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Clonal diversity of *Salix* for growth parameters

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Abstract
Twenty-two willow clones were planted in randomized block design at two sites (University Seed Farm, Ladhowal and Alamwala forest, Range Malout) to study the clonal diversity among different clones for their growth parameters. The data for plant height, collar diameter, number of branches per plant, canopy spread and diameter at breast height were recorded. All the growth characters exhibited significant differences and positive correlation among different clones at both the locations. On the basis of plant height and collar diameter, clones UHFS-1, UHFS-3 and UHFS-13 performed best at Ludhiana with stagnating water conditions and clones UHFS-1 and UHFS-19 were best at Alamwala. Clones UHFS-1 and UHFS-19 showed wider adaptability at both the sites.

Keywords: Willow, genetic diversity, growth characteristics, submerged conditions, clone

1. Introduction
Diversification of crops from rice-wheat rotation has attracted the attention of government and farmers of Punjab due to continuous decrease in ground water table and deterioration of soil and water quality due to high use of fertilizers and pesticides. To promote diversification, huge emphasis is given on practicing short rotation forestry in different forms. In Punjab, *Populus*, *Eucalyptus* and *Melia* species are mainly used for on-farm plantations. But, another species *Salix*, which is multipurpose, fast growing and has lot of potential in industry, can be introduced for agroforestry under diverse climatic and edaphic conditions of Punjab. Willows are light demanding, deciduous trees and shrubs, found primarily on moist soils in cold and temperate regions of the northern hemisphere. Cricket bat willow *Salix alba* cv. c*oerulea* is a female cultivar of hybrid origin between *S. alba* and *S. fragilis* (Desch and Dinwoodie 1996) [1], which was introduced by Britishers during 1899 at Kitriteng, Bejbehara in Jammu and Kashmir. The average estimated yield of willow is 65 t/ha at a rotation of 12 years. Evaluating the performance of clones to be used in short rotation intensive culture (SRIC) plantations for biomass production is critical for identifying superior clones and matching them with sites on which they will perform best. This will lead to increased production and a strengthening of the commercial prospects of these plantations. *Salix* is one such species, which can tolerate stagnating water conditions, therefore the present study was undertaken to identify suitable clones under stagnating water and saline soil conditions. The study comprising 22 different clones of Salix was conducted at two different sites with the objectives to diversify the tree species used in agroforestry system, which otherwise is dominated by Eucalyptus and Poplar.

2. Material and Methods
The study was conducted in 2015-16 on 22 *Salix* clones established at University Seed Farm, Ladhowal, Ludhiana (30^0 58' N latitude and 75^0 45' E) longitude and at Alamwala forest, Range- Malout, Division- Muktsar ($30^0$15' N latitude and $74^0$25' E) longitude with average annual rainfall ranging from 400-600mm and 300-500mm, respectively. Soil analysis was done at different depths of both the sites. Two separate experiments were laid out in Randomized Block Design at two sites with same 22 *Salix* clones raised at 4×4 m spacing with single plant replicate. Planting was done in the month of March 2012. Observations for plant height, collar diameter, number of branches (diameter above 10mm), diameter at breast height and crown spread were recorded, whereas data for plant biomass was recorded only at USF, Ladhowal. Paddy variety PR-121 was transplanted at USF, Ladhowal with willows to maintain stagnating water conditions in the field for around 3-4 months (June-Sept).

Analysis of variance (ANOVA) was done according to Sukhatme and Amble (1989) [9]. The Mean values of plant height, collar diameter, number of branches, diameter at breast height, crown spread and plant biomass were calculated and the coefficient of variation for phenotypic and genotypic values were also calculated. Heritability and genetic gain were calculated for all parameters for both the sites. Heritability in broad sense was calculated by the formula suggested by Johnson *et al.* (1955) [2] for each character. The genetic advance was calculated by the formula used by Miller *et al.* (1958) [3]. Correlation studies were carried out for phenotypic and genotypic values.

3. Results and Discussion

The data for plant height, collar diameter, diameter at breast height, crown spread and number of branches were recorded at two locations and rest of the traits (plant biomass and survival per cent) were collected only at USF, Ladhowal. The data depicted in table 1 and table 2 showed variations in plant height, collar diameter, number of branches, diameter at breast height and crown spread of different clones at Ladhowal and Alamwala site respectively. Clone UHFS-13 registered the maximum plant height (9.16m) whereas; the clone UHFS-2 registered the minimum height (3.50m) in USF, Ladhowal while in Alamwala forest, clone UHFS-19 registered maximum plant height (8.86m) and clone UHFS-21 registered minimum plant height of 2.26m. In USF, Ladhowal, maximum collar diameter (15cm) was observed in clone UHFS-13 and minimum (7.8cm) in clone UHFS-17, while in Alamwala forest, maximum collar diameter (15.4cm) was recorded in clone UHFS-19 and minimum (3.76cm) was in clone UHFS-21. Diameter at breast height followed the trend of collar diameter. Maximum diameter at breast height (8.59cm) was noticed in clone UHFS-13 and minimum (4.10cm) was in clone UHFS-15 at USF, Ladhowal. At Alamwala forest, maximum DBH (10.96cm) was found in clone UHFS-19 and minimum (2cm) was in clone UHFS-21. In USF, Ladhowal, maximum crown spread (18.09 m^2) was recorded in clone UHFS-8 and minimum (3.24m^2) in clone UHFS-17 and in Alamwala forest, maximum crown spread (10.96 m^2) was observed in clone UHFS-19 and minimum (1.30 m^2) in clone UHFS-14. Highest number of branches were found in clone UHFS-1 (4.30) and lowest were found in clone UHFS-2 (1.67), UHFS-4 (1.67) and UHFS-15 (1.67) at USF, Ladhowal. At Alamwala forest, highest number of branches were found in clone UHFS-19 (4.30) and UHFS-20 (4.30) and the lowest number of branches was found in clone UHFS-10 (1.67).

Table 1: Mean values of plant height (m), collar diameter (cm), diameter at breast height (cm), crown spread (m^2), number of branches and plant biomass (kg) recorded at USF, Ladhowal

Clone	Plant height	Collar diameter	DBH	Crown spread	Number of branches	Plant biomass
UHFS-1	7.80	12.90	8.50	10.60	4.30	29.48
UHFS-2	3.50	8.60	4.86	5.22	1.67	5.26
UHFS-3	7.60	13.30	8.40	7.34	4.00	27.6
UHFS-4	4.50	8.20	4.70	4.45	1.67	6.02
UHFS-5	6.20	8.80	5.63	5.57	2.67	16.05
UHFS-6	6.10	12.30	7.53	11.72	3.00	17.43
UHFS-7	4.10	9.00	4.70	5.34	2.67	6.71
UHFS-8	4.00	10.50	6.19	18.09	3.00	9.90
UHFS-9	3.90	9.60	5.26	4.97	2.00	10.81
UHFS-10	4.13	9.16	6.06	8.96	3.00	6.09
UHFS-11	7.30	14.00	8.26	11.40	3.30	31.93
UHFS-12	6.46	10.90	5.40	5.17	2.00	15.18
UHFS-13	9.16	15.00	8.59	8.11	2.00	42.17
UHFS-14	6.86	11.30	8.06	8.25	3.67	17.40
UHFS-15	4.70	8.10	4.10	4.41	1.67	5.41
UHFS-16	4.90	9.00	5.76	7.18	3.00	6.77
UHFS-17	3.60	7.80	4.23	3.24	3.00	3.98
UHFS-18	5.36	8.90	6.19	4.67	3.30	6.59
UHFS-19	4.36	9.60	6.19	6.69	3.00	7.40
UHFS-20	6.43	9.70	6.70	6.45	3.00	11.64
UHFS-21	5.36	12.50	7.73	11.41	3.30	18.04
UHFS-22	3.80	9.10	4.46	6.02	2.30	7.07
Mean	5.46	10.38	6.25	7.51	2.80	14.04
Range	3.50-9.16	7.80-15.00	4.10-8.59	3.24-18.09	1.67-4.30	3.98-42.17
CD (5%)	2.21	3.62	2.38	5.17	NS	15.02

Table 2: Mean values of plant height (m), collar diameter (cm), diameter at breast height (cm), crown spread (m^2) and number of branches recorded at Alamwala forest

Clone	Plant height	Collar diameter	DBH	Crown spread	Number of branches
UHFS-1	5.80	11.86	6.20	10.03	4.00
UHFS-2	4.20	8.76	5.46	5.63	3.30
UHFS-3	5.16	10.20	6.56	8.96	3.00
UHFS-4	2.60	4.90	2.40	1.66	2.67
UHFS-5	3.53	6.76	3.23	2.16	3.00
UHFS-6	5.00	11.30	7.93	8.90	3.67
UHFS-7	5.00	7.30	4.63	4.43	2.30
UHFS-8	2.46	4.83	2.86	1.73	2.67
UHFS-9	3.70	8.20	4.56	7.63	3.67
UHFS-10	3.06	7.16	3.76	2.83	1.67
UHFS-11	5.00	8.63	4.93	7.69	2.30
UHFS-12	3.03	4.90	3.00	1.70	2.30

UHFS-13	3.53	6.70	4.80	2.96	2.30
UHFS-14	3.16	5.50	2.23	1.30	2.30
UHFS-15	4.96	5.70	3.66	4.53	2.00
UHFS-16	2.53	5.43	3.10	2.40	3.30
UHFS-17	3.60	7.20	4.43	4.20	2.67
UHFS-18	4.30	6.00	3.13	2.60	2.67
UHFS-19	8.86	15.40	10.96	10.96	4.30
UHFS-20	4.10	7.60	3.76	5.03	4.30
UHFS-21	2.26	3.76	2.00	1.76	2.67
UHFS-22	4.60	9.40	5.69	3.46	3.00
Mean	4.11	7.61	4.51	4.66	2.91
Range	2.26-8.86	3.76-15.40	2.00-10.96	1.30-10.96	1.67-4.30
CD (5%)	2.10	4.09	2.90	6.09	NS

The plant biomass of different clones ranged between 3.98 and 42.17 kg with a mean of 13.01 kg. Maximum plant biomass (42.17 kg) was recorded in clone UHFS-13 and minimum plant biomass in clone UHFS-17 (3.98 kg). Significant differences were observed between clones for plant biomass. Performance of clones was comparatively better at Ladhowal then Alamwala. Only clone UHFS-2, UHFS-19 and UHFS-22 outperformed at Alamwala, whereas the performance of other clones was better at Ladhowal area.

Fig 1 and 2 shows the incremental data for 156 days and 197 days of USF, Ladhowal and Alamwala forest respectively of different clones showed that clones at USF, Ladhowal showed comparatively more increment than at Alamwala forest. Clone UHFS-13 USF, Ladhowal, was ranked first in plant height (2.50m) and collar diameter (2.80cm). While at Alamwala forest, clone UHFS-16 was at rank first for highest increment in plant height and clone UHFS-19 for highest increment in collar diameter.

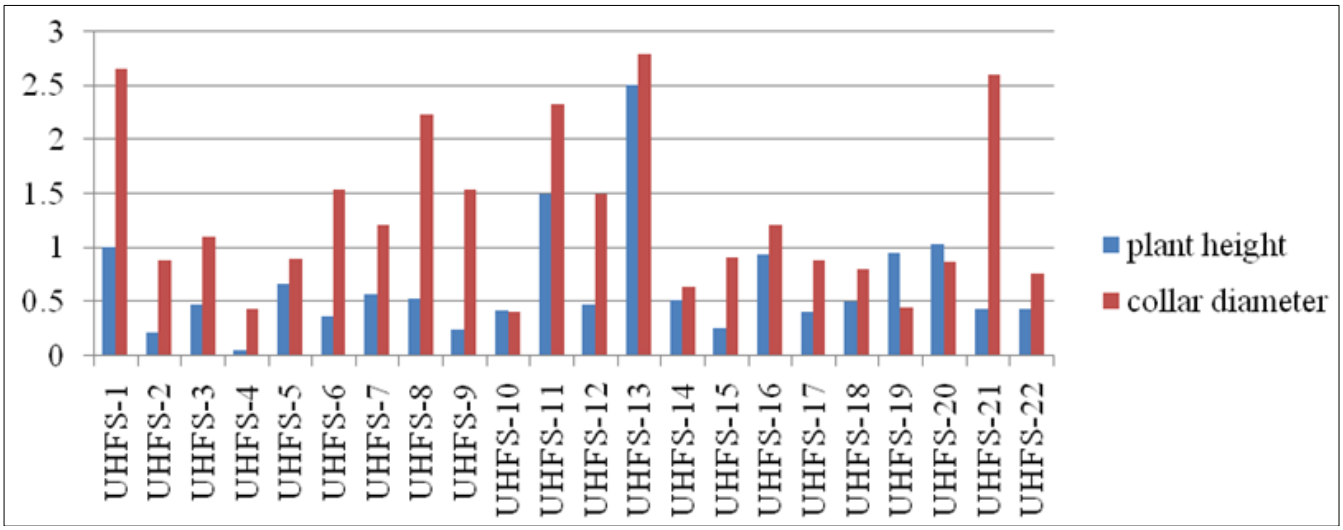

Fig 1: Increment (156 days) of different clones for plant height (m) and collar diameter (cm) at USF, Ladhowal

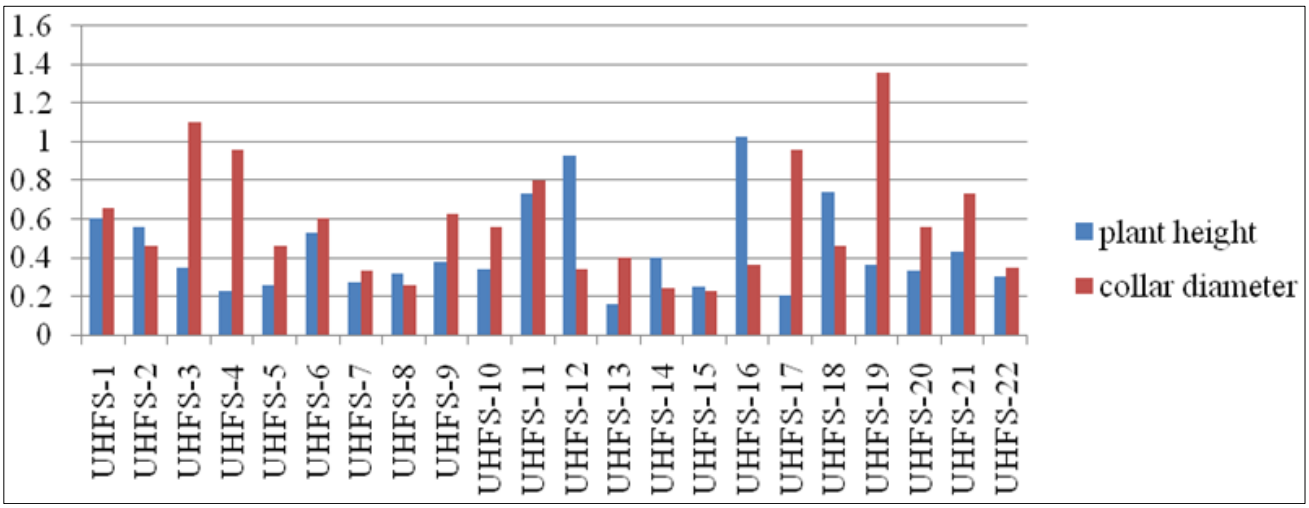

Fig 2: Increment (197 days) of different clones for plant height (m) and collar diameter (cm) at Alamwala forest

Table 3 includes the values of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for all traits taken at two different sites ranged between moderate to high. Highest variation was present in crown spread in Alamwala forest (91.8) while collar diameter in USF, Ladhowal recorded the lowest variation (26.5) among different parameters at two sites. Crown spread in Alamwala forest registered the highest GCV (46.4) while number of

branches in USF, Ladhowal registered the lowest GCV (6.1). Table 3 also shows values for heritability and genetic gain. Plant height at Ladhowal recorded the highest heritability (98.1%), whereas, number of branches at same site recorded the lowest heritability (1.7%). Results of the present study are in line with the observations of Sharma *et al.* (2011) [7] and Singh *et al.* (2016) [8] in different tree willow species. Highest genetic gain of 74% was registered by plant height USF, Ladhowal while the number of branches at Ladhowal exhibited the lowest (1%) genetic gain. Genetic gain for number of branches was low under two different sites. While collar diameter, crown spread and diameter at breast height ranged between moderate to high genetic gain at both the sites.

Table 3: Variability, heritability and genetic gain magnitude of different parameters at two different sites

Sr. No.	Parameters	Site	PCV (%)	GCV (%)	Heritability (%)	Genetic gain (%)
1	Plant height	USF, Ladhowal	35.5	25.6	98.1	74.0
		Alamwala forest	43.8	30.9	50.0	45.1
2	Collar diameter	USF, Ladhowal	26.5	15.9	36.4	19.6
		Alamwala forest	44.9	30.9	47.3	43.5
3	Diameter at breast height	USF, Ladhowal	30.6	19.8	42.6	26.4
		Alamwala forest	56.3	40.1	51.5	59.2
4	Number of branches	USF, Ladhowal	46.4	6.1	1.7	1.0
		Alamwala forest	40.5	14.4	12.8	10.0
5	Crown spread	USF, Ladhowal	56.9	38.7	46.3	54.0
		Alamwala forest	91.8	46.4	25.5	47.3

Correlation studies help to reveal the degree of inter-relationship between different parameters. Some traits are strongly interlinked with each other as compared to others and it helps to select clones for particular trait on the basis of some other related traits. In general, the genotypic correlation coefficient values were higher than corresponding phenotypic values (Table 4). All traits showed positive relationships.

Table 4: Phenotypic and genotypic correlation among different parameters of *Salix* clones at two different sites

Characters		Plant height	Collar diameter	No. of branches	Diameter at breast height
Collar diameter	P	0.8896**			
	g	0.8867**			
No. of branches	p	0.5301**	0.6720**		
	g	0.5798**	0.8136**		
Diameter at breast height	p	0.8653**	0.9320**	0.6507**	
	g	0.9040**	0.9912**	0.7136**	
Crown spread	p	0.8179**	0.8642**	0.6782**	0.8394**
	g	0.8524**	0.9774**	0.7176**	0.9220**

Critical value of 'r' at 5% = 0.2441 and at 1% = 0.3174**: Significant at 1% level. p = Phenotypic correlation, g = Genotypic correlation

Rice-wheat rotation is common practices in Punjab and farmers are testing for option to rinse trees with rice. Poplar does not tolerate stagnating water. Positive response of *Salix* to stagnating water during paddy season is a positive outcome and opens new options for the farmers to adopt *Salix* based agroforestry with rice cultivation. The parameters like plant height, collar diameter, number of branches, diameter at breast height and crown spread were positively and significantly correlated among all. Tunctaner (2002) [12], Sharma *et al.* (2011) [7] and Thakur *et al.* (2019) [11] observed highly significant correlation between plant height and collar diameter in their study on willow clones. Singh *et al.* (2016) [8] also reported successful introduction of *Salix* in Punjab. Similar results were found by results are in agreement with the findings Sharma *et al*. (2018, 2019) [4, 5] while doing genotypic evaluation of growth traits. The variation in productivity has also been reported in many other tree species like in *Terminalia chebula* by Sharma *et al.* (2016) [6], and by Thakur *et al.* (2008) [10] in *Grewia optiva*. Assessment of genetic variability is a key to progress in tree improvement programme (Zobel, 1981) [13] and is a useful tool in determining the strategies for tree improvement and breeding of any species.

4. Conclusions

On the basis of evaluation of growth performance of studied clones of Salix, clones UHFS-1, UHFS-3 and UHFS-13 were found best for stagnating water while UHFS-1 and UHFS-19 performed best at Alamwala. Significant variation among all genotypes was found for height, diameter growth, crown spread and biomass. The high value of heritability (h^2) and genetic gain for all studied characters in evaluated clones suggest that early selection can be made for these traits in *Salix alba*. The study also revealed strong correlation among evaluated traits thereby making it possible to select a clone for a particular trait on the basis of its performance for other related traits.

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