids of *C. capsularis* and *C. olitorius* to produce amphidiploids with the application of hormone (GA). *C. olitorius* was used as a pistillate parent. Only two apparently normal seeds germinated were like the female parent and F_2 did not segregate. Thus, an increase in the number of genome between two cultivated species of *Corchorus* offers no advantages to reduce the incompatibility barrier.

2.4 Cross compatibility of wild and cultivated species of *Corchorus* at diploid and tetraploid level.

Hybridization was attempted by Patel and Datta (1960) between *C. siliquosus* and *C. capsularis* without any pod setting. But according to, Chouduari and Mia (1962) successful hybrid of *C. capsularis* x *C. trilocularis* at the tetraploid level was obtained. Mughal (1967) who reported production of sterile hybrids when *C. hirtus* (2n=28) is crossed with *C. trilocularis.*

Datta and Bose (1965) attempted inter-species hybridization between different species of *Corchorus.* They concluded that some sort of genetic disharmony and imbalance prevailed in the development of pods and seeds.

Arangzeb (1994e) obtained a hybrid from *C. trilocularis*-Africa x *C. septentrionalis* at diploid level in bud pollination without the application of any growth hormone. The F_1 was intermediate in most of the characters. Meiotic irregularities were observed. The F_2 plants segregated in different phenotypes.

Arangzeb (1994f) produced a hybrid between *C. aestuans* (2n=14) x *C. trilocularis*-India (2n=14) with the application of GA (75ppm). F_1 was intermediate with variable and irregular characteristics. Flower buds did not open till 28 days and no fruit setting was observed. Meiosis was precocious and irregular.

Hossain (1965) produced a hybrid by crossing autotraploids (2n=28) of *C. capsularis* x *C. trilocularis*, which had a few viable seeds. Basak (1966) produced a hybrid of *C. olitorius* and *C. trilocularis.* He analyzed pachytone and M_1 synapsis of chromosomes in this inter-species hybrids. Pachytene analysis showed incomplete pairing. Sterility was noticed following hybridization of *C. siliquosus* and Colchicine induced tetraploid *C. olitorius* (Islam and Abbasi, 1966). There was a report on a natural hybrid of *C. olitorius* and *C. aestuans* (Isalm and Haque, 1967).

Arangzeb and Khatun (1980) reported that in spite of repeated crossing with and without the application of growth hormone (IAA and GA), it was not possible to get fertile hybrid of *C. aestusns* with wither of the two cultivated species at diploid level.

Islam and Feroza (1967) reported that they did not get any viable seeds in the fruits obtained with improved crossing techniques from the cross of *C. trilocularis* with *C. olitorius.*

Arangzeb (1994a) who reported to have obtained a hybrid plant from *C. trilocularis* x *C. capsularis* cv. D-154 at the diploid level with the application of the growth hormone GA(75ppm). Hybrid was intermediate between the parents and F_2 population segregated including the parental and hybrid types.

Arangzeb (1994b) produced a hybrid between *C. olitorius* cv. O-4(2n=14) and *C. trilocularis* India (2n=14) with the application of growth hormone GA (75 ppm). Meiosis was highly irregular. Only one fruit was obtained the fruit contained seven grayish black seed which did not germinate and after dissection these were found empty.

Arangzeb (1994c) who reported to have obtained another hybrid plant between *C. capsularis* (Atom-5) x *C. trilocularis* India at the diploid level by applying growth hormone GA (75ppm). Almost all the characters of F_1 were intermediate between the parents. Meiotic irregularities were observed. The F_2 plants segregated in different phenotypic types.

A hybrid was obtained by Arangzeb (1994d) using the cross of *C. trilocularis* Mozambique x *C. olitorius* cv. 0-4 at the diploid level in bud pollination with the application of GA. Most of the characters of F_1 were intermediate between male and female parents. Meiotic irregularities were frequently observed. The F_2 plants were segregated in different types.

Patel and Datta (1960) worked on hybridization programme for three consecutive years (1953-1955) and crossed between different cultivated and wild type of the species *Corchorus.* They observed variable percentage of pod setting in different crosses and these pods produced small quantity of seeds. Among these seeds some were normal looking, but not variable and did not germinate.

At BJRI, Arangzeb and Khatun (1980, 1983, 1986, 1988) obtained a hybrid between *C. trilocularis,* a wild species of jute and *C. capsularis* variety D-154. Two tri-caps strains (*C. trilocularis* x *C. capsularis*) are on advanced stage at the parietal level and have superiority in yield and quality. These strains were tolerant to both stem rot and leaf mosaic diseases.

Datta and Sen (1961) crossed *C. sidoides* (2n=14) with *C. siliquosus* (2n=28) but did not get any hybrid. Sanyal (1958) got full viable seeds in the reciprocal cross between *C. radiatus* x *C. cannabinus* with more setting when *C. radiatus* was used as the pistillate parent.

Menzel and Wilson (1961) produced vigorous highly fertile F_1 hybrids between *H. acetosella* and *H. radiatus* easily, showing complete chromosome pairing and giving rise to freely segregating, vigorous, fertile F_2.

2.5 Heterosis

The exploitation of hybrid vigor or heterosis is an alternate breeding method, which helps to increase the yield per unit area. Following the success of hybrid maize, the phenomenon of heterosis has been investigated in all major self and cross pollinated crops. The heterosis effect is n general more pronounced in cross pollinated than in self pollinated crops (Gallains, 1988). However, significant progress has been made in a number of self pollinated crops. Literature availability on heterosis in jute is very limited. The literatures so far available on this aspect have been reviewed in this part of the chapter.

Basak and Dana (1971) studied the nature and inheritance of plant height and base diameter in *C. olitorius* L. taking 3 crosses with 4 inbred varieties. They reported negative heterosis in all crosses for plant height. For base diameter, heterosis in one cross was negative and in other two crosses it was positive, but of negligible amount. The reduction of heterosis was due to mutual cancellation of dominance and additive x additive effects.

Paul and Eunus (1975) studied the genetic nature of plant height and fibre yield in an eight parent diallel cross of *C. olitorius* L. the degree and direction of heterosis was found to vary greatly for different characters and crosses. The average heterosis values of F_1 based on mid-parent means were significant for plant height.

Ghoshdastidar and Das (1982) from an 8 parent diallel cross in white jute reported that the degree and direction of heterosis varied greatly for different characters and crosses. They found significant positive mid parent heterosis for plant height, base diameter and fiber yield. A positive relationship was also observed between SCA effects and estimates of heterosis.

Chaudhury and Sasmal (1992) studied the heterosis in relation to GCA and SCA in a 14 x 14 diallel fashion in tossa jute (*C. olitorius* L.). Manifestation of heterosis, in general, was very low, but a definite trend was observed in relation to genetic divergence of the parents. The importance of both additive and non-additive gene effects was evident in the inheritance of characters.

2.6 Correlation coefficient

Yield, the ultimate goal for a plant breeder, is the outcome of the interaction of a number of characters inherent both in the plants and in the environment in which the plant grows. Fibre of jute (*C. capsularis* L. and *C. olitorius* L.). Kenaf (*Hibiscus cannabinus* L) and roselle (*H. sabdariffa* L.) are the product of vegetative growth of the plant. Yield of these fibers is dependent on various component characters such as plant height, base diameter, number of nodes per plant, fiber percentage, stick weight, days to flower etc. (Sanyal and Datta, 1961; Pak, 1966; Sasmal and Chakraborty, 1978; Patil and Thombre, 1980; Navale and Sonone, 1981; Sinha *et al.*, 1986 and Aruna *et al.* 1989). These yield contributing or component characters are related to fiber yield and also among themselves. The correlation studies can provide information about the relationship among these characters. The related literature on this aspect for jute and allied fibers, in general, is reviewed here.

Ghosh and Patel (1945) reported that plant height and base diameter maintained strong positive correlation with fibre yield in *C. capsularis* L. The coefficient of correlation being +0.761 for plant height and +0.914 for base diameter. These two characters were recommended as very useful criteria for primary selection.

Sanyal and Datta (1961) studied correlation of plant height, base diameter, green weight, stripped weight with fiber yield in three varieties of *Hibiscus sabdariffa* L. The total correlation co-efficient of fiber yield with plant height, base diameter, green weight and stripped weight in all the three varieties were found to be very high. They also observed that plant height, base diameter, green weight and fibre yield were highly correlated amongst themselves. Between plant height and base diameter, base diameter had, however, stronger correlation with fibre weight than plant height.

Shukla and Singh (1967) worked out phenotypic, genotypic and environmental correlation co-efficient for different quantitative characters in *C. capsularis* jute. The correlation coefficient at environmental level indicated that fibre weight was positively correlated with base diameter, stick weight, green weight and plant height, showing that vigorous plants give more fiber. For all combination of characters, genotypic correlation were reported to be slightly higher than corresponding phenotypic correlation co-efficient.

Shukla *et al.* (1967) reported that stick weight was highly correlated with fibre weight and base diameter in *C. olitorius* jute. Correlation between fibre weight and base diameter was very high, but the correlation between fiber weight and plant height was not of that magnitude, though it was highly significant. Plant height and base diameter were highly correlated with each other as well as with fibre weight. They also showed through partial correlation co-efficient that base diameter had a greater bearing on fibre weight than height. They further observed that the contribution of plant height and base diameter to fibre weight may not be the same for all varieties.

Eunus (1968) observed simple correlation co-efficient and indicated that fibre yield in jute was directly correlated with base diameter while plant height was not a dependable indicator of fiber performance.

Datta and Abbas (1969) observed in *Hibiscus cannabinus,* strong positive correlation between fibre yield and base diameter, fibre yield and plant height and between plant height and base diameter.

Singh (1970) observed in *C. olitorius* L. that correlation co-efficient at environmental level was significantly positive between fibre weights on the one hand and plant height, base diameter and stick weight on the other. The genotypic and phenotypic correlation calculated from varietal means of all the characters was positive. In all the cases genotypic correlations were slightly higher than the phenotypic correlations. Phenotypic and genotypic correlation co-efficient between the fibre yield and its different yield components e.g., plant height, base diameter and stick weight were also highly significant and positive.

Joseph (1975) studied fibre percentage, green weight, fibre weight, plant height, base diameter and node number in F2 population of intervarietal cross in *C. capsularis* jute. These characters showed significantly positive phenotypic and high genotypic correlation.

Sinhamahapatra and Rakshit (1977) observed that fibre yield was positively correlated genotypically with plant height, base diameter, middle diameter, wood diameter, node number and inter-nadal length in *C. olitorius* jute.

Maiti *et al.,* (1977) observed the genotypic correlation of fibre yield with base diameter, green weight and stick weight in sada jute (*C. capsularis* L.) was significant and considered plant as significantly correlated with fibre yield in tossa jute (*C. olitorius* L.).

Srivastava *et al.,* (1979) found in *C. capsularis* jute that correlation coefficient was non-significant and negative between yield and plant height and it was non-significant but positive between yield and node number. It was close to unity between yield and base diameter.

Mandal *et al.,* (1980) conducted correlation studies in *C. olitorius* jute and proved that fibre yield was positively correlated with plant height, base diameter and node number.

Chaudhury *et al.,* (1981) studied different characters in *C. olitorius* jute. All the characters studied as plant height, node number, base diameter, intermodal length and fibre yield were positively correlated except node number in intermodal length both at phenotypic and genotypic levels. Furthermore, genotypic correlations were higher than phenotypic correlations. Some combinations were singnificant at only genotypic levels as between base diameter and intermodal length. Other characters were significant at both genotypic and phenotypic levels. It was indicated that in spite of strong inherent association between the characters, the expression of phenotypic correlation was affected due to environment.

Ghoshdastidar and Bhaduri (1938) observed strong positive genetic association of plant height and base diameter with fibre yield, but poor correlation was observed between node number and other components in *C. capsularis* jute. While according to Ghoshdastidar and Das (1984) plant height, base diameter and node number showed significantly high positive correlation with fibre yield in *C. olitorius* jute. These three component characters were also significantly correlated with each other.

Zheng *et al.* (1985) reported in *C. capsularis* jute that plant height, thickness of stem and fresh weight were positively correlated with dry weight per plant.

Sinha *et al.* (1986) observed in *Hibiscus cannabinus* that both at the phenotypic and genotypic levels, fibre yield showed significant and positive correlations with plant height, green weight, middle diameter, base diameter and fibre strength. Significant negative associations were observed between fibre yield and stick weight, node number and intermodal length. In most of the characters, the genotypic correlations were higher than the phenotypic correlations.

Das (1987) found in *C. capsularis* and *C. olitorius* that characters like plant height, base diameter, diameter at '1' meter, leaf area and node number showed highly significant correlation coefficients with fibre yield. Petiole length was found to be significantly correlated with leaf area only.

Aruna *et al.* (1988) conducted correlation experiment in roselle (*Hibiscus sabdariffa).* Each of the character e.g. plant height, base diameter, fibre weight, fibre: wood ratio and days to 50 percent flowering had strong positive significant correlation with fibre yield. Individually the genotypic correlation was much higher in magnitude than phenotypic correlation. Indicating the influence of environment in reducing the actual inherent association between various characters.

Banarjee *et al.* (1998) selfed seeds of 20 gonotypes of *Hibiscus sabdariffa* and assessed for 10 characters related to fibre yield. Fiber yield was significantly and positively correlated with plant height, green weight, base diameter and stick weight.

Das and Rakshit (1998) analysed character association in 28 lines of *C. olitorius* jute and observed highly significant correlation of fibre yield with plant height, base diameter at '1' m, node number and leaf area but non-significant correlation with petiole length.

Chakraborty *et al.* (1998) studied growth behavior of yield attributes in *C. capsularis* jute. Correlation analysis revealed that plant height and base diameter were significantly correlated with bark weight and dry fibre weight. These traits also had positive correlation with the thickness of fibre bundles.

Sardana *et al.* (1990) who reported that plant height and base diameter had highly significant and positive correlation with dry fibre yield per plant. The association between plant height and node number was also positive and significant in the study of jute germplasm.

Manjunatha and Sheriff (1991) reported that fibre yield had significant correlation with plant height, base diameter, green weight and fibre length in *Hibiscus cannabinus.*

Thirthamallappa and Sheriff (1991) showed that fibre yield had significant correlation with plant height, base diameter, top diameter and node number in *Hibiscus sabdariffa.*

In kenaf and mesta a positive and significant correlations have been found between fibre yield and base diameter (Subramanyan *et al.*, 1995; Manjunatha and Sheriff, 1944; Devi *et al.*, 1990).

Intermodal length has positive correlation in respect to fibre yield in *C. olitorius*, as reported by Sinhamahapatra and Rakahit (1977). While in Kenaf and Mesta, Subramanyan *et al.* (1995) reported negative association between intermodal length and fibre yield.

Manjunatha and Shariff (1994) have observed positive correlation between fibre yield and green weight of plant in kenaf. In conformity with this result, Devi *et al.* (1990) in kenaf and Sinha *et al.* (1986) in mesta had also recorded the similar type of association between fibre yield and green weight of plants.

Shukla *et al.* (1967) have observed strong and positive correlation between fibre yield and dry stick weight in Kenaf. On the contrary, Roy (1965) has reported a negative association between these two characters in a set of *capsularis* genotypes.

Roy (1966) reported that a highly significant negative correlation existed between plant height and flowering time (taller the plants, earlier the flowering) and that the negative correlation is beneficial from the agronomic point of view since taller plants will not only give higher yield but also earlier harvest by virtue of their earlier flowering and maturity.

Chaudhary (1979) suggested that strains having large base diameter, longer plant height, increased fibre-wood ration followed by less number of nodes should be regarded as the potential high yielding strains.

Kar (1962) observed that *C. casularis* began to flower 110-130 days after sowing, had and optimum period of flushing and flowering for 35-75 days whereas the *C. olitorius* varieties flowered after 120-135 days for 45-75 days with no optimum period of flushing. Roy (1964) found a highly significant association between plant height and flowering time.

CHAPTER III

MATERIALS AND METHODS

This study was consisted of two experiments which were conducted during in the years of 2018 and 2019 at the Dept. of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University. The first experiment was hybridization of different varieties of *Corchorus capsularis* and *Corchorus olitorius* by applying phytohormones. The second set was experimented to determine the performance of the putative inter-specific hybrids in respect of variability, heterosis and character association. These two sets of experiment were conducted at the Rooftop Net House of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka. The first year experiment conducted during August to December, 2018 and the second year experiment conducted during jute growing season, March to November, 2019

3.1 Experiment-1

3.1.1 Effect of phytohormones on inter-specific hybridization of two cultivated species of jute

3.1.1.1 Parent materials

For the present study, the five (5) varieties of *Corchorus capsularis* and six (6) varieties of *C. olitorius* were taken as the parental materials. The varieties of the respective species are listed in Table 1..

Table 1. List of jute varieties of *Corchorus capsularis and Corchorus olitorius* used in hybridization programme

Sl. No.	***Corchorus capsularis****	**Sl. No.**	***Corchorus olitorius****
1.	BJRI-2141	1.	O-72
2.	CVE-3	2.	OM-1
3.	CVL-1	3.	O-795
4.	CC-45	4.	O-3820
5.	BJRI-2197	5.	O-9897
		6.	JRO-524

* All the *Corchorus capsularis and Corchorus olitorius* varieties were collected from BJRI (Bangladesh Jute Research Institute), Dhaka.

3.1.1.2 Synchronization of flowering through different dates of sowing

Jute exhibits short day flowering behavior with critical day lengths generally being about 12 hrs. for *C. capsularis* varieties and 12.5 hrs. for *C. olitorius.* (Johansen *et al*. 1985) In order to synchronize flower initiation in both of the species, seeds of the varieties of these two species were sown in the pots in consecutive three times at seven (7) day intervals. The 1st seeding was done on 23 August, 2018, the 2nd seeding was on 30 August 2018 and 3rd was on 6 September 2018. This was essential to help to get more flowers of similar anthesis period for higher number of hybridization between *C. capsularis* and *C. olitorius*.

3.1.1.3. Hormones used in hybridization programme

For enhancing the fertilization, phytohormones (Table 2)were applied during the hand pollination with several concentrations up to three (3) days after pollination. Suma (2004).

Table 2. The phytohormones and its concentrations used in hybridization programme

Hormone Name	Strength (mg/L)
1. Indole-3-Acetic Acid	300
2. Mixed Hormone	
➢ Gibberellic Acid (GA3)	100
➢ Napthelene Acetic Acid	40
➢ Kinetin	5

3.1.1.4. Method of Hybridization (Emasculation and Pollination) and Application of Hormones

When the varieties representing both the species *Corchorus capsularis* and *C. olitorius* started flowering, hybridization was carried out in both cross and reciprocal directions. In case of *C. capsularis* varieties were BJRI-2142, CVE-3, CVL-1, BJRI-2197 and CC-45 and in case of *C. olitorius* varieties were JRO-524, O-72, O-795, O-3820, O-9897, OM-1 (Table 1) were used.

Jute is bisexual and self-pollinating crop. At the time of emasculation, all the matured flower buds excluding those for pollination purpose were removed from the inflorescence of the maternal parents one day before the pollination date. These flower buds were emasculated in the evening and kept closed in a paper bag to prevent contamination by foreign pollen. For emasculation, undehisced anthers were removed with fine forceps in the evening before the day pollination and bagged the emasculated flower buds to protect them from unexpected pollination. Simultaneously, the inflorescences containing mature flower buds which were about to open within 12 hrs. were also bagged. These flower buds were used for pollination as male flowers. The inflorescences (both maternal and pollen donor parent) were unbaged in the next morning. Pollens from the male flowers were transferred to the exposed stigma of emasculated flowers of the maternal plant using a thin and soft painting brush in the early morning. The pollination flower buds were labeled and bagged again. The bags were finally removed 24 hrs. after pollination as the stigmas of the pistillate flowers usually do not remain receptive after 24 hrs.

In the crossing experiment, pollinated flower buds were treated with plant growth hormones (IAA and mixed hormone) separately to see the effect of these hormones in post fertilization success or failure. These hormones were prepared by dissolving those in a few drops of absolute alcohol and then adding distilled water to make to final volume to get the desired concentrations. The solution was kept at 4°C until required. Few drops (2-5) of each hormone were applied at the pedicel of each pollinated flower buds using a piece of cotton wool wrapped around the pedicel. Hormones were applied twice a day and this had continued for 3 days after the pollination. In this hybridization program among 25 crosses, eleven crosses failed to produce hybrid lines (Table 3).

Table 3. List of crosses failed to produce hybrid lines

Sl. No.	Cross combinations	Species x Species
1.	CC-45 X O-72	*C. capsularis* x *C. olitorius*
2.	O-524 X CC-45	*C. olitorius* x *C. capsularis*
3.	O-72 X CVL-1	*C. olitorius* x *C. capsularis*
4.	BJRI-2197 X O-524	*C. capsularis* x *C. olitorius*
5.	CVL-1 X O-795	*C. capsularis* x *C. olitorius*
6.	BJRI-2142 X OM-1	*C. capsularis* x *C. olitorius*
7.	BJRI-2142 X O-9897	*C. capsularis* x *C. olitorius*
8.	CVL-1 X O-72	*C. capsularis* x *C. olitorius*
9.	BJRI-2142 X O-795	*C. capsularis* x *C. olitorius*
10.	CVL-1 X O-3820	*C. capsularis* x *C. olitorius*
11.	CVL-1 X OM-1	*C. capsularis* x *C. olitorius*

Here in below shown some experimental activities of inter-specific hybridization and application of phytohormones after pollination in different varieties of two cultivated jute species conducted in 2018.

Plate 1. Research supervisor Prof. Jamilur Rahman showed the crossing procedure of inter-specific hybridization in Jute in October 2018 at rooftop garden of Dept. of Genetics and Plant Breeding, SAU.

Plate 2. Performing inter-specific hybridization and application of hormones after pollination in jute in October 2018.

3.2 Experiment-2

3.2.1 Assessment of the performance of inter-species putative hybrids

3.2.1.1 Genetic materials:

For this study, eleven (11) parental jute varieties of listed in Table 1 and their interspecific putative hybrids that were obtained from the pollination through application of hormones were used in Experiment-2. The list of fourteen (14) putative inter-specific hybrids of *C. olitorius* and *C. capsularis* used in the experiment-2 is given in below.

Table 4. List of inter-specific putative hybrid lines used

Sl. No.	Cross combinations	Species x Species
1.	JRO-524 X CVL-1	*C. olitorius* x *C. capsularis*
2.	O-795 X CVL-1	*C. olitorius* x *C. capsularis*
3.	O-72 X CVE-3	*C. olitorius* x *C. capsularis*
4.	O-72 X CC-45	*C. olitorius* x *C. capsularis*
5.	O-3820 X BJRI-2142	*C. olitorius* x *C. capsularis*
6.	CC-45 X JRO-524	*C. capsularis* x *C. olitorius*
7.	O-9897 X BJRI- 2197	*C. olitorius* x *C. capsularis*
8.	O-3820 X BJRI- 2142	*C. olitorius* x *C. capsularis*
9.	O-795 X BJRI- 2142	*C. olitorius* x *C. capsularis*
10.	O-72 X BJRI- 2197	*C. olitorius* x *C. capsularis*
11.	O-9897 X CC-45	*C. olitorius* x *C. capsularis*
12.	O-9897 X CVL-1	*C. olitorius* x *C. capsularis*
13.	O-3820 X CVE-3	*C. olitorius* x *C. capsularis*
14.	OM-1 X CC-45	*C. olitorius* x *C. capsularis*

Plate 3. Taking care and intercultural operation for raising of jute parental lines and inter-specific putative F_1 hybrid lines of jute in April 2019

Plate 4. Late seedling stage of parental lines and inter-specific putative F_1 hybrid of jute in 2019 at rooftop garden of Dept. of Genetics and Plant Breeding, SAU, Dhaka

3.2.1.2. Methods

3.2.1.2.1. Soil preparation and fertilization

The soil of the old Brahmaputra flood plain about 6.8 pH was used to fill up the experimental pots in ratio of 2:1 soil: cow dung. Fertilizers with NPK in ratio of 1:1:1 were applied at the recommended rates (https://agritech.tnau.ac.in/agriculture/agri_nutrientmgt_jute.html). Urea was applied when seedling got established in the pots, and was done for two times at one-month interval.

3.2.1.2.2. Experimental design

The experiment was laid out in a completely randomized design (CRD) with three replications. Three pots were considered as one replication.

3.2.1.2.3. Seedling and intercultural operation

Seeds of the eleven (11) parental lines (Table 1) and fourteen (14) interspecific putative hybrid lines (Table 2) materials were sown in the experimental pots on 16th March 2019. Intercultural operations such as thinning, weeding, irrigation and basal placement of fertilizers were done. The plants in the pots were kept up to maturity for collection seeds of respective lines.

3.2.1.2.4. Recording data

Data from five randomly selected plants from each replication were recorded. The following data were recorded.

i. Plant height (cm)

Randomly selected five plants from each replication and their height was recorded in centimeter (cm) by using meter tap at the time of harvesting. The height was recorded from the ground level to the tip of the plant. Finally, the average value was worked out for recording the plant height.

ii. Base diameter (cm)

Randomly selected five plants from each replication and their basal width was measured by slide calipers in cm. The average value was worked out for recording the base diameter.

iii. Petiole length (cm):

Five leaves were collected from each of the randomly selected five plants of the parents and their putative hybrids. Then petiole length of each leaf was measured. From their mean, average petiole length was determined.

iv. Root length (cm):

After measuring the total plant height, root length of each selected plant from each replication were measured through the measuring scale in cm. The average value was work out for recording the root length.

v. Root weight (g):

The root weight of five selected plants of each replication of each genotype were weighed through digital weigh machine in gram (gm) and its average was calculated.

vi. Fresh weight with leaves (g):

The whole plant weight regard as fresh weight with leaves were measured of five selected plants of each replication of each genotype by using digital weight machine in gram (gm). The average value was recorded for fresh weight with leaves in gm as per plant.

vii. Fresh weight without leaves (g):

After removing the leaves from plant another weight were measured from five selected plants of each replication of each genotype and the average value was calculated for fresh weight without leaves in gram as per plant.

viii. Dry stick weight (g):

After retting of jute in water, sticks were kept in sunlight for seven days for drying. Each selected plants of each replication were weighted by digital weight machine in gm and calculated the average dry stick weight in gram.

ix. Dry fiber weight (g):

Dry fiber weight was measured from five tagged plants of each replication of each genotype by digital weight machine in gram and the average value was calculated to measure the dry fiver weight in gm as per plant.

Plate 5. Supervisor Prof. Jamilur Rahman inspected the experiment, collected and preserved the experimental samples of inter-specific putative F_1 hybrids in liquid N_2.

Plate 6. Vegetative growth stage of parental lines and inter-specific putative F_1 hybrid of jute at rooftop garden of Dept. of Genetics and Plant Breeding, SAU, Dhaka

Plate 7. Flowering stage of parental lines and inter-specific putative F_1 hybrid of jute at rooftop garden of Dept. of Genetics and Plant Breeding, SAU, Dhaka

Plate 8. Maturity stage of parental lines and inter-specific putative F_1 hybrid lines of jute at rooftop garden of Dept. of Genetics and Plant Breeding, SAU, Dhaka

3.3. Statistical Analysis

Appropriate statistical methods were used for estimation of different parameters as per requirement of the data.

(i) Analysis of variance and DMRT

Analysis of variance (ANOVA) and Tukey HSD All-Pairwise Comparisons Test were performed following Steel and Torrie, (1960) for determining the variation among the genotypes for the characters in question. Standard error and co-efficient of variation were also calculated for each character. On the other hand, heterosis over mid parent and better parent in inter-specific putative hybrids was estimated for all the characters under study. Again correlation co-efficients were calculated for the characters.

(ii) Estimation of heterosis

The heterosis in percent was estimated by using following formula:

(a) Heterosis over better parent =F_1-BP/BP x 100

BP= Mean value of better parent

F_1 = Mean value of hybrids

(b) Heterosis over mid parent =F1-MP/MP x 100

MP= Mean value of mid parent

F_1 = Mean value of hybrids

Student's t-test

Student's t-test was employed to test the significance of heterosis. The general formula of t-test was,

t = Difference of means/Standard error of difference

t-value was calculated and then compared with the tabulated t-value at the relevant degrees of freedom (d.f.) and probability (P) level.

(iii) Correlation co-efficient

Phenotypic correlation co-efficient (r_p) among seven characters of parents and inter-species hybrids was estimated with the following formula (Miller *et al.* 1958).

$r_p = Cov_p \, x.y/\sqrt{(v_p x \times v_p y)}$

where, r_p = Phenotypic correlation co-efficient

$Cov_p \, x.y$ = Phenotypic covariance of x and y

$V_p x$ = Phenotypic variance of x

$v_p y$ = Phenotypic variance of y

CHAPTER IV

RESULT AND DISCUSSION

With a view to achieve the objectives of this study, two experiments were performed in two seasons in 2018 and 2019. In the first season, 5 varieties of *Corchorus capsularis* and 6 varieties of *C. olitorius* were used as parental lines to develop inter-species hybrids where two different hormones IAA and mixture of hormones (GA_3, NAA & Kinetin) were applied in crossing programme. In the second season, the performances of the inter-species putative hybrids were evaluated for variation, correlation and heterosis. The results of these experiment have been discussed in this chapter under two headings.

4.1 Experiment-1

4.1.1 Effect of hormones on inter-species crosses between *C. capsularis* and *C. olitorius*

The parental materials were inter-species crossed between five varieties of *C. capsularis* and six varieties of *C. olitorius* to develop F_1 hybrids. Two hormones, IAA in 300ppm and a mixture of hormones that contained GA3-100ppm, NAA-40ppm and Kinetin-5ppm were used in crossing programme. It was observed that variable number of mature seeds in the pods were developed in different cross combinations. Thus, the data related to the number of flower crossed, number of fruit set, number of mature seeds formed in different crosses including their reciprocals were collected. The data are presented in Table 3 and Table 4. Out of 30 crosses performed, the the putative F1 mature pods and seeds were obtained only from the 14 cross combinations shown in Tables, 5 and 6. Different phytohormones with different concentrations have been reported to study in cross incompatible hybridization program in jute (Frost and Bose, 1966). In the present study we used IAA (300ppm) and mixed hormones (GA3-100ppm, NAA-40ppm and Kinetin-5ppm) to study overcoming the cross incompatibly barrier between *C. capsularis* and *C. Olitorius.* The results in the present study showed that the effect of IAA was better than the mixed hormone. In the cross combination JRO-524 XCVL-1, the application of IAA treatment produced 11.11% mature seeds, where the mixed hormone produced only 2.2% mature seeds (Tables 5 and 6). The O-795 X CVL-1 cross produced all empty seeds when mixed hormone was used, but produced 19.23% mature seeds in IAA treatment (Tables 5 and 6). Again, when IAA used in O-72 X CVE-3 cross, 0% mature seeds were found and 21.95% mature seeds found in case of mixed hormone treatment.

Table 5. Effect of exogenous IAA application on production of inter-species putative F_1 hybrids of *C. capsularis* and *C. Olitorius*

Sl. No.	Cross combinations	Number of flowers pollinated	Number of fruit set (in %)	Number of fruits harvested	Total seeds harvested	Mature seeds (in %)
1.	JRO-524 XCVL-1	20	4 (20%)	4	90	10 (11.11%)
2.	O-795 X CVL-1	22	10 (45%)	6	78	15 (19.23%)
3.	O-72 X CVE-3	21	10 (47%)	9	119	0
4.	O-72 X CC-45	8	4 (50%)	2	16	7 (43.75%)
5.	O-3820 X BJRI-2142	13	6 (46%)	5	75	0
6.	CC-45 X JRO-524	21	12 (57%)	7	96	10 (10.42%)
7.	O-9897 X BJRI-2197	12	4 (33%)	2	22	9 (40.90%)
8.	O-9897 X BJRI-2142	11	5 (45%)	4	54	0
9.	O-795 X BJRI-2142	16	5 (31%)	3	69	11 (15.94%)
10.	O-72 X BJRI-2197	13	3 (23%)	3	190	31 (16.32%)
11.	O-9897 X CC-45	10	4 (40%)	2	184	28 (15.22%)
12.	O-9897 X CVL-1	8	4 (50%)	4	242	32 (13.22%)
13.	O-3820 X CVE-3	20	8 (40%)	7	595	42 (7.06%)
14.	OM-1 X CC-45	14	7 (50%)	2	97	0

Table 6. Effect of exogenous mixed hormones (GA3, NAA, Kinetin) application on production of inter-species putative F_1 hybrids of *C. capsularis* and *C. Olitorius*

Sl. No.	Cross combinations	Number of flowers pollinated	Number of fruit set (in %)	Number of fruits harvested	Total seeds	Mature seeds (in %)
1.	JRO-524 XCVL-1	12	6 (50%)	4	45	1 (2.20%)
2.	O-795 X CVL-1	17	9 (52%)	8	46	0
3.	O-72 X CVE-3	17	6 (35%)	5	41	9 (21.95%)
4.	O-72 X CC-45	12	3 (25%)	1	7	0
5.	O-3820 X BJRI-2142	14	9 (64%)	7	132	23 (17.42%)
6.	CC-45 X JRO-524	22	15 (68%)	9	81	0
7.	O-9897 X BJRI-2197	11	1 (9%)	1	8	0
8.	O-9897 X BJRI-2142	11	4 (36%)	2	33	7 (21.21%)
9.	O-795 X BJRI-2142	22	6 (27%)	6	85	9 (10.59%)
10.	O-72 X BJRI-2197	14	7 (50%)	5	294	3 (1.02%)
11.	O-9897 X CC-45	11	11 (100%)	2	64	2 (3.13%)
12.	O-9897 X CVL-1	8	2 (25%)	2	78	7 (8.97%)
13.	O-3820 X CVE-3	16	9 (56%)	7	223	3 (1.35%)
14.	OM-1 X CC-45	19	9 (47%)	4	290	3 (14.83%)

Crossing O-72 with CC-45, produced 43.75% mature seeds in IAA treatment and 0% mature seeds in mixed hormone treatment. In O-3820 X BJRI-2142 cross, IAA produced mature seeds 0% but when mixed hormone was used, it produced 17.42% mature seeds. In CC-45 X JRO-524, only 10.45% of mature seeds were produced in IAA treatment, where mixed hormone produced 0% mature seeds (Table 5 and 6).

When IAA was applied in the crosses between O-9897 and BJRI-2197, they produced all empty seeds in mixed hormone treatment. But in case of IAA treatment, it produced 40.90% of mature seeds. In O-9897 X BJRI-2142 cross, 21.21% mature seeds found in mixed hormone treatment, where 0% mature seeds found in IAA treatment.

In case of the cross O-795 X BJRI-2142, 15.94% mature seeds were obtained under IAA hormonal treatment and in mixed hormone treatment it was 10.59%. In case of O-72 X BJRI-2197, 16.32% obtained from IAA treatment. Where obtained 1.02% from mixed hormone treatment. Almost similar results were reported by Finlow in his study with jute during the years 1917, 1921 and 1923.

In O-9897 X CC-45 cross, only 15.22% of mature seeds were produced when IAA hormone was used for hormonal treatment and 3.13% of mature seeds were produced when mixed hormone was used for hormonal treatment (Table 5 and 6). In case of the cross O-9897 X CVL-1, 13.22% mature seeds were obtained from IAA hormone treatment. But only 8.97% seeds were produced when mixed hormone was used (Table 6).

When O-3820 was crossed with CVE-3, they produced 7.06% and 1.35% of mature seeds in IAA and mixed hormone treatment, respectively. But their reciprocal cross produced all empty seed in both hormonal treatments. In case of OM-1 X CC-45 cross, 14.83% mature seeds were obtained from mixed hormone treatment and no mature seeds from IAA treatments.

4.2 Experiment-2: Study of variation, correlation & heterosis in Jute

4.2.1 Variation in parental lines of *C. capsularis* and *C. olitorius*

Analysis of variance for the character's plant height, base diameter, petiole length, Root length, Root weight, Fresh weight with leaves, Fresh weight without leaves, Dry stick weight and Dry fiber weight of Parents have been presented in the Table 7. According to the data in the Table 7, it was observed that significant variation exists among the Parents for all the characters studiedexcept base diameter and dry fiber weight. The co-efficient of variation for the characters ranged from 6.20% to 16.51% (Table 8) which indicated the experimental error was minimum in the present study. The mean values of the parents for the characters studied have been shown in the Table 8.

Table 7. Analysis of variance for nine morphological traits of eleven parents of *C. capsularis* and *C. olitorius*

Sources of variation	d.f	Plant height (cm)	Base diameter (cm)	Petiole length (cm)	Root length (cm)	Root weight (g)	Fresh weight with leaves (g)	Fresh weight without leaves (g)	Dry stick weight (g)	Dry fiber weight (g)
Genotypes	10	2849.86*	0.03^{NS}	0.35**	73.34**	443.82**	10744.6**	9497.02**	42.54**	0.4^{NS}
Replications	2	35.35	0.12	0.02	50.7	15.15	68.5	0.82	4.87	0.42
Error	20	942.98	0.01	0.06	10.9	9.33	57.7	82.65	2.57	0.4

*****P>0.05, **P >0.01, NS= non-significant

Table 8. Mean performance for nine morphological traits of eleven parents of jute species (*C. capsularis* and *C. olitorius*)

Genotypes	Plant height (cm)	Base diameter (cm)	Petiole length (cm)	Root length (cm)	Root weight (g)	Fresh weight with leaves (g)	Fresh weight without leaves (g)	Dry stick weight (g)	Dry fiber weight (g)
O-72	242.67^{ab}	1.10	2.31^{a}	26.06^{ab}	6.00^{h}	73.73^{e}	59.87^{d}	6.46^{de}	4.20
O-795	215.20^{ab}	1.23	1.76^{a}	17.97^{bc}	14.00^{fgh}	64.00^{e}	48.53^{d}	7.40^{cde}	4.66
O-9897	294.87^{a}	1.22	2.08^{a}	28.40^{a}	11.67^{gh}	66.13^{e}	59.59^{d}	6.85^{de}	4.24
O-3820	229.87^{ab}	1.19	1.80^{a}	18.17^{bc}	20.64^{defg}	111.40^{d}	97.87^{c}	11.15^{bcd}	5.23
OM-1	242.27^{ab}	1.27	0.96^{b}	18.75^{abc}	49.33^{a}	173.00^{c}	157.67^{b}	8.53^{cde}	4.33
JRO-524	294.00^{a}	1.16	2.00^{a}	15.27^{c}	21.05^{def}	56.33^{e}	45.94^{d}	6.11^{e}	4.23
CVL-1	211.94^{ab}	1.12	1.93^{a}	26.88^{ab}	28.83^{bcd}	200.47^{b}	174.52^{b}	11.91^{bc}	4.36
CVE-3	198.87^{b}	1.35	1.70^{ab}	18.60^{bc}	24.46^{cde}	123.96^{d}	103.76^{c}	10.11^{a}	4.50
BJRI-2197	239.47^{ab}	1.49	1.92^{a}	22.53^{abc}	31.93^{bc}	112.00^{d}	105.48^{c}	7.66^{cde}	4.66
BJRI-2142	231.71^{ab}	1.18	1.62^{ab}	27.22^{ab}	36.40^{b}	231.27^{a}	205.00^{a}	12.23^{ab}	4.86
CC-45	222.07^{ab}	1.16	1.99^{a}	28.40^{a}	18.33^{efg}	158.60^{c}	134.80^{b}	8.60^{cde}	5.15
CV (%)	12.88	11.49	14.22	14.63	12.75	6.20	8.05	16.51	13.93
LSD (0.05)	90.54	0.415	0.76	9.73	9.00	22.39	26.80	4.73	1.88
SE(±)	25.03	0.11	0.21	2.69	2.49	6.20	7.42	1.31	0.52

4.2.2 Variation in Inter-species putative hybrids

Analysis of variance for all the character's plant height, base diameter, petiole length, Root length, Root weight, Fresh weight with leaves, Fresh weight without leaves, Dry stick weight and Dry fiber weight of inter-species putative hybrids have been presented in the Table 9. According to the data in the Table 9, it was observed that significant variation exists among the Parents for all the characters studied. The co-efficient of variation for the characters ranged from 4.02% to 17.54% (Table 10) which indicated the experimental error was minimum in the present study. The mean values of the inter-species putative hybrids for the characters studied have been shown in the Table 10.

Table 9. Analysis of variance for nine morphological traits of fourteen inter-species putative hybrids of *C. capsularis* and *C. olitorius*

Sources of variation	d.f	Plant height (cm)	Base diameter (cm)	Petiole length (cm)	Root length (cm)	Root weight (g)	Fresh weight with leaves (g)	Fresh weight without leaves (g)	Dry stick weight (g)	Dry fiber weight (g)
Genotypes	13	4268.69**	0.15*	0.19**	351.12**	3691.66**	74125.6**	103830**	47.73**	2.95*
Replications	2	915.9	0.14	0.01	8.11	15.62	77.7	41	16.7	6.31
Error	26	728.71	0.05	0.06	22.2	12.61	165.1	189	5.71	1.28

***P>0.05, **P >0.01, NS= non-significant

According to data in the table 8, plant height was highest (400.67 cm) in hybrid OM-1 X CC-45 and lowest in hybrid CC-45 X JRO-524 (267.78 cm). The base diameter was highest in hybrid O-3820 X CVE-3 (1.81 cm) and lowest in hybrid O-9897 X BJRI-2197 (1.06 cm). Petiole length was highest (2.18 cm) in hybrid OM-1 X CC-45 and lowest in O-3820 X CVE-3 (1.18cm). Root length was highest (40.05 cm) in hybrid JRO-524 XCVL-1 where the lowest was 23.33cm in hybrid O-9897 X BJRI-2197. Root weight was highest (85.21g) in hybrid O-795 X BJRI-2142 where the lowest was 14.30g in hybrid O-72 X CC-45. Fresh weight with leaves was highest (506.67g) in hybrid O-72 X BJRI-2197 where the lowest was (86.53g) in hybrid O-9897 X BJRI-2197. Fresh weight without leaves was highest (471.78g) in hybrid O-72 X BJRI-2197 where the lowest was (79.76g) in hybrid O-9897 X BJRI-2197. Dry stick weight was highest (25.69g) in hybrid O-9897 X BJRI-2142, where the lowest was (13.33g) in hybrid O-9897 X BJRI-2197. Dry fiber weight was highest (12.01g) in hybrid JRO-524 XCVL-1 where the lowest was (9.0g) in hybrid O-3820 X CVE-3

Table 10. Mean performance for nine morphological traits of fourteen inter-species putative hybrids of *C. capsularis* and *C. olitorius*

Genotypes	Plant height (cm)	Base diameter (cm)	Petiole length (cm)	Root length (cm)	Root weight (g)	Fresh weight with leaves (g)	Fresh weight without leaves (g)	Dry stick weight (g)	Dry fiber weight (g)
JRO-524 XCVL-1	324.73 ^{abcd}	1.43 ^{ab}	1.53 ^{ab}	40.05 ^{a}	22.13 ^{fgh}	230.23 ^{f}	192.30 ^{g}	23.33 ^{abc}	12.01 ^{a}
O-795 X CVL-1	292.07 ^{bcd}	1.27 ^{ab}	2.03 ^{a}	32.60 ^{ab}	26.63 ^{efg}	183.13 ^{g}	138.12 ^{h}	18.91 ^{cde}	9.34 ^{a}
O-72 X CVE-3	345.59 ^{abc}	1.33 ^{ab}	2.12 ^{a}	34.04 ^{ab}	31.88 ^{def}	281.77 ^{e}	250.76 ^{f}	15.59 ^{ef}	10.85 ^{a}
O-72 X CC-45	305.20 ^{bcd}	1.17 ^{ab}	1.96 ^{ab}	25.26 ^{b}	14.30 ^{h}	112.87 ^{h}	94.02 ^{i}	17.00 ^{def}	10.23 ^{a}
O-3820 X BJRI-2142	298.83 ^{bcd}	1.10 ^{ab}	1.85 ^{ab}	26.61 ^{ab}	50.72 ^{c}	307.00 ^{de}	286.69 ^{c}	23.33 ^{abc}	11.11 ^{a}
CC-45 X JRO-524	267.78 ^{cd}	1.47 ^{ab}	2.03 ^{a}	24.11 ^{b}	49.41 ^{c}	291.00 ^{e}	238.68 ^{f}	21.88 ^{abcd}	9.16 ^{a}
O-9897 X BJRI-2197	268.60 ^{bcd}	1.06 ^{b}	2.01 ^{a}	23.33 ^{b}	20.13 ^{gh}	86.53 ^{h}	79.76 ^{i}	13.33 ^{f}	9.40 ^{a}
O-9897 X BJRI-2142	312.56 ^{bcd}	1.66 ^{ab}	1.96 ^{ab}	24.97 ^{b}	31.98 ^{def}	268.83 ^{ef}	242.31 ^{ef}	25.69 ^{ab}	10.81 ^{a}
O-795 X BJRI-2142	336.00 ^{abc}	1.25 ^{ab}	1.83 ^{ab}	23.66 ^{b}	85.21 ^{a}	451.67 ^{b}	385.66 ^{b}	20.84 ^{abcd}	10.39 ^{a}
O-72 X BJRI-2197	350.00 ^{ab}	1.13 ^{ab}	1.60 ^{ab}	26.16 ^{ab}	61.95 ^{b}	506.67 ^{a}	471.78 ^{a}	27.80 ^{a}	10.55 ^{a}
O-9897 X CC-45	333.33 ^{abcd}	1.42 ^{ab}	1.93 ^{ab}	28.85 ^{ab}	34.60 ^{de}	306.33 ^{de}	277.77 ^{cd}	18.79 ^{cde}	11.50 ^{a}
O-9897 X CVL-1	329.50 ^{abcd}	1.40 ^{ab}	1.71 ^{ab}	27.83 ^{ab}	32.47 ^{def}	360.43 ^{c}	324.90 ^{c}	20.50 ^{bcde}	9.16 ^{a}
O-3820 X CVE-3	273.33 ^{bcd}	1.81 ^{a}	1.18 ^{b}	20.66 ^{b}	32.33 ^{def}	338.67 ^{cd}	294.33 ^{cde}	19.33 ^{cde}	9.00 ^{a}
OM-1 X CC-45	400.67 ^{a}	1.68 ^{ab}	2.18 ^{a}	27.00 ^{ab}	41.00 ^{cd}	353.40 ^{c}	272.41 ^{def}	19.92 ^{cde}	10.00 ^{a}
CV (%)	8.64	17.45	13.81	15.88	7.81	4.02	4.39	11.50	11.50
LSD (0.05)	82.10	0.73	0.78	14.33	10.80	39.08	41.78	7.27	3.44
SE(±)	22.04	0.19	0.21	3.84	2.89	10.49	11.21	1.95	0.92

JRO-524

JRO-524 x CVL-1

CVL-1

Plate 9. Plant of JRO-524 X CVL-1 along with their parents

O-795

O-795 x CVL-1

CVL-1

Plate 10. Plant of O-795X CVL-1 along with their parents

O-72

O-72 x CVE-3

CVE-3

Plate11. Plant of O-72 X CVE-3 along with their parents

O-72

O-72 X CC-45 (Red)

CC-45

Plate 12. Plant of O-72 X CC-45 along with their parents

O-3820

O-3820 X BJRI-2142

BJRI-2142

Plate 13. Plant of O-3820 X BJRI-2142 along with their parents

CC-45

CC-45 X JRO-524

JRO-524

Plate 14. Plant of CC-45 X JRO-524 along with their parents

O-9897

O-9897 X BJRI-2197

BJRI-2197

Plate 15. Plant of O-9897 X BJRI-2197 along with their parents

O-9897

O-9897 X BJRI-2142

BJRI-2142

Plate 16. Plant of O-9897 X BJRI-2142 along with their parents

O-795

O-795 x BJRI-2142

BJRI-2142

Plate 17. Plant of O-795 X BJRI-2142 along with their parents

O-72

O-72 X BJRI-2197

BJRI-2197

Plate 18. Plant of O-72X BJRI-2197 along with their parents

O-9897

O-9897 X CC-45

CC-45

Plate 19. Plant of O-9897 X CC-45 along with their parents

O-9897

O-9897 X CVL-1

CVL-1

Plate 20. Plant of O-9897 X CVL-1 along with their parents

O-3820

O-3820 X CVE-3

CVE-3

Plate 21. Plant of O-3820 X CVE-3 along with their parents

OM-1

OM-1 X CC-45

CC-45

Plate 22. Plant of OM-1 X CC-45 along with their parents

JRO-524

JRO-524 x CVL-1

CVL-1

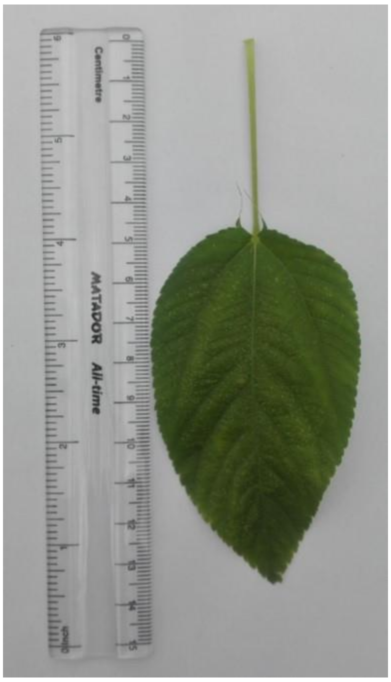
Plate 23. Leaf of JRO-524 X CVL-1 along with their parents

O-795

O-795 x CVL-1

CVL-1

Plate 24. Leaf of O-795 x CVL-1 along with their parents



O-72

O-72 x CVE-3

CVE-3

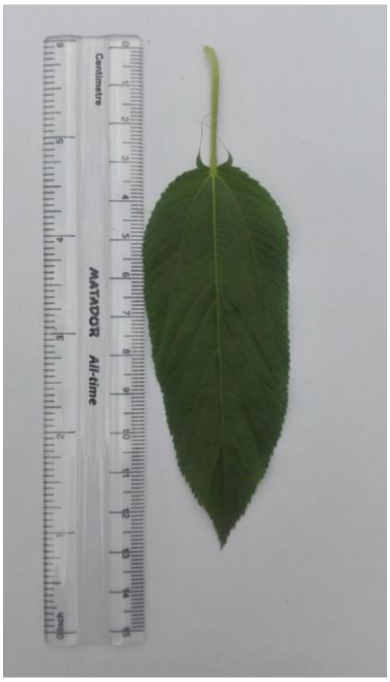
Plate 25. Leaf of O-72 X CVE-3 along with their parents

O-72

O-72 X CC-45

CC-45

Plate 26. Leaf of O-72 X CC-45 along with their parents



O-3820

O-3820 X BJRI-2142

BJRI-2142

Plate 27. Leaf of O-3820 X BJRI-2142 along with their parents

CC-45

CC-45 X JRO-524

JRO-524

Plate 28. Leaf of CC-45 X JRO-524 along with their parents

O-9897

O-9897 X BJRI-2197

BJRI-2197

Plate 29. Leaf of O-9897 X BJRI-2197 along with their parents

O-9897

O-9897 X BJRI-2142

BJRI-2142

Plate 30. Leaf of O-9897 X BJRI-2142 along with their parents

O-795

O-795 x BJRI-2142

BJRI-2142

Plate 31. Leaf of O-795 X BJRI-2142 along with their parents

O-72

O-72 X BJRI-2197

BJRI-2197

Plate 32. Leaf of O-72 X BJRI-2197 along with their parents

O-9897

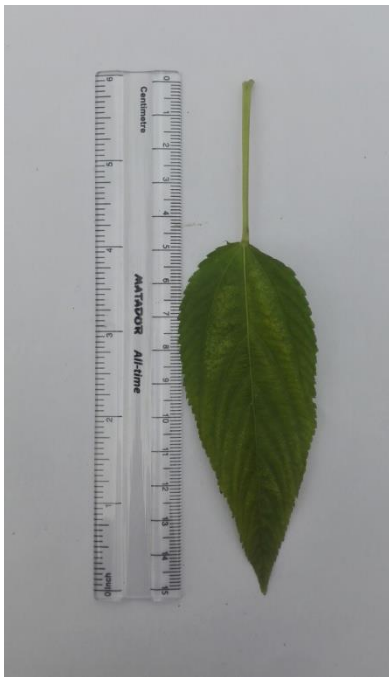
O-9897 X CC-45

CC-45

Plate 33. Leaf of O-9897 X CC-45 along with their parents

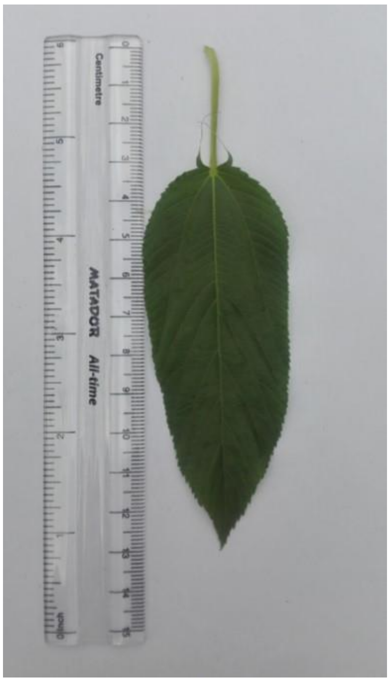
O-9897

O-9897 X CVL-1



CVL-1

Plate 34. Leaf of O-9897 X CVL-1 along with their parents



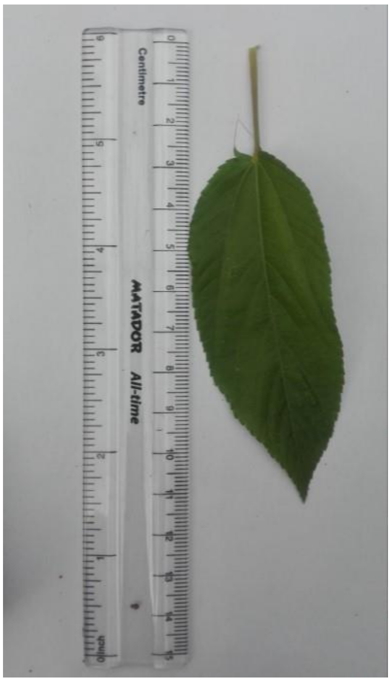
O-3820

O-3820 X CVE-3

CVE-3

Plate 35. Leaf of O-3820 X CVE-3 along with their parents

OM-1



OM-1 X CC-45

CC-45

Plate 36. Leaf of OM-1 X CC-45 along with their parents

JRO-524 JRO-524 x CVL-1 CVL-1

Plate 37. Pod of JRO-524 X CVL-1 along with their parents

O-795 O-795 x CVL-1 CVL-1

Plate 38. Pod of O-795X CVL-1 along with their parents

O-72 O-72 x CVE-3 CVE-3

Plate 39. Pod of O-72 X CVE-3 along with their parents

O-72

O-72 X CC-45

CC-45

Plate 40. Pod of O-72 X CC-45 along with their parents

O-3820

O-3820 X BJRI-2142

BJRI-2142

Plate 41. Pod of O-3820 X BJRI-2142 along with their parents

CC-45

CC-45 X JRO-524

JRO-524

Plate 42. Pod of CC-45 X JRO-524 along with their parents

O-9897

O-9897 X BJRI-2197

BJRI-2197

Plate 43. Pod of O-9897 X BJRI-2197 along with their parents

O-9897

O-9897 X BJRI-2142 (Green)

BJRI-2142

Plate 44. Pod of O-9897 X BJRI-2142 along with their parents

O-795

O-795 x BJRI-2142

BJRI-2142

Plate 45. Pod of O-795 X BJRI-2142 along with their parents

O-72

O-72 X BJRI-2197

BJRI-2197

Plate 46. Pod of O-72X BJRI-2197 along with their parents

O-9897

O-9897 X CC-45

CC-45

Plate 47. Pod of O-9897 X CC-45 along with their parents

O-9897

O-9897 X CVL-1 (Green)

CVL-1

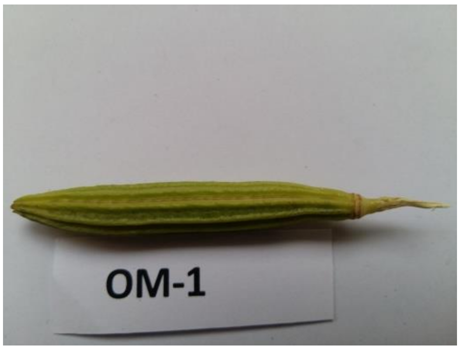
Plate 48. Pod of O-9897 X CVL-1 along with their parents

O-3820

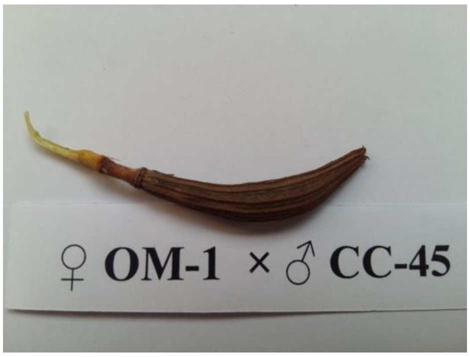
O-3820 X CVE-3

CVE-3

Plate 49. Pod of O-3820 X CVE-3 along with their parents



OM-1



OM-1 X CC-45

CC-45

Plate 50. Pod of OM-1 X CC-45 along with their parents

4.3 Heterosis:

Mean values of the parents and hybrids for the character's Plant height, Base diameter, Petiole length, Root length, Root weight, Fresh weight with leaves, Fresh weight without leaves, Dry stick weight and Dry fiber weight along with percent heterosis in F1 over mid-parent and better parent have been shown in the Table 11a and 11b.

a) **Plant height**:

Plant height is an important character related to jute fiber yield. Higher plant height produces long fibre in case of *Corchorus* species. Thus, significant positive heterosis is desirable in this character. The mean plant height along with percent heterosis in F1 hybrids have been shown in Table 11a. In plant height, 14 out of 14 hybrids showed positive heterosis over mid parents and 12 out 14 hybrids showed positive heterosis over better parents. Rest two hybrids CC-45 X JRO-524 and O-9897 X BJRI-2197 showed negative heterosis over better parents containing value -8.91 and -8.90 respectively.

b) Base diameter:

Base diameter was observed that out of fourteen inter-species hybrids, 11 showed positive heterosis over mid parent and 3 showed negative heterosis over mid parents. Where 10 showed positive heterosis over better parent and 4 showed negative heterosis over better parents (Table 11a). The range of the percent heterosis was -21.77% to 42.52% over mid parent and -28.85% to 36.06% over better parent (Table 11a).

c) **Petiole length**:

In case of petiole length out of fourteen inter-species hybrids, 8 showed positive heterosis over mid parent and 6 showed negative heterosis over mid parents. Where 5 showed positive heterosis over better parent and 9 showed negative heterosis over better parents (Table 11a). The range of the percent heterosis was -32.57% to 47.79% over mid parent and -34.44% to 9.54% over better parent (Table 11a). This indicated that almost all cases, petiole length got reduced due to inter-species cross.

d) **Root length**:

In root length, 11 hybrids out of 14 showed positive heterosis over mid parent and 6 out of 14 showed positive heterosis over better parent, 3 hybrid showed negative heterosis over mid parent as well as over better parent. Rest of them showed negative heterosis over mid parent as well as over better parent. The range of the percent heterosis was -10.21% to 90.03% over mid parent and -17.85% to 48.99% over better parent (Table 11a). This indicated that in some cases, petiole length got reduced due to inter-species cross.

e) **Root weight**:

In inter-species crosses, out of 14 hybrids 12 showed positive heterosis over mid parent and 9 showed positive heterosis over better parent. Two hybrid showed negative heterosis over mid parent and five showed negative heterosis over better parent. The range of the percent heterosis was -11.27 % to 238.13% over mid parent and -36.96% to 174.04% over better parent (Table 11a). This indicated that almost all cases, root weight got increased due to inter-species cross.

f) Fresh weight with leaves:

Out of fourteen inter-species hybrids, 12 showed positive heterosis over mid parent and 11 showed positive heterosis over better parent. The highest value exhibited by O-72 X BJRI-2197 were 445.60% over mid parent and 352.38% over better parent (Table 11b). The range of the percent heterosis was -2.85% to 445.60% over mid parent and -28.83% to 352.38% over better parent (Table 11b).

g) **Fresh weight without leaves**:

In case of fresh weight without leaves, 12 inter-species hybrids showed positive heterosis over mid parent and 11 showed positive heterosis over better parents. The range of percent heterosis was -3.36% to 470.64 over mid parent while the values were -29.84 to 347.27 for over better parent (Table 11b). Positive heterosis might have been exhibited due to the partial dominant allele (s). The highest heterosis value was exhibited by the hybrid of the cross O-72 X BJRI-2197. The range of the percent heterosis was -3.36% to 470.64% over mid parent and -29.84% to 347.27% over better parent (Table 11b).

h) **Dry stick weight**:

In case of dry stick weight, all of the inter-species hybrids showed positive heterosis over both mid and better parents. The range of percent heterosis was 81.84% to 293.77% over mid parent while the same values were 54.20% to 275.04% over better parent (Table 11b). The highest heterosis value was exhibited by the hybrid of the cross O-72 x BJRI-2197. The range of the percent heterosis was 81.84% to 293.77% over mid parent and 54.20% to 275.04% over better parent (Table 11b).

Dry fiber weight: In case of Dry fiber weight, all of the inter-species hybrids showed positive heterosis over both mid and better parents. The range of percent heterosis was 84.99% to 179.63% over mid parent while the same values were 72.08% to 175.46% over better parent (Table 11b). The highest heterosis value was exhibited by the hybrid of the cross JRO-524 X CVL-1.

Table 11a. Heterosis (%) over mid and better parents of fourteen inter-species putative hybrids of *C. capsularis* and *C. olitorius*

Cross combinations	%Heterosis									
	Plant height		Base diameter		Petiole length		Root length		Root weight	
	Over MP	Over BP	Over MP	Over BP	Over MP	Over BP	Over MP	Over BP	Over MP	Over BP
JRO-524 XCVL-1	28.36**	10.45^{NS}	25.43^{NS}	23.27^{NS}	-22.13*	-23.5*	90.03**	48.99**	-11.27^{NS}	-23.24*
O-795 X CVL-1	36.75**	35.72**	8.08^{NS}	3.25^{NS}	10.02^{NS}	5.18^{NS}	45.37*	21.27^{NS}	24.35*	-7.63^{NS}
O-72 X CVE-3	56.53**	42.41**	8.57^{NS}	-1.48^{NS}	5.73^{NS}	-8.22^{NS}	52.44**	30.62*	109.32**	30.34*
O-72 X CC-45	31.34**	25.76**	3.53^{NS}	0.86^{NS}	-8.83^{NS}	-15.15^{NS}	-7.23^{NS}	-11.05^{NS}	17.55^{NS}	-21.99^{NS}
O-3820 X BJRI-2142	29.48**	28.96**	-7.17^{NS}	-7.56^{NS}	8.18^{NS}	2.77^{NS}	17.25^{NS}	-2.24^{NS}	77.84**	145.74**
CC-45 X JRO-524	3.77^{NS}	-8.91^{NS}	26.72^{NS}	26.724^{NS}	1.75^{NS}	1.5^{NS}	10.41^{NS}	-15.10^{NS}	150.94**	169.56**
O-9897 X BJRI-2197	0.53^{NS}	-8.91^{NS}	-21.77^{NS}	-28.85*	0.5^{NS}	-3.36^{NS}	-8.38^{NS}	-17.85^{NS}	-7.66^{NS}	-36.96**
O-9897 X BJRI-2142	18.71*	5.99^{NS}	38.33*	36.06*	5.94^{NS}	-5.77^{NS}	-10.21^{NS}	-12.07^{NS}	33.06**	174.04^{NS}
O-795 X BJRI-2142	50.36**	45.00**	3.73^{NS}	1.62^{NS}	8.28^{NS}	3.97^{NS}	4.71^{NS}	-13.07^{NS}	238.13**	134.09**
O-72 X BJRI-2197	45.18**	44.22**	-12.74^{NS}	-24.16*	-24.35*	-30.73**	7.67^{NS}	0.38^{NS}	226.65**	94.02**
O-9897 X CC-45	28.96**	13.04^{NS}	19.32^{NS}	22.41^{NS}	-5.16^{NS}	-7.21^{NS}	1.58^{NS}	1.58^{NS}	130.67**	88.76**
O-9897 X CVL-1	30.03**	11.74^{NS}	19.65^{NS}	14.75^{NS}	-14.71^{NS}	-17.78^{NS}	0.68^{NS}	-2.00^{NS}	60.35**	12.63^{NS}
O-3820 X CVE-3	27.50**	18.90*	42.52**	34.07*	-32.57**	-34.44**	12.37^{NS}	11.07^{NS}	43.37**	56.64**
OM-1 X CC-45	72.57**	65.38**	38.27*	32.28*	47.79**	9.54^{NS}	14.52^{NS}	-4.92^{NS}	21.19*	-16.89**

*****P>0.05, **P >0.01 and NS = Non-significant

Table 11b. Heterosis (%) over mid and better parents of fourteen inter-species putative hybrids of *C. capsularis* and *C. olitorius*

Cross combinations	%Heterosis							
	Fresh weight with leaves		Fresh weight without leaves		Dry stick weight		Dry fiber weight	
	Over MP	Over BP	Over MP	Over BP	Over MP	Over BP	Over MP	Over BP
JRO-524 XCVL-1	79.31**	14.85**	74.45**	10.19 NS	158.93**	95.89**	179.63**	175.46**
O-795 X CVL-1	38.49**	-8.65 NS	23.85*	-20.86**	95.86**	58.77**	107.10**	114.22**
O-72 X CVE-3	185.06**	127.31**	206.50**	141.67**	88.17**	54.20**	149.43**	141.11**
O-72 X CC-45	-2.84 NS	-28.83**	-3.01 NS	-29.84**	125.76**	97.67**	118.82**	98.64**
O-3820 X BJRI-2142	79.18**	175.58**	89.32**	192.93**	99.57**	109.24**	120.22**	112.43**
CC-45 X JRO-524	170.79**	83.48**	165.29**	78.12**	197.48**	154.42**	95.31**	77.86**
O-9897 X BJRI-2197	-2.85 NS	-22.74*	-3.36 NS	-24.38*	83.74**	74.02**	111.24**	101.72**
O-9897 X BJRI-2142	80.79**	306.52**	83.16**	306.63**	169.29**	275.04**	137.58**	154.95**
O-795 X BJRI-2142	205.94**	95.30**	204.23**	88.13**	112.33**	70.40**	118.28**	113.79**
O-72 X BJRI-2197	445.60**	352.38**	470.64**	347.27**	293.77**	262.92**	138.15**	126.39**
O-9897 X CC-45	172.62**	93.15**	186.97**	107.29**	143.24**	118.49**	144.94**	123.30**
O-9897 X CVL-1	170.39**	79.79**	177.56**	86.17**	118.55**	72.12**	113.02**	110.09**
O-3820 X CVE-3	187.79**	204.01**	191.95**	200.74**	81.84**	73.36**	84.99**	72.08**
OM-1 X CC-45	113.15**	104.28**	86.79**	72.77**	132.57**	133.53**	110.97**	130.95**

*****P>0.05, **P >0.01 and NS = Non-significant

4.4 Correlation coefficient:

The estimation of phenotypic correlation coefficient was made for parents and inter-species putative hybrids between Plant height, Base diameter, Petiole length, Root length, Root weight, Fresh weight with leaves, Fresh weight without leaves, Dry stick weight and Dry fiber weight in all possible way. The value of phenotypic correlation and the characters correlated have been shown in the Table 12a and 12b.

Plant height with other characters

In parents of both the species of jute (5 varieties representing each species) plant height was phenotypically positively correlated with Base diameter (rp = 0.273), Petiole length (rp = 0.059), Root length (rp=0.432), Root weight (rp=0.396), Fresh weight with leaves (rp=0.666), Fresh weight without leaves (rp=0.645), Dry stick weight (rp=0.524), Dry fiber weight (rp=0.437).

In inter-species hybrids, plant height was phenotypically positively correlated with Base diameter (rp = 0.248), Root length (rp=0.128), Root weight (rp=0.112), Fresh weight with leaves (rp=0.274), Fresh weight without leaves (rp=0.295), Dry stick weight (rp=0.182), Dry fiber weight (rp=0.122), but negatively correlated with Petiole length (rp = -0.007).

Base diameter with other characters:

In parents of both the species of jute (5 varieties representing each species) Base diameter was phenotypically positively correlated with Root length (rp=0.019), Root weight (rp=0.173), Fresh weight with leaves (rp=0.273), Fresh weight without leaves (rp=0.212), Dry stick weight (rp=0.252), Dry fiber weight (rp=0.186). but negatively correlated with Petiole length (rp = -0.236).

In inter-species hybrids, base diameter was phenotypically positively correlated with Root length (rp=0.157), Root weight (rp=0.152), Fresh weight with leaves (rp=0.244), Fresh weight without leaves (rp=0.055), Dry stick weight (rp=0.191), Dry fiber weight (rp=0.069), but negatively correlated with Petiole length (rp = -0.128).

Petiole length with other characters

In parents, petiole length was positively correlated with Root length (rp = 0.256) and Dry fiber weight (rp = 0.003) at phenotypic levels. But petiole length was negatively correlated with

Root weight (rp=-0.285), Fresh weight with leaves (rp=-0.174), Fresh weight without leaves (rp=-0.192), Dry stick weight (rp=-0.041)

In case of the inter-species hybrids, petiole length was positively correlated with Root length (rp = 0.85) and Dry fiber weight (rp = 0.020) at phenotypic levels. But petiole length was negatively correlated with Root weight (rp=-0.006), Fresh weight with leaves (rp=-0.147), Fresh weight without leaves (rp=-0.191), Dry stick weight (rp=-0.214)

Table 12a. Phenotypic correlation coefficient in parents

Traits	Plant Height	Base Diameter	Petiole Length	Root Length	Root weight	Fresh weight with Leaves	Fresh weight without Leaves	Dry Stick Weight	Dry Fiber Weight
Plant Height		.273	.059	.432**	.396**	.666**	.645**	.524**	.437**
Base Diameter			-.236	.019	.173	.273	.212	.252	.186
Petiole Length				.256	-.285*	-.174	-.192	-.041	.003
Root Length					.589**	.638**	.524**	.614**	.228
Root weight						.841**	.809**	.779**	.435**
Fresh weight with Leaves							.943**	.846**	.524**
Fresh weight without Leaves								.780**	.584**
Dry Stick Weight									.777**

*. Correlation is significant at the 5% level, **. Correlation is significant at the 1% level

Table 12b. Phenotypic correlation coefficient in inter-species hybrids

Traits	Plant Height	Base Diameter	Petiole Length	Root Length	Root weight	Fresh weight with Leaves	Fresh weight without Leaves	Dry Stick Weight	Dry Fiber Weight
Plant Height		.248	-.007	.128	.112	.274	.295*	.182	.122
Base Diameter			-.128	.157	.152	.244	.055	.191	.069
Petiole Length				.085	-.006	-.147	-.191	-.214	.020
Root Length					.669**	.570**	.309*	.674**	.121
Root weight						.905**	.803**	.670**	.264
Fresh weight with Leaves							.891**	.660**	.255
Fresh weight without Leaves								.522**	.282
Dry Stick Weight									.493**

*. Correlation is significant at the 5% level, **. Correlation is significant at the 1% level

Root length with other characters

In parents, root length was positively correlated with Root weight (rp=0.589), Fresh weight with leaves (rp=0.638), Fresh weight without leaves (rp=0.524), Dry stick weight (rp=0.614), Dry fiber weight (rp=0.228). In case of the inter-species hybrids, root length was positively correlated with Root weight (rp=0.669), Fresh weight with leaves (rp=0.570), Fresh weight without leaves (rp=0.309), Dry stick weight (rp=0.674), Dry fiber weight (rp=0.121).

Root weight with other characters

In parents, root weight was positively correlated with Fresh weight with leaves (rp=0.841), Fresh weight without leaves (rp=0.809), Dry stick weight (rp=0.779), Dry fiber weight (rp=0.435) at phenotypic level.

In case of the inter-species hybrids, root weight was positively correlated with Fresh weight with leaves (rp=0.905), Fresh weight without leaves (rp=0.803), Dry stick weight (rp=0.670), Dry fiber weight (rp=0.264) at phenotypic level.

Fresh weight with leaves with other characters

In parents, Fresh weight with leaves was positively correlated with Fresh weight without leaves (rp=0.943), Dry stick weight (rp=0.846), Dry fiber weight (rp=0.524) at phenotypic level.

In case of the inter-species hybrids, Fresh weight with leaves was positively correlated with Fresh weight without leaves (rp=0.891), Dry stick weight (rp=0.660), Dry fiber weight (rp=0.255) at phenotypic level.

Fresh weight without leaves with other characters

In parents, Fresh weight without leaves was positively correlated with Dry stick weight (rp=0.780), Dry fiber weight (rp=0.584) at phenotypic level.

In case of the inter-species hybrids, Fresh weight without leaves was positively correlated with Dry stick weight (rp=0.522), Dry fiber weight (rp=0.282) at phenotypic level.

Dry stick weight with dry fiber weight

In parents, Dry stick weight was positively correlated with Dry fiber weight (rp=0.777) at phenotypic level.

In case of the inter-species hybrids, Dry stick weight was positively correlated with Dry fiber weight (rp=0.493) at phenotypic level.

CHAPTER V

SUMMARY AND CONCLUSION

Two independent experiments were conducted during the period of 2018-2019 in the experimental area of the Department of Genetics and Plant Breeding, SAU, Dhaka. These were conducted to find out the effects of hormones in producing inter-species hybrids between two cultivated jute species *Corchorus capsularis* and *C. olitorius* and to determine variation in parents and inter-species hybrids, percent heterosis in inter-species hybrids and correlation between traits in parent's hybrids.

5.1 Experiment -1

5.1.1 Effects of hormone treatments on the performance of inter-species crosses

When IAA was used, variable number of fruit setting was obtained from 14 crosses as well as small number of mature seeds was obtained from 10 crosses, out of the 25 crosses. The highest number of fruit setting was found CC-45 X JRO-524 (12) and the highest number of mature seeds was found in O-3820 X CVE-3 (42). When treated with mixture of hormones, variable number of fruit settings was also observed in a14 crosses. But out of all crosses,11 produced small number of mature seeds. The highest number of fruit setting was obtained in CC-45 X JRO-524 (15) and the highest number of mature seeds was found in O-3820 X BJRI-2142 (23)

5.2 Experiment -2

5.2.1 Parental variation in morphological traits

All the parents showed highly significant variation for all the characters. The highest value for plant height was observed in O-9897 (294.87cm) but base diameter was highest in BJRI-2197 (1.49cm). The highest value for petiole length was found in O-72 (2.31cm).

O-9897 and CC-45 showed the highest value for root length (28.40cm). In case of root weight, OM-1 showed the highest value (49.33g) and for fresh weight with leaves BJRI-2142 showed highest value (231.27g). The highest value for fresh weight without leaves also obtained from BJRI-2142 (205.00g). Dry stick weight was highest in BJRI-2142 (12.33g) where dry fiber weight was highest in CC-45(5.15)

5.2.2 Variation in inter-species hybrids

Analysis of variance for all the characters showed the presence of significant variation among the hybrids. On the basis of mean values, the highest value for plant height was observed in OM-1 X CC-45 (400.67cm) but base diameter was highest in O-3820 X CVE-3 (1.81cm). The highest value for petiole length was found in OM-1 X CC-45 (2.18cm). JRO-524 XCVL-1 showed the highest value for root length (40.05cm). In case of root weight, O-795 X BJRI-2142 showed the highest value (85.21g) and for fresh weight with leaves O-72 X BJRI-2197 hybrid showed highest value (506.67g). The highest value for fresh weight without leaves also obtained from O-72 X BJRI-2197 (471.78g). Dry stick weight was also highest in O-72 X BJRI-2197 (27.80g) where dry fiber weight was highest in JRO-524 X CVL-1 (12.01g)

5.2.3 Heterosis in inter-species hybrids

In case of plant height, 14 out of 14 hybrids showed positive heterosis over mid parents and 12 out 14 hybrids showed positive heterosis over better parents. Base diameter was observed that out of fourteen inter-species hybrids, 11 showed positive heterosis over mid parent and 3 showed negative heterosis over mid parents. Where 10 showed positive heterosis over better parent and 4 showed negative heterosis over better parents. In case of petiole length out of fourteen inter-species hybrids, 8 showed positive heterosis over mid parent and 6 showed negative heterosis over mid parents. Where 5 showed positive heterosis over better parent and 9 showed negative heterosis over better parents. In root length, 11 hybrids out of 14 showed positive heterosis over mid parent and 6 out of 14 showed positive heterosis over better parent, 3 hybrid showed negative heterosis over mid parent and 8 showed negative heterosis over better parent. In root weight, out of 14 hybrids 12 showed positive heterosis over mid parent and 9 showed positive heterosis over better parent. Two hybrid showed negative heterosis over mid parent and 5 hybrid showed negative heterosis over better parent. In case of fresh weight with leaves out of fourteen inter-species hybrids, 12 showed positive heterosis over mid parent and 11 showed positive heterosis over better parent. In case of fresh weight without leaves, 12 inter-species hybrids showed positive heterosis over mid parent and 11 showed positive heterosis over better parents. In case of dry stick weight, all of the inter-species hybrids showed positive heterosis over both mid and better parents. In case of dry fiber weight, all of the inter-species hybrids showed positive heterosis over both mid and better parents.

5.2.4 Correlation co-efficient

In parents plant height was phenotypically positively correlated with base diameter, petiole length, root length, root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight, dry fiber weight. base diameter was phenotypically positively correlated with root length, root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight, dry fiber weight. But negatively correlated with petiole length. Petiole length was positively correlated with root length and dry fiber weight at phenotypic levels. But petiole length was negatively correlated with oot weight, fresh weight with leaves, fresh weight without leaves, dry stick weight. Root length was positively correlated with root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight, dry fiber weight. Root weight was positively correlated with fresh weight with leaves, fresh weight without leaves, dry stick weight, dry fiber weight at phenotypic level. Fresh weight with leaves was positively correlated with fresh weight without leaves, dry stick weight, dry fiber weight at phenotypic level. Fresh weight without leaves was positively correlated with dry stick weight, dry fiber weight at phenotypic level. Dry stick weight was positively correlated with dry fiber weight at phenotypic level.

In inter-species hybrids, plant height was phenotypically positively correlated with base diameter, root length, root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight, dry fiber weight, but negatively correlated with petiole length. base diameter was phenotypically positively correlated with root length, root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight, dry fiber weight, but negatively correlated with petiole length. Petiole length was positively correlated with root length, and dry fiber weight at phenotypic levels. But petiole length was negatively correlated with root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight. Root length was positively correlated with root weight, fresh weight with leaves, fresh weight without leaves, dry stick weight, dry fiber weight. Root weight was positively correlated with fresh weight with leaves, fresh weight without leaves, dry stick weight, dry fiber weight at phenotypic level. Fresh weight with leaves was positively correlated with fresh weight without leaves, dry stick weight, dry fiber weight at phenotypic level. Fresh weight without leaves was positively correlated with dry stick weight, dry fiber weight at phenotypic level. Dry stick weight was positively correlated with dry fiber weight at phenotypic level.

5.2.5 Future directions

1. In the present research fourteen putative hybrids of two cross-incompatible jute species were found. The hybridity should be confirmed further by PCR molecular analysis.
2. The seeds pf fourteen types F_2 populations were harvested in the present research, these F_2 populations should be a potential source to develop stable/superior lines in future.
3. The highest fiber weight was 12.01g, 11.50g and 11.11g were found in JRO-524 XCVL-1, O-9897 X CC-45 and O-3820 X BJRI-2142 cross combinations, respectively. So the cross combinations might be used in future for high yielding jute variety development.

CHAPTER VI

REFERENCES

Alam, M. J. (2009). *Genetic Divergence, Variability, Correlation And Path Analysis In White Jute (Core/Torus Capsularis L)* (Doctoral Dissertation, Department Of Genetics and Plant Breeding, Sher-E-Bangla Agricultural University, Dhaka, Bangladesh).

Bangladesh Bureau of Statistics. (2017). The Year Book of Agricultural Statistics of Bangladesh. Statistics Division Ministry of Planning. Government Peoples Republic of Bangladesh, Dhaka.

Begum, H., Khalequzzaman, M., Akter, A., Ali, M. P., & Motalib, M. A. (2009). Influence of Different Concentration Of Vitamins On Plant Regeneration From Two Cultivated Species Of Jute. *A Participatory Approach To Improve The Economic Condition Of Resource Poor Farmers In Semi-Arid Regions Of Rajasthan, India*, 73.

Brar, P. S. (1986). Wide hybridization and chromozome manipulation in cereals. *Handbook of plant cell culture*. *4*:221-256.

Das, A. K., Sahu, R., Dua, T. K., Bag, S., Gangopadhyay, M., Sinha, M. K., & Dewanjee, S. (2010). Arsenic-induced myocardial injury: protective role of *Corchorus olitorius* leaves. *Food and chemical toxicology*. *48*(5): 1210-1217.

Das, A., & Kumar, D. (2016). Genetic divergence and character association for yield and quality attributing characters in tossa jute (*Corchorus olitorius* L.). *Electronic Journal of Plant Breeding*. *7*(3): 529-537.

Das, M., Banerjee, S., Topdar, N., Kundu, A., Mir, R. R., Sarkar, D., ... & Gupta, P. K. (2012). QTL identification for molecular breeding of fibre yield and fibre quality traits in jute. *Euphytica*, *187*(2): 175-189.

Dempsey, J. M. (1975). *Fiber crops*. Univ. Presses of Florida.

Export Promotion Bureau. (2016). Bangladesh Export Dictionary, Bangladesh Ministry of Commerce, Jute and Jute Goods. Government Peoples Republic of Bangladesh, Dhaka

FAO. STATISTICS; (2014) for Jute, Kenaf, Sisal, Abaca, Coir and Allied Fibers. Rome: Food and Agriculture Organization (FAO)

Finlow, R. S. (1917). Historical notes on experiments with jute in Bengal. *Agric J India*, *12*: 3-29.

Finlow, R. S. (1921). Historical notes on experiments with jute in Bengal. *Agric J India*, *16:* 265-279.

Finlow, R. S. (1923). Note on the work on fiber selection in Bengal. *Agric J India*, *3: 138*

Furumoto, T., Wang, R., Okazaki, K., Hasan, A., Ali, M. I., Kondo, A., & Fukui, H. (2002). Standard Tables of Food Composition in Japan Standard Tables of Food Composition in Japan, 2000. *Food science and technology research*. *8*(3): 239-243.

Ghosh, A., Biswas, B. K., & Arifuzzaman, M. (2020). Variability and Character Association Study in Morphological Traits of Tossa Jute (*Corchorus olitorius* L.). *The Agriculturists*. *18*(1):116-128.

Ghosh, B. K., & Jethi, A. (2013). Growth and instability in world jute production: a disaggregated analysis. *Int J Electron Commun Technol*. *4*: 191-195.

Ghosh, R. L. M., & Patel, J. S. (1945). Jute breeding experimental technique. Selection and handling of breeding materials. *Agr. Res. Bull., Indian Central Jute Comm*.

Howard, A. (1924). *Crop-production in India*. Oxford University; London..

https://agritech.tnau.ac.in/agriculture/agri_nutrientmgt_jute.html

http:// www.jutecomm.gov.in

Ilhan, S., Savaroglu, F., & Çolak, F. (2007). Antibacterial and Antifungal Activity of Corchorus olitorius L.(Molokhia) Extracts. *International Journal of Natural & Engineering Sciences*, *1*(3).

Islam, M. M. (2010). Technological advances in off-season jute seed production. *J. Expt. Biosci*, *1*(1): 75-82.

Islam, M. M. (2019). Varietal advances of jute, kenaf and mesta crops in Bangladesh: A review. *Int J Bioorganic Chem*, *4*(1):24-41.

Islam, M. S., Nasreen, A. L. E. Y. A., Begum, S. E. L. I. N. A., & Haque, S. A. M. I. U. L. (2004). Correlated response and path analysis in tossa jute (*Corchorus olitorius* L.). *Bangladesh J. Bot*. *33*(2): 99-102.

Johansen, C., Waseque, M., Ahmed, M. M., & Begum, S. (1985). Plant growth curves and fibre quality changes of jute (*Corchorus* spp.) grown in Bangladesh. *Field Crops Research*. *12*: 387-395.

Joseph, J. (1975). Genetic Parameters in a Segregating Population of *Corchorus Capsularis* L. *Indian Journal of Genetics and Plant Breeding*. *35*(1): 57-60.

Kar, C. S., Kundu, A., Sarkar, D., Sinha, M. K., & Mahapatra, B. S. (2009). Genetic diversity in jute (*Corchorus* spp) and its utilization: a review. *Indian Journal of Agricultural Sciences*, *79*(8): 575.

Khatun, R., Sarker, R. H., & Sobhan, M. A. (2010). Combining ability for yield and yield contributing characters of white jute (*Corchorus capsularis* L.). *Bangladesh Journal of Botany*, *39*(1): 79-85.

Kumar, D., Das, A., & Shil, S. (2011). Breeding for combining yield and fibre quality in white jute (*Corchorus capsularis* L.) accessions. *Journal of Tropical Agriculture*, *49*:72-77.

Kumar, V., Singh, P. K., Dudhane, A. S., De, D. K., & Satya, P. (2014). Anatomical and morphological characteristics of nine jute genotypes. *Journal of Crop and Weed*, *10*(2): 334-339.

Kundu, A., Sarkar, D., Mandal, N. A., Sinha, M. K., & Mahapatra, B. S. (2012). A secondary phloic (bast) fibre-shy (bfs) mutant of dark jute (*Corchorus olitorius* L.) develops lignified fibre cells but is defective in cambial activity. *Plant Growth Regulation*. *67*(1): 45-55.

Maiti, S. N., Biswas, S. R., & Sen, S. (1977). A comparative study of selection indices in Jute (*Corchorus* sp.)[India]. *Mysore Journal of Agricultural Sciences*.

Mandal, B.D.; Chandra, N. Majumdar, M.K. and banerjee, S.P. (1980). pathway fiber yield in jute (*Corchorus olitorius*). Genetic polonica 21(4): 455-460.

Menzel, M. Y., & Wilson, F. D. (1961). Chromosomes and crossing behavior of *Hibiscus cannabinus*, H. acetosella, and H. radiatus. *American Journal of Botany*, *48*(8): 651-657.

Mia, M. M., & Shaikh, A. Q. (1967). Gamma radiation and interspecific hybridization in jute (*Corchorus capsularis* L. and *C. olitorius* L.). *Euphytica*, *16*(1): 61-68.

Miah, A., Saha, N. R., Rafiq, M. Z. A., Ali, M. Y., & Hasanuzzaman, M. (2020). Performance study on yield and yield attributes of seven white jute breeding lines at different regions of Bangladesh. *Progressive Agriculture*, *31*(1): 19-25.

Mir, R. R., Banerjee, S., Das, M., Gupta, V., Tyagi, A. K., Sinha, M. K., ... & Gupta, P. K. (2009). Development and characterization of large-scale simple sequence repeats in jute. *Crop science*, *49*(5): 1687-1694.

Mughal, R. (1967). Sterile hybrids between the two allopatric species, *Corchorus trilocu-cularis* Local x *C. hirtus* ex-Argentina. *Sind University Research Journal*, *2*(2): 215-219.

Mukul, M. (2020). Elucidation of Genotypic Variability, Character Association, and Genetic Diversity for Stem Anatomy of Twelve Tossa Jute (*Corchorus olitorius* L.) Genotypes. *BioMed Research International*, *2020*.

Patel, G. I., & Datta, R. M. (1960). Interspecific hybridization between Corchorus olitorius Linn. and *C. capsularis* Linn. and the cytogenetical basis of incompatibility between them. *Euphytica*. *9*(1): 89-110.

Paul, N. K., & Eunus, A. M. (1975). Heterosis and combining ability in jute (*Corchorus olitirius* 1.). *Bangladesh Journal of Scientific and Industrial Research*.

Raut, R. N., & Naik, G. (1983). Interspecific hybridization in cultivated jute. *Proc. FAO expert consultation on jute and kenaf improvement. Calcutta, India*.

Roy, B. (1965). Studies on correlation and means of yield components in relation to jute breeding. *Indian agric*, *9*: 107-111.

Roy, B. (1966). Correlation between plant height and flowering time in jute (*Corchorus olitorius* L.). *Indian Agrilst*, *10*: 59-63.

Saha, D., Rana, R. S., Chakraborty, S., Datta, S., Kumar, A. A., Chakraborty, A. K., & Karmakar, P. G. (2017). Development of a set of SSR markers for genetic polymorphism detection and interspecific hybrid jute breeding. *The Crop Journal*, *5*(5): 416-429.

Samanta, P., Sadhukhan, S., Das, S., Joshi, A., Sen, S. K., & Basu, A. (2011). Isolation of RNA from field-grown jute (*Corchorus capsularis*) plant in different developmental stages for effective downstream molecular analysis. *Molecular biotechnology*, *49*(2): 109-115.

Sanyal, P. (1958). Studies on the pollen tube growth in six species of Hibiscus and their crosses in vivo. *Cytologia*, *23*(4): 460-467.

Sanyal, P., & Dutta, A. N. (1961). Correlation study of growth components in roselle (*H. sabdariffa* L.). *Indian Agric*, *5*(1): 40-47.

Sarkar, D., Satya, P., Mandal, N. A., Das, D., Karmakar, P. G., & Singh, N. K. (2016). Jute genomics: emerging resources and tools for molecular breeding. In *Fiber Plants* (pp. 155-200). Springer, Cham.

Sarker, R. H., Al-Amin, G. M., & Hoque, M. I. (2007). In vitro regeneration in three varieties of white jute (*Corchorus capsularis* L.). *Plant tissue culture and biotechnology*, *17*(1): 11-18.

Sawarkar, A. S. H. U. T. O. S. H., Yumnam, S. O. N. I. K. A., Patil, S. G., & Mukherjee, S. (2014). Correlation and path coefficient analysis of yield and its attributing traits in tossa jute (*Corchorus olitorius* L.). *The Bioscan*, *9*(2): 883-87.

Sezgin, H., & Berkalp, O. B. (2017). The effect of hybridization on significant characteristics of jute/glass and jute/carbon-reinforced composites. *Journal of Industrial Textiles*, *47*(3): 283-296.

Shukla, G. K., & Singh, D. P. (1967). Studies on heritability correlation and discriminant function selection in jute. *Indian Journal of Genetics and Plant Breeding*, *27*(2): 220.

Shukla, G. K., Das, D., & Vattacharya, K. (1967). Correlation and regression studies on jute. *Jute Bull*, *30*(7): 229-32.

Singh, D. P. (1970). Estimates of correlation, heritability and discriminant function in jute (*Corchorus olitorius*, L.). *Indian Journal of Heredity*, *2*(1): 65-68.

Sinha, M. K., GUHA ROY, M. K., & Chaudhury, S. K. (1986). Correlation and path-coefficient analysis in mesta. *Indian Journal of Agricultural Science*, *56*(2): 83-85.

Sinha, M. K., Kar, C. S., Ramasubramanian, T., Kundu, A., & Mahapatra, B. S. (2011). Corchorus. In *Wild Crop Relatives: Genomic and Breeding Resources* (pp. 29-61). Springer, Berlin, Heidelberg.

Sinhamahapatra, S. P., & Rakshit, S. C. (1977). Association of plant characters with fibre yield in olitorius jute. *J. Soc. Expet. Agric*, *2*(1): 9-12.

Srivastava, S. K., Pandey, B. P., & Lal, R. S. (1979). Diallel analysis of characters governing fibre yield in white jute [India]. *Indian Journal of Agricultural Sciences (India)*.

Steel, R. G. D., & Torrie, J. H. (1990). Principles and Procedures of Statistics: With Special References to Biological. *Sciences. McGraw-Hill, New York, New York. 481pp*.

Subramanyan, D., Kumar, P. V. R., Krishnamurthy, B., & Islam, S. (1995). Heritability and correlation studies in Kenaf (*Hibiscus cannabinus* L.). *Indian J. Genet. Plant Breed*. *55*:279-282.

Suma, U. D. (2004). Production of Interspecies Hybrids Between Two Cultivated Jute Species Through Application of Hormone and Estimation of Heterosis in F1

Swaminathan, M. S., & Iyer, R. D. (1961). Skewed recombination in a rare interspecific jute hybrid. *Nature*. *192*(4805): 893-894.

Swaminathan, M. S., Iyer, R. D., & Sulbha, K. (1961). Morphology, cytology and breeding behaviour of hybrids between *Corchorus olitorius* and *C. capsularis*. *Current Science*. *30*(2):67-68.

Tanmoy, A. M., Alum, M. A., Islam, M. S., Farzana, T., & Khan, H. (2014). Jute (*Corchorus olitorius* var. O-72) stem lignin: variation in content with age. *Bangladesh Journal of Botany*, *43*(3): 309-314.

Thirthamallappa, G., & Sherif, R. A. (1991). Genetic variability studies in roselle. *Current research, University Agricultural Science, Bangalore*. *20*: 257-258.

Topdar, N., Kundu, A., Sinha, M. K., Sarkar, D., Das, M., Banerjee, S., ... & Gupta, P. K. (2013). A complete genetic linkage map and QTL analyses for bast fibre quality traits, yield and yield components in jute (*Corchorus olitorius* L.). *Cytology and Genetics*. *47*(3): 129-137.

Willis, J. C. (1966). A dictionary of the flowering plants and ferns. *A dictionary of the flowering plants and ferns.*, (7).

Wilson, F. D., & Adamson, W. C. (1970). Reaction to the cotton root-knot nematodes and the pollen and seed fertility of kenaf-roselle (*Hibiscus cannabinus* × *H. sabdariffa*) allohexaploids. *Euphytica*. *19*(3): 349-355.

Wilson, F. D., & Menzel, M. Y. (1967). Interspecific hybrids between kenaf (*Hibiscus cannabinus*) and roselle (*H. sabdariffa*). *Euphytica*, *16*(1): 33-44.

Zhang, L., Cai, R., Yuan, M., Tao, A., Xu, J., Lin, L., ... & Qi, J. (2015). Genetic diversity and DNA fingerprinting in jute (*Corchorus* spp.) based on SSR markers. *The Crop Journal*, *3*(5):416-422.

Zhang, L., Ibrahim, A. K., Niyitanga, S., Zhang, L., & Qi, J. (2019). Jute (*Corchorus* spp.) breeding. In *Advances in Plant Breeding Strategies: Industrial and Food Crops* (pp. 85-113). Springer, Cham.

CHAPTER VII

APPENDIX

Monthly average temperature, average relative humidity and total rainfall and average sunshine of the experimental site during the period from: for first year from August to December, 2018 and the second year from March to November, 2019

Months	Average temperature (ºc)		Average RH (%)	Rainfall (mm) (total)	Average sunshine (hr)
	Minimum	Maximum			
August, 2018	25.3	31.9	82	187.6	11.9
September, 2018	24.7	31.6	81	174.3	11.7
October, 2018	23.8	31.6	77	172.3	11.6
November, 2018	19.2	29.6	64	34.4	8
December, 2018	14.1	26.4	73	12.8	9
March, 2019	20.4	32.5	56	65.8	7
April, 2019	21.7	28.4	66	12.94	9
May, 2019	21.8	29.9	62	28.9	9.7
June, 2019	16	30.1	76	188.9	9.9
July, 2019	16	30.7	64	218.9	9.7
August, 2019	16	31.5	69	128.9	8.1
September, 2019	24.8	31.7	79	173.3	11.7
October, 2019	24.6	30.9	78	162.3	11.6
November, 2019	18.2	29.7	67	35.4	8.7

Source: Bangladesh Meteorological department (Climate & Weather Division), Agargoan,