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Developing climate resilient *Salix* clones through control breeding

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Abstract

Over the years, two hundred clones/strains/species of *Salix* were introduced from different countries and raised in the germplasm bank. The best clones after nursery and field screening were selected for control crossing using Line × Tester design with 8 parents to develop superior hybrids. The F_1 populations of the successful crosses were raised in the nursery in uniform environment to study the extent and pattern of variation in growth and morphometric characters. In case of overall performance PN-227 × NZ-1140, J-799 × *S. tetrasperma*, PN-227 × J-795 and J-799 × Austree hybrid progenies were found outstanding for most of the growth and morphometric traits. High heritability and genetic gain were recorded for plant height followed by number of leaves and branches. The superior hybrids after further field evaluation and parental verification will be commercially released covering wider climatic range from tropical to temperate regions of the country.

Key words: Salix, hybrid, control breeding, climate resiliance

Introduction

Increasing concerns over global climate change have led to heightened emphasis in exploiting plants as renewable source of energy. Willows, grown as short rotation coppice, are among the most advanced biomass crops in temperate and sub tropical regions because of their potential for high yields in short cultivation cycles, ease of vegetative propagation and ability to resprout after multiple harvests. Short rotation *Salix* plantations can accelerate the shift of wood supply from natural forests to plantations. Willows belong to the genus *Salix* and family Salicaceae; are rich in species diversity. There are about 330-500 species in the world, mainly distributed in North-temperate zone [1]. In India about 33 species of *Salix* are reported from temperate regions, except *S. tetrasperma* and *S. acmophylla* which are found in tropical and sub-tropical riparian areas of the entire country [2]. Majority of these species are not suitable for industrial uses or has high bio-mass except *Salix tetrasperma*, which meets only certain requirements. Characteristics of good clear bole and low wood density as required by industrial entrepreneurs are also lacking in these species [3].

Salix is a multipurpose agroforestry tree species which serves not only purpose of producing fodder, fuel and timber but also as a phytoremediation measure [4]**.** It is the lifeline in Lahaul and Spiti dry temperate region of Himachal Pradesh. Willows wood is used for sport goods, furniture, reconstituted wood products, veneer plywood, paper and pulp, as a substrate for shitake mushroom *etc*. The essential purpose of tree improvement is to develop a suitable clones/variety that eventually brings about economic returns and related benefits to growers [5]. Examples of important achievements were reported by Ragonese and Alberti [6] from Argentina, Krstinic [7] from Yugoslavia and May [8] from Italy. However well planned genetic and breeding studies were undertaken recently and encouraging results were reported earlier [9-11]. In *Salix*, programmes in genetics and breeding of tree form willows were started first in India at Dr. Y.S. Parmar University of Horticulture and Forestry and crossability pattern was studied [12]. Wide range of collection, evaluation and multiplication of superior willow clones and production of interspecific hybrids are necessary for increasing biomass production [13]. Keeping this in view, newly developed hybrid progenies were evaluated out of which best performing progenies has been selected for further field evaluation, improvement and advance breeding programs.

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Materials and methods

Over the year's two hundred clones/strains/species were procured from twenty different countries covering five continents namely Europe, North America, South America, Asia and Africa and raised in the germplasm block of Naganji nursery of Department of Tree Improvement and Genetic Resources, which is located at an altitude of 1200 m above mean sea level in the north-west of Himalayas and lies between 30°51'N latitude and 76°11'E longitude. These clones were repeatedly screened in the nursery followed by field testing. The selected superior clones were planted at many locations to test Gene×Environment interactions. On the basis of their stability performance control crossing of the selected clones (Table 1) was carried out in 2013-2014 using Line × Tester (4 × 4 factorial) with 8 parents in 2013. The seedlings were raised in the glass house and were shifted to nursery in March 2014 in Randomized Block Design. The F_1 populations of the successful crosses were grown in the nursery under uniform environment and were evaluated for growth and morphometric characters in October-November 2014.

Observations were recorded on plant height (cm), collar diameter (mm), number of branches, number of leaves, internodal length (cm), petiole length (cm) and leaf area (cm^2). The statistical analysis for each parameter was carried out on mean values. Variability for growth and morphometric characters was estimated in terms of mean, range, genotypic and phenotypic coefficient of variation. Genetic parameters were also worked out with regards to estimates of heritability (broad sense), genetic advance and genetic gain as per cent of mean [14-17].

Results and discussion

In the present study hybrids (seedlings) obtained by crossing superior parents were evaluated. Analysis of variance revealed significant differences among different progenies for growth and morphometric characters except leaf area, thereby indicating existence of variability amongst the different hybrids.

Further, Tables 2 and 3 show the overall performance of progenies derived from PN 227 × NZ 1140 (Plant height 215.83 cm, number of branches 23.67 and number of leaves 302.37), J 799 × *S. tetrasperma* (Plant height 209.75 cm, number of branches 26.60 and number of leaves 293.57), PN 227 × J 795 (Plant height 208.87 cm, number of branches 27.98 and number of leaves 311.75) and J 799 × Austree (Plant height 201.50 cm, number of branches 20.80 and number of leaves 255.38) were found outstanding for most of the growth and morphometric traits which may be ascribed to genotypic superiority of the parents. However, in case of collar diameter J 799 × NZ 1140 (13.14 mm) was found to be promising at par with J 799 × J 795 (12.48 mm), *S. tetrasperma* × *S. tetrasperma* (12.44 mm), *S. tetrasperma* × J 795 (12.02 mm), *S. tetrasperma* × Austree (12.01 mm) and PN 227 × NZ-1140 (11.41 mm).

On the basis of mean values of progenies (Tables 2 and 3) overall contribution of females J-799 and PN-227 were found to be better for most of the growth and morphometric characters. However the contribution of male parents was found to be at par with respect to each other. In consonance with the present study on growth and morphometric traits, Luna and Singh [5] on the basis of their study on *Eucalyptus* hybrids suggested that growth characters are governed by the genetic makeup of the trait and attribute significantly to the phenotypic performance at early stage giving ample opportunity for selection of the outstanding genotypes. Among all the characters (Table 4), number of leaves showed widest range of values (42.50-311.75, mean

Table 1. List of clones involved in control crossing

S.No.	Clone	Species	Source country/originally developed	Used as
1	J 795	*S. matsudana x S. alba*	UK/China	Male
2	J 799	*S. matsudana x S. alba*	UK/China	Female
3	*S.tetrasperma*	*S.tetrasperma*	India (Rajasthan)	Male
4	Austree	*S.alba x* S. *matsudana*	UK/Newzealand	Male
5	NZ 1140	*S. matsudana x S. alba*	UK	Male
6	PN 227	*S. matsudana*	Newzealand	Female
7	*S.tetrasperma*	*S.tetrasperma*	Local selection, H.P., India	Female
8	*S.babylonica*	*S.babylonica*	Local selection, H.P., India	Female

Table 2. Growth and morphometric traits in 16 progenies of *Salix* hybrids

Crosses/parents	Plant height (cm)	Collar diameter (mm)	No. of branches	Internodal length (cm)
Salix tetrasperma × NZ 1140	112.50	10.78	8.25	2.60
Salix tetrasperma × Austree	132.17	12.01	9.17	2.78
Salix tetrasperma × J 795	114.61	12.02	11.50	3.11
Salix tetrasperma × *S.tetrasperma*	103.91	12.44	12.44	2.71
J 799 × NZ 1140	125.00	13.14	8.75	2.17
J 799 × Austree	207.40	10.51	18.89	2.56
J 799 ×J 795	158.50	12.48	18.66	2.52
J 799 × *S.tetrasperma*	209.75	10.73	26.60	2.82
PN 227 × NZ 1140	215.83	11.41	23.67	2.70
PN 227 × Austree	201.50	10.67	20.80	2.34
PN 227 × J-795	208.87	10.64	27.98	2.80
PN 227 × *S. tetrasperma*	95.33	10.66	12.66	2.46
Salix babylonica × NZ 1140	75.00	6.93	4.00	1.90
Salix babylonica × Austree	97.50	10.31	12.00	1.85
Salix babylonica × J 795	86.78	9.14	8.00	2.32
Salix babylonica ×*S.tetrasperma*	114.50	11.03	22.17	2.30
S. tetrasperma (Female)	115.80	11.82	10.34	2.80
J 799 (Female)	175.16	11.72	18.23	2.52
PN 227(Female)	180.38	10.85	21.28	2.58
S. babylonica (Female)	93.44	9.35	11.54	2.09
NZ 1140 (Male)	132.08	10.57	11.17	2.34
Austree (Male)	159.64	10.88	15.21	2.38
J 795 (Male)	142.19	11.07	16.54	2.69
S. tetrasperma (Male)	130.87	11.22	18.47	2.57
CD				
Female	15.55	0.87	3.99	0.13
Male	15.55	NS	3.99	0.13
Female × Male	31.09	1.73	7.98	0.26

175.82), followed by plant height (75.00-215.83 cm, mean 141.20 cm) indicating the extent of variation existing in the plants. Phenotypic coefficient of variation (PCV) was found to be maximum for number of branches (54.27%) followed by number of leaves (52.53%).

In the related *Populus* species, growth of hybrids (seedling) has been evaluated previous studies [18-20] and these are in conformity with the results obtained under present study. The characteristic studied significantly varied between the families except for leaf width and leaf area. The significant differences were obtained for plant height, stem diameter, number of internodes and petiole length between populations of eastern cottonwood developed by crossing two sources length [18]. Significant plant height and mean number of leaves were reported by Vaario *et al*. [19] in the families of *P. tremula* obtained by controlled crossing between four male and three female trees at two different soil types. Intraspecific breeding in *Populus deltoides* was carried out by Singh *et al*. [20] and growth traits of cottonwood hybrids at nursery stage have been studied earlier [21].

Table 3. Morphometric traits in 16 progenies of *Salix* hybrids

Crosses/parents	Number of leaves	Petiole length (cm)	Leaf area (cm^2)
Salix tetrasperma × NZ 1140	103.62	1.87	27.73
Salix tetrasperma × Austree	143.67	1.90	30.38
Salix tetrasperma × J 795	128.33	1.47	25.03
Salix tetrasperma × *S.tetrasperma*	135.55	1.57	23.89
J 799 × NZ 1140	138.83	1.00	17.87
J 799 × Austree	255.38	0.87	21.36
J 799 × J 795	236.50	0.80	18.63
J 799 × *S.tetrasperma*	293.57	0.87	18.50
PN-227 × NZ-1140	302.37	1.00	19.10
PN 227 × Austree	247.00	0.97	17.02
PN 227 × J 795	311.75	1.17	15.37
PN 227 × *S. tetrasperma*	129.55	0.73	20.07
Salix babylonica × NZ 1140	42.50	1.53	19.57
Salix babylonica × Austree	120.67	0.97	21.19
Salix babylonica × J 795	91.83	1.20	15.62
Salix babylonica ×*tetrasperma*	132.00	0.97	19.55
S. tetrasperma (Female)	127.79	1.70	26.76
J 799 (Female)	231.07	0.88	19.09
PN 227(Female)	247.67	0.97	17.89
S. babylonica (Female)	96.75	1.17	18.98
NZ 1140 (Male)	146.83	1.35	21.07
Austree (Male)	191.68	1.18	22.49
J 795 (Male)	192.10	1.16	18.66
S. tetrasperma (Male)	172.67	1.03	20.50
CD			
Female	38.29	0.24	3.52
Male	NS	0.24	NS
Female × Male	76.59	0.47	N.S

Table 4. Mean, range, GCV, PCV, heritability, genetic advance and genetic gain of growth and morphometric characteristics of *Salix* progenies

Characters	Mean	Range	Coefficient of variance (%)		Heritability	Genetic advance (K=2.06)	Genetic gain (%)
			Genotypic	Phenotypic			
Height (cm)	141.20	75.00 - 215.83	35.06	37.47	0.88	95.90	67.92
Collar diameter (mm)	10.93	6.93 - 13.14	12.23	15.50	0.62	2.16	19.76
Number of branches	15.34	4.00 - 27.98	44.41	54.27	0.67	11.50	74.92
Number of leaves	175.82	42.50 – 311.75	45.57	52.53	0.75	92.69	81.16
Leaf area (cm^2)	20.68	15.37 - 30.38	16.48	26.23	0.39	4.36	21.08
Petiole length (cm)	1.18	0.73 – 1.90	28.40	37.25	0.58	0.53	44.92
Internodal length	2.50	1.85 - 3.11	13.10	14.55	0.81	0.61	24.40

Heritability and other genetic parameters signify the utility of variability in advanced breeding programmes. High genotypic coefficient of variance, heritability and genetic gain were recorded for plant height followed by number of leaves and number of branches which revealed that traits were under strong genetic control. Higher genetic gain (81.16%) was recorded for number of leaves followed by number of branches (74.92%) and plant height (67.92%) suggesting that additive genetic effects are important in the determination of these characters and therefore, selection would be effective for these traits. Johnson *et al.* [16] reported that heritability estimates along with expected gain is more useful and realistic than the heritability alone predicting the resultant effect for selecting the best genotype. The results are in accordance with findings of Kadam [22] in full sib progenies of selected clones of *Populus deltoides*. Negligible coefficient of variance, heritability and genetic advance has been found for collar diameter and leaf area which implies that selection for these traits would be ineffective. Thus the characteristics with higher heritability and genetic gain will be exploited well for advanced breeding programs and the superior hybrids after further field evaluation for growth, biomass and physiological parameters as well as parental verification will be commercially released covering wider climatic range of the country.

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