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Research Article

Assessment of Reproductive Biology and Crossing between Adapted and Non –Adapted Clones of *Populus deltoides* Bartr.

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Abstract

Study on reproductive biology was conducted in selected male and female clones of *Populus deltoides*. Flower is dioecious and dichogamous in nature. Both male and female clones bear pendulous catkins with the male catkins are long reddish- purple and the female catkins are green in colour. Flowering occur once in year, during late February to April, 1 to 2 weeks before leaf initiation, strong anemophilous adaptations such as very high pollen output and light weighing winged seeds. *Populus deltoides* produces first seed at approximately 10 years of age. The capsule and seed set percentage is very high, if there is no seed set in bagged inflorescence indicating cross pollinating nature. But in cross pollination resulted in lower seed set than observed in open pollination. Pollen germination rates were affected by sucrose concentrations and the solution containing 2% and 15% sucrose concentration had the highest germination rates than 1%, 5% and 10% sucrose concentration. The significant differences for crossability parameters viz., successful crosses (%), germination (%) and survival (%) among the clones of *Populus deltoides*. The overall performance of G-48 X S7C1 and Kranthi X 25-N hybrids were found outstanding for most of morphological traits.

Keywords: Flowering; Dioecious; Pollen; Capsule; Sucrose; Hybrids

Introduction

Populus deltoides commonly known as poplar or eastern cottonwood belongs to the family Salicaceae, is a multipurpose tree species and one of the most common tree in agroforestry systems FAO [1]. It consist of more than thirty species occurs throughout the forests of temperate and cold regions of northern hemisphere. It is a native to North America and attains 40 meters height and almost 2 meters diameter Silberhorn [2]. *Populus deltoides* based agroforestry system is one of the viable alternate land use systems to prevent degradation, obtain biological production on sustainable basis and ameliorate the environment Chauhan., *et al* [3]. Its wood is in demand for plywood, pulp and paper, matchwood, packing cases and light constructional timber all over the world Rizvi., *et al* [4].

In recent times, *Populus* growers have started looking for improved planting material to obtain high yield in short duration Slavov and Zhelev [5]. So its new clones were introduced in India to meet demand of wood in plywood industries but less attention has been paid to its reproductive biology and breeding system Stettler., *et al* [6]. Combining superior selections obtained from the any programs either by orchards or through control pollination programs depend on the knowledge how reproduction is governed in the species Nagarajan., *et al* [7].

Reproduction is the only life processes which ensure the perpetuation of life. The study of reproductive biology and breeding system is essential for tree improvement programme to develop a suitable clones/variety that eventually brings about economic returns

and related benefits to growers Luna and Singh [8]. For successful cultivation and conservation of plants a detailed study of their reproductive biology is required Mozaand Bhatnagar [9]. Information on reproductive biology is useful for understanding genetic and taxonomic relationships between species and as such data are prerequisite for initiating a meaningful breeding programme Kearns and Inouye [10]. To develop superior poplar cultivars for several different end uses, study on reproductive biology is particularly important in these cases.

Tree breeders have always favoured poplars in their programmes for various reasons namely high vigour of most of the poplar species, short generation, dioecious nature of plant, natural ability for inter-specific hybridization and great potential for vegetative propagation Schriener [11]. The success of a programme of improvement of poplars depends upon this basic material (clone) available and on the variation in character that exists between the different species or within the particular species selected and vegetatively multiplied as clonal material Comtois., *et al* [12]. Intraspecific and interspecific breeding of poplars can easily provide a broad genetic base for the establishment of gene pools and for the selection of ortets for clonal tests and continued breeding programme Schriener (1970). Selecting superior poplar genotypes (clones) and their mass multiplication can increase its productivity El-Lakany and Yuness [13]. The genetic similarity for genetic make-up was estimated by means of foliar, morphological characters like leaf size, shape, as well as the length of petiole. Keeping these facts in view, a detailed study of the reproductive biology and also breeding system in *Populus deltoides* tree has been made.

Materials and Methods

Study Area

The study was conducted at germplasm block of Naganji nursery, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Himachal Pradesh, located at an elevation of 1200 m above mean sea level and lies between 30˚ 51' N latitude and 76˚11' E longitude. The experimental area is hilly, marked with elevations, depressions and has a gentle slope towards the south-eastern aspect. The area experiences a wide range of temperature with a minimum of 2^0C in winters to a maximum of 32.6^0C in the summers. The soil is well drained and sandy-loam type with pH of 7.2.

Study Material

The study on reproductive biology and control pollination in flowering branches of eleven males (82-42-5, UD-88, L- 124/86, 39-N, S7C11, 25-N, 26-N, S7C1, S7C4, L-17/92 and G-3) and thirteen females (G-48, S7C8, S7C15, L-62/84, L-34/82, 82- 33-3, D-121, Kranthi, L-39, RD-01, S1, S2 and 63-N) clones of *Populus deltoides* was conducted during 2013 for one flowering season. The flowering branches of parents were collected from approximately fifteen years old trees of *Populus deltiodes*.

The flowering branches of 18 to 25 cm length and 1to 2.5 cm thick having at least four buds from females and males trees were obtained from State Forest Department, Haldwani and Shyampur, Haridwar Forest Division in month of January 2013 and February 2013, respectively. Flowering branches of male clones are kept in the water buckets to get abundant pollen for hybridization work. Flowering branches of female clones were grafted separately on root stock of *Populus deltoides*. The grafted plants were kept moist by intermittent irrigation/watering.

Reproductive Study

The weekly observations on flowering branches were recorded for each male and female clones. Each shoot was tagged with metallic tag and data recorded on the following characters. The size and colour of both males and females bud were measured using digital vernier calliper and royal horticultural society (RHS) colour chart, respectively. The period of male flowering was observed visually. The flower (catkin) colour was recorded with the help of RHS colour chart.

Pollen Studies

Male catkins of *Populus deltoides* ready for pollen dehiscence were enclosed in butter paper bags which was allowed to dehisce at room temperature (22–24°C) and freshly released pollen were collected, to study the pollen viability and morphology. All the pollen samples were collected in isolation to prevent contamination from any other source. Using a clean dry muslin cloth, pollen spread on glass plates was scooped and transferred in oven dried glass vials and left in a glass desiccation chamber impregnated with silica and stored in a refrigerator at 4°C.

Pollen viability was tested periodically according to standard microscopy sampling procedure using an acetocarmine dye Stanley and Linksens [14]. The pollen sizes were recorded using ocular micrometer under light microscope. The pollen germination tests were conducted with 1%, 2%, 5%, 10% and 15% sucrose concentration. Each concentration contained 10 ml distilled water and small amount of pollen grains. All these concentrations was kept at room temperature for one day and in next day, 100 µl solution from each concentration were kept on the cavity slide and pollen tube germination were observed under light microscope Koncalova and Jicinske [15].

Controlled Pollination

Maximum anthesis and anther dehiscence was observed between 7.00 am to 8.00 pm and 7.30 am to 8.30 pm, respectively, while the maximum stigma receptivity was observed after 8 hours of anthesis. Stored pollens (4°C) after reaching ambient temperature (20–22°C) were dusted on female catkin during still mornings (7.30–8.00 hrs.) to avoid strong wind movement. Pollen was applied on the stigma from emergent stage (Day 1) through peak receptivity (Days 3–4). Pollen was dusted until the gloss was completely reduced in the treated flowers and was bagged.

Pollen penetration is noticed in poplar flowers after three days of pollination. Even at this stage despite heavy loading of pollen, only a few germinated on the stigma surface and of which only a very few penetrated and gained entry into ovule. Pollen penetration patterns were similar in control cross and self-pollinated pistils, they traverse stigma intra-cellular and branching of pollen tube was quite common. After confirmation of drying and withering of stigma the inflorescences were debagged. The immature developing capsules were tagged and observed during the following days until harvest. After recording seed set in individual capsules and germination trials were conducted. The inflorescences of the female clones were selected for breeding system experiments and assessment of fruit set. The period of cross pollination and maturation of capsules maturation were also recorded. Each capsule/cross was harvested to quantify size and number of seeds produced.

Observations Recorded

Observations were recorded on per cent successful crosses (SC%) as suggested by Jan and Pfeffer Jan and Pfeffer [16] using following formulae.

$$SC\ (\%) = \frac{SC}{TC} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, SC is the number of successful crosses and TC is the total number of crosses. Germination count was made within 10 days after sowing. The germination per cent (GP%) was calculated as the number of seeds that germinated out of number of seeds using following formulae Kumar., *et al* [17].

$$GP = \frac{n}{N} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, n is the number of germinated seeds and N is the total number of seeds. The survival percent (SP%) was calculated as the number of seedlings that survived after it reached 4 leaves stage (SS) out of number of germinated seedlings (GS) using following formulae.

$$SP = \frac{SS}{GS} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Nursery Studies

The seedlings were raised in the glass house in the month of May, 2013 and were shifted to nursery in March, 2014. The F_1 population of the successful crosses was grown in the nursery under uniform environmental conditions. The five plants of each cross were taken randomly for recording for observations on morphological characters in October to December, 2014.

Figure 1: Intraspecific hybrids development in Populus deltoides.

Results and Discussion

Variation in parents bud sizes and its colour

The Greyed Green 189 (Group A) colour in buds was observed in maximum number of male clones (Table 1). The bud length was ranged from 1.96 cm - 3.80 cm among the male clones and it was recorded higher and lower in UD-88 and S_7C_4 clone, respectively. Similarly, bud breadth was ranged from 6.40cm- 10.52 cm and it was recorded higher and lower in L-17/92 and 82-42-5 male clone, respectively.

Sr. No.	Male Clones	Bud Colour	Bud Length (cm)	Bud Breadth (cm)
1	82-42-5	Greyed Orange 173 (Group A)	2.62 ± 0.05	6.40 ± 0.19
2	UD-88	Greyed Green 189 (Group A)	3.80 ± 0.20	9.93 ± 0.44
3	L-124/86	Greyed Green 189 (Group A)	3.24 ± 0.11	9.65 ± 0.26
4	39-N	Greyed Green 191 (Group A)	3.36 ± 0.06	10.30 ± 0.35
5	S_7C_{11}	Greyed Orange 174 (Group A)	3.24 ± 0.15	9.21 ± 0.28
6	25-N	Greyed Green 189 (Group A)	2.14 ± 0.16	7.38 ± 0.73
7	26-N	Greyed Yellow 160 (Group A)	3.32 ± 0.09	8.90 ± 0.30
8	S_7C_1	Greyed Green 189 (Group A)	3.26 ± 0.11	9.46 ± 0.54
9	S_7C_4	Greyed Red 189 (Group A)	1.96 ± 0.12	6.56 ± 0.45
10	L-17/92	Greyed Yellow 160 (Group A)	3.50 ± 0.07	10.52 ± 1.02
11	G-3	Greyed Green 189 (Group A)	3.74 ± 0.26	7.46 ± 0.33

Table 1: The variation in bud size and its colour among different male clones.

The Greyed Yellow 160 (Group A) colour was observed in maximum number of female clones (Table 2). The bud breadth was ranged from 1.36 cm- 2.20 cm, in which higher and lower bud breadth was recorded in L-62/84 and S1female clone, respectively. Likewise, bud breadth was ranged from 2.58cm- 4.59cm, which was higher and lower in L-34/84 and 82-33-3 female clone, respectively.

Sr. No.	Female Clones	Bud Colour	Bud Length (cm)	Bud Breadth (cm)
1	G-48	Greyed Red 180 (Group A)	1.62 ± 0.03	3.93 ± 0.28
2	S_7C_8	Greyed Orange 167 (Group A)	2.12 ± 0.07	3.87 ± 0.25
3	S_7C_{15}	Greyed Orange 170 (Group A)	2.12 ± 0.07	3.87 ± 0.25
4	L-62/84	Greyed Orange 167 (Group A)	2.20 ± 0.12	3.78 ± 0.23
5	L-34/84	Greyed Orange 171 (Group A)	2.18 ± 0.08	4.59 ± 0.16
6	82-33-3	Greyed Yellow 160 (Group A)	2.12 ± 0.05	2.58 ± 0.56
7	D-121	Greyed Orange 164 (Group A)	1.82 ± 0.08	3.71 ± 0.50
8	Kranthi	Greyed Orange 173 (Group A)	1.58 ± 0.07	4.31± 0.17
9	L-39	Greyed Yellow 162 (Group A)	1.76 ± 0.06	3.49 ± 0.27
10	RD-01	Greyed Yellow 160 (Group A)	1.90 ± 0.18	3.06 ± 0.46
11	S_1	Greyed Yellow 160 (Group A)	1.36 ± 0.13	2.85 ± 0.37
12	S_2	Greyed Yellow 160 (Group A)	1.62 ± 0.10	2.98 ± 0.64
13	63-N	Greyed Yellow 162 (Group A)	1.50 ± 0.08	3.58 ± 0.54

Table 2: The variation in bud size and its colour among different female clones.

Floral and pollen biology

A male catkin develops and matures within 2 weeks of early March. Male flower lasted for 2-3 days for pollen harvest after this it become dry and dead. Each male clones producing yellowish, powdery smooth exine pollen in varying range of sizes. With increasing day temperature (22– 32°C) as the air gets lighter pollen are wind borne. The earliest flowering and pollen collection were observed in 82-42-5 clone on date 27/02/2013 and (02/03/2013), respectively. The latest flowering was observed on 06/03/2013 G-3 in male clone. The Greyed Green 193 (Group A) catkin colour was found only in L-17/92 clone. The maximum length (41.89µ) and breadth (40.18µ) of pollen was found in G-3 male clone, while minimum length (32.34µ) and breadth (31.90µ) of pollen was found in S7C4 clone. The period between initiation and flowering is correlated with growth habit of the tree, which is in turn governed

by climatic range of species Sedgley and Griffin [18]. Knowledge of the development of flower buds is essential in achieving successful breeding programme.

Sr. No.	Male clones	Floral bud burst (collection of bud cuttings: 21/02/2013)	Floral (catkin) colour	Pollen collection	Pollen length (µ)	Pollen breadth (µ)
1	82-42-5	27/02/2013	Greyed Yellow 160 (Group A)	02/03/2013	33.34 ± 2.09	32.49 ± 2.13
2	UD-88	04/03/2013	Greyed Green 194 (Group A)	08/03/2014	35.05 ± 1.39	32.49 ± 1.14
3	L-124/86	04/03/2013	Greyed Purple 185 (Group A)	07/03/2013	33.77 ± 2.42	32.06 ± 2.48
4	39-N	03/03/2013	Greyed Green 194 (Group A)	08/03/2013	36.76 ± 1.71	33.34 ± 1.89
5	S_7C_{11}	04/03/2013	Greyed Purple 185 (Group A)	08/03/2013	33.22 ± 0.89	32.56 ± 0.78
6	25-N	05/03/2013	Greyed Yellow 162 (Group A)	11/03/2013	35.48 ± 2.21	33.77 ± 2.33
7	26-N	02/03/2013	Greyed Green 194 (Group A)	07/03/2013	36.33 ± 1.46	32.91 ± 1.43
8	S_7C_1	04/03/2013	Greyed Yellow 160 (Group A)	08/03/2013	36.76 ± 2.22	37.62 ± 1.89
9	S_7C_4	03/03/2013	Greyed Yellow 160 (Group A)	07/03/2013	32.34 ± 0.66	31.90 ± 0.49
10	L-17/92	04/03/2013	Greyed Green 193 (Group A)	08/03/2013	34.62 ± 1.48	33.77± 0.99
11	G-3	06/03/2013	Greyed Yellow 162 (Group A)	10/03/2013	41.89 ± 1.99	40.18 ± 1.82

Table 3: The variation in first and last date of male flowering, pollen collection, catkin colour and pollen size among different male clones

In vitro pollen germination test

The 2% and 15% sucrose concentration resulted in higher pollen germination rate, while 1%, 5% and 10% sucrose concentration resulted in lower pollen germination rate (Figure 2). Similarly, in walnut, pollen viability test of freshly collected showed that the pollen remains viable when stored pollens at 4^0C Radicati [19]. In *Moringa oelifera*, in-vitro pollen germination was recorded maximum on medium containing 10% sucrose supplemented with 200µg/ml boric acid Bhattacharya and Mandal [20].

Sr. No.	Crosses	Date of cross pollination	No. of days involved in capsule (fruit) maturation	Capsule length (mm)	Capsule breadth (mm)	Number of seeds/capsule
1	G-48 X S_7C_{11}	30/03/2013	38 days (08/05/2013)	10.74 ± 0.33	7.66 ± 0.32	31.4 ± 7.80
2	G-48 X L-124/86	09/04/2013	36 days (16/05/2013)	6.66 ± 0.29	4.42 ± 0.37	0.4 ± 0.24
3	G-48 X L-17/92	04/04/2013	30 days (05/05/2013)	10.25 ± 0.42	5.87 ± 0.09	28.0 ± 1.92
4	G-48 X S_7C_1	23/03/2013	45 days (08/05/2013)	4.48 ± 0.32	4.83 ± 0.62	25.4 ± 2.15
5	G-48 X 26-N	28/03/2013	35 days (03/05/2013)	11.49 ± 0.40	7.20 ± 0.24	14.8 ± 2.95
6	G-48 X UD-88	30/03/2013	38 days (08/05/2013)	9.82 ± 0.13	6.20 ± 0.17	32.8 ± 2.74
7	S_1 X S_7C_{11}	28/03/2013	41 days (09/05/2013)	8.57 ± 0.29	5.44 ± 0.31	51.2 ± 1.35
8	S_1 X L-124/86	09/04/2013	23 days (03/05/2013)	9.78 ± 0.72	6.84 ± 0.73	31.8 ± 3.77
9	S_1 X L-17/92	28/03/2013	42 days (10/05/2013)	12.37 ± 0.85	6.98 ± 0.14	49.2 ± 2.55
10	S_1 X S_7C_4	28/03/2013	35 days (03/05/2013)	14.46 ± 0.43	8.36 ± 0.15	38.2 ± 3.52
11	S_7C_8 X S_7C_{11}	01/04/2013	31 days (03/05/2013)	16.76 ± 2.86	5.79 ± 0.27	26.8 ± 2.55
12	S_7C_8 X L-17/92	28/03/2013	42 days (10/05/2013)	13.36 ± 0.66	8.13 ± 0.28	26.8 ± 4.36
13	L-62/84 X L-124/86	04/04/2013	30 days (05/05/2013)	12.32 ± 0.14	5.93 ± 0.52	11.4± 2.78
14	L-62/84 X L-17/92	01/04/2013	38 days (10/05/2013)	14.17 ± 0.69	6.82 ± 0.21	45.4 ± 3.69
15	L-62/84 X S_7C_1	22/03/2013	44 days (06/05/2013)	10.05 ± 0.57	5.46 ± 0.21	18.6 ± 5.51
16	Kranthi X 39-N	30/03/2013	38 days (08/05/2013)	11.60 ± 0.16	7.25 ± 0.19	43.2 ± 0.94
17	Kranthi X 25-N	30/03/2013	38 days (08/05/2013)	11.76 ± 0.31	6.55 ± 0.15	20.4 ± 2.56

Table 4: The variation in first and last date of cross pollination, number of days involved in capsule maturation, capsule size and number of seeds/capsule among the crosses.

Seed Production

Hand-pollination experiments were performed on all the selected female clones. The capsules were elliptical in shape (egg/capsule shaped) which later on releases cottony seeds. The capsules formation starts in April, it ripe and falls till the May and the number of seed varies among the clones. The colour of capsules was observed greenish whose capsules formation varies among the clones. The maximum (16.76 mm) capsule length was recorded in S_7C_8 x S_7C_{11}, and minimum of 4.48 mm was however, recorded in G-48 X S_7C_1. The maximum (8.36 mm) breadth of capsule was obtained in S_1 X S_7C_4, while minimum (4.42mm) capsule breadth was recorded in G-48 X L-124/86 hybrid.

It is seen from data that maximum (51.2) number of seed/capsule was recorded in S_1 X S_7C_{11} hybrid, while the minimum number (0.4) of number of seed/ capsule was observed in G-48 X L-124/86 hybrid of *Populus deltoides*. Similarly, *Populus cilliata* also reported that the fruits ripen in May-June with catkins elongating up to 20-30 cm in size Khuranaand Narkhede [21]. Studies on fruit set in Jack fruit (*Artocarpus heterophyllus* L.) was reported that percentage fruit set in open pollinated flowers was 80 per cent whereas, in hand pollination it was 100 per cent Thimmaraju and Shivananda [22].

Crossability Parameters

The range of successful crosses varied between 13.35 (S_7C_8 X S_7C_{11}) to 66.64 (S_1 X L-17/92) per cent. The range of germination per cent varied between 14.71 (G-48 X L-124/86) to 96.00 (Kranthi X 39-N) per cent. The range for survival per cent was between 5.44 (S_7C_8 X L-17/92) to 90.44 (G-48 X S_7C_{11}) per cent among the crosses. Our results find support in clones of *Populus nigra* which produced twenty one full sib families Pichot and Teissier [23]. The results are in conformity with the findings the crossability relationships among poplars Dhiman and Gandhi [24].

Sr. No.	Crosses	Successful Crosses (%)	Germination (%)	Survival (%)
1	G-48 X S_7C_{11}	14.41 (22.83)	52.33 (46.33)	90.44 (71.99)
2	G-48 X L-124/86	22.22 (28.77)	14.71 (6.67)	76.67 (66.14)
3	G-48 X L-17/92	27.22 (31.62)	93.33 (75.28)	5.56 (1.43)
4	G-48 X S_7C_1	40.00 (39.23)	18.16 (9.78)	60.85 (51.60)
5	G-48 X 26-N	20.00 (26.57)	32.89 (34.98)	18.66 (25.33)
6	G-48 X UD-88	16.13 (24.53)	72.89 (58.63)	14.74 (6.66)
7	S_1 X S_7C_{11}	25.00 (27.21)	88.24 (70.31)	15.12 (6.99)
8	S_1 X L-124/86	41.65 (44.61)	85.99 (68.46)	49.17 (39.36)
9	S_1 X L-17/92	66.64 (61.62)	60.98 (52.02)	18.54 (25.39)
10	S_1 X S_7C_4	50.00 (45.00)	84.89 (68.74)	17.34 (9.07)
11	S_7C_8 X S_7C_{11}	13.35 (21.73)	59.56 (50.66)	18.47 (25.44)
12	S_7C_8 X L-17/92	16.66 (25.03)	44.67 (41.88)	5.44 (1.35)
13	L-62/84 X L-124/86	27.31 (31.72)	73.33 (59.61)	14.55 (21.18)
14	L-62/84 X L-17/92	33.39 (36.26)	65.79 (55.60)	23.49 (27.74)
15	L-62/84 X S_7C_1	33.00 (36.21)	80.65 (64.77)	46.42 (42.72)
16	Kranthi X 39-N	27.37 (31.72)	96.00 (78.57)	27.65 (31.23)
17	Kranthi X 25-N	22.18 (28.69)	68.00 (56.03)	7.06 (2.26)
CD (0.05)		7.87	13.44	15.67

Table 5: The variation in different crossability parameters of various intra-specific hybrids of *Populus deltoides.*

*Values in parenthesis are arcsine values

S r. No.	Crosses	Plant height (cm)	Collar diam-eter (mm)	Inter-nodal length (cm)	No. of leaves/ plant	Leaf area (cm^2)	Apex angle (^{0})	Length of lamina (cm)	Maxi-mum width of leaf (cm)	Ratio of length of lamina/ maximum width of leaf	Petiole length (cm)	Angle be-tween the midrib and 2nd lower lateral mid rib (^{0})	No. of branch-es/ plant	Branch angle (^{0})	Branch length (cm)
1	G-48 X S_7C_{11}	340	21.59	8.36	44.8	270.52	43.3	15.85	17.41	0.91	8.76	51.6	5.0	55.0	15.40
2	G-48 X L-124/86	296	18.56	4.84	63.6	203.92	44.1	14.77	15.92	0.92	9.52	53.2	2.4	54.8	16.12
3	G-48 X L-17/92	314	23.99	4.34	56.0	180.44	44.0	15.16	15.75	0.99	8.35	55.0	2.0	45.0	12.50
4	G-48 X S_7C_1	408	25.27	4.46	118.0	182.98	45.0	15.47	15.60	0.98	9.19	48.4	6.3	49.0	38.00
5	G-48 X 26-N	382	23.57	3.88	95.0	244.86	43.2	15.52	17.14	0.89	9.84	41.6	6.4	37.0	25.08
6	G-48 X UD-88	385	22.43	4.70	66.8	222.76	42.5	16.66	16.65	0.95	8.10	48.0	1.0	30.0	35.80
7	S_1 X S_7C_{11}	400	22.82	4.66	102.6	231.78	43.8	16.31	17.97	0.90	11.75	56.0	8.4	55.0	21.50
8	S_1X L-124/86	372	26.10	4.74	47.6	253.25	41.5	17.48	19.29	0.90	10.75	53.6	6.2	51.6	21.22
9	S_1X L-17/92	310	19.32	4.78	72.6	244.15	41.5	16.41	16.07	1.02	9.51	56.8	4.8	53.0	15.22
10	S_1X S_7C_4	308	19.49	4.38	58.6	263.80	42.4	15.48	16.58	0.93	10.76	52.4	7.2	66.75	19.77
11	S_7C_8 X S_7C_{11}	378	22.29	5.22	76.8	216.65	44.2	15.58	17.69	0.87	10.77	54.4	7.0	45.0	26.42
12	S_7C_8 X L-17/92	338	19.71	5.08	88.0	203.26	42.3	14.62	16.38	0.88	9.64	49.6	4.0	60.0	25.00
13	L-62/84X L-124/86	191	12.45	4.02	37.8	161.75	38.2	13.38	13.41	0.98	6.97	51.2	2.5	55.0	47.05
14	L-62/84X L-17/92	310	19.40	5.98	50.0	217.92	43.6	16.90	16.76	1.00	9.14	60.0	6.0	50.0	14.90
15	L-62/84 X S_7C_1	362	20.57	6.20	63.2	234.61	41.9	17.18	17.22	0.99	10.38	54.4	2.0	40.0	40.85
16	Kranthi X 39-N	354	22.28	4.74	69.8	214.33	43.5	14.28	16.82	0.84	10.74	57.2	5.6	60.0	16.90
17	Kranthi X 25-N	235	17.82	4.80	54.0	149.78	42.5	20.88	22.56	0.90	13.15	50.0	2.0	70.0	6.70
	SE	13.99	0.78	0.25	5.28	8.32	0.37	0.40	0.45	0.01	0.35	1.04	0.54	2.47	2.68
	CV	17.26	15.37	20.88	31.76	15.79	3.62	10.34	11.09	5.65	14.82	8.20	48.73	19.78	47.25

Table 6. The variation in different morphological characters among seventeen hybrids of *Populus deltoides.*

Morphological Characters

After crossing parents, five seedlings in each cross were evaluated for morphological characters in nursery conditions. The greatest plant height among hybrids was observed in G-48 x S_7C_1 (408 cm) whereas, minimum value was observed in L-62/84 x L-124/86 (191 cm). The maximum collar diameter was observed in S_1 X L-124/86 (26.10 mm), whereas, minimum value for this trait was recorded in L-62/84 X L-124/86 (12.45 mm) hybrid. For internodal length, maximum value was depicted by G-48 X S_7C_{11} (8.36 cm), whereas minimum value by G-48 X 26-N (3.88 cm) hybrid. The maximum average number of leaves per plant was observed in G-48 X S_7C_1 (118.0) and minimum value was recorded in L-62/84 X L-124/86 (37.8) hybrid.

For leaf area, maximum value was depicted by G-48 X S_7C_{11} (270.52 cm^2), whereas minimum value recorded in Kranthi X 25-N (149.78 cm^2) hybrid. The maximum average apex angle among hybrids was observed in G-48 X S_7C_1 (450) and minimum value was recorded in L-62/84 X L-124/86 (38.20) hybrid. For length of lamina, maximum value was depicted by Kranthi X 25-N (20.88cm), whereas minimum value by L-62/84 X L-124/86 (13.38 cm) hybrid.

The maximum width of leaf maximum among hybrids was observed in Kranthi X 25-N (22.56cm) and minimum value was recorded in L-62/84 X L-124/86 (13.41 cm) hybrid. For ratio of length of lamina/ maximum width of leaf maximum value was depicted by S_1 X L-17/92 (1.02), whereas minimum value by Kranthi X 39-N (0.84) hybrid. The mean performance for petiole length was recorded maximum in Kranthi X 25-N (13.15 cm) hybrid. However, the minimum value was observed in L-62/84 X L-124/86 (6.97 cm) hybrid.

For angle between the midrib and 2nd lower lateral mid rib, maximum value was depicted by L-62/84X L-17/92 (600), whereas minimum value by G-48 X 26-N (41.60) hybrid. The maximum number of branches/plant was recorded in S_1 X S_7C_{11} (8.4) and minimum value for the trait was observed in G-48 X UD-88 (1.0) hybrid. For branch angle, maximum value was depicted by Kranthi X 25-N (700), whereas minimum value by G-48 X UD-88 (300). The data clearly indicated that maximum branch length was recorded in L-62/84 X L-124/86 (47.05 cm) and minimum value for the trait was observed in Kranthi X 25-N (6.70 cm) hybrid.

The superiority of F1 over their parents for height and diameter growth, leaf phenology, leaf number and number of branches in a cross between *Populus deltoides* X P. *trichocarpa* Ceulemans, Scarascia., *et al* [25]. Also reported significant characteristics variation between the families except leaf width and leaf area hybrids of *Populus* species Singh., *et al* [26]. The significant differences between populations of eastern cottonwood developed by crossing two sources for plant height, stem diameter, number of internodes and petiole length Dhir. and Mohn [27]. Similar findings on *P. tremula* reported and they observed that significant height and mean number of leaves was obtained in families by controlled crossing between four male and three female trees at two different soil types Vaario., *et al* [28].

Conclusion

Male buds are significantly longer in size than observed in the female buds. The male clones flowered one week earlier than females clone. Flowering and pollen intensity varied considerably among clones. Pollen of *Populus deltoides* is moderately allergenic, highly viable up to 99% and can be stored (in 4°C). Number of seeds produced/ capsule varies significantly in crosses when observed in the month of May. The survival (%) is one of the important factors in successful establishment of a species and is the best indicator of species with respect to adaptation and growth. The overall performance of G-48 X S_7C_1 and Kranthi X 25-N hybrids were found outstanding for most of morphological traits.

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Volume 3 Issue 4 April 2019