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Evaluation and selection of *Salix* clones for different end uses under Punjab conditions

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Abstract
The field trial was conducted during 2012-13 at Punjab Agricultural University seed farm, Ladhowal, Ludhiana located in central plains of Punjab. Twenty-two willow clones were planted in a randomized block design with three replications, to study the growth and genetic performance of different clones. The data was recorded for plant height, collar diameter, leaf area, leaf less days and number of branches. All the characters under study exhibited significant differences among different clones. On the basis of plant height and collar diameter, clone UHFS-13 showed the maximum growth (4.00 m and 3.57 cm, respectively) and overall performance of other best clones was in the order of UHFS-14, UHFS-3, UHFS-12 and UHFS-19. The values of genotypic variability for different traits were between low (8.57%) in collar diameter to high (36.33%) in leaf area and for phenotypic variability between moderate (16.78%) in plant height to high (40.14%) in leaf area. Values of heritability and genetic gain were observed between low to high. On phenological basis, clone UHFS-2, UHFS-5, UHFS-12 and UHFS-18 would be suitable for tree-crop combination, and clone UHFS-3, UHFS-13, UHFS-14 and UHFS-16 for biofuel or phyto-remediation and clone UHFS-10 with drooping branches for landscape purposes.

Keywords: Collar diameter, Genetic gain, Heritability, Variability, Willow

Introduction

Willows are multipurpose, fast growing with lots of potential in sports industry, phyto-remediation and biomass production widely used world over for plantations. *Salix* is a very diverse genus of about 350–500 species worldwide (Argus, 1997), and are classified into three groups *viz*., tree willows, shrub willows and alpine or arctic willows. There are about 32 willow species in India, of which four exotic willows namely *Salix alba, S. daphnoides, S. fragilis,* and *S. babylonica* and an indigenous willow, *S. tetrasperma* are categorized into tree willows. Willow provide a wide range of wood products (including industrial roundwood and poles, pulp and paper, reconstituted boards, plywood, veneer, sawn timber, packing crates, pallets and furniture), non-wood products (fodder, fuelwood, medicines, etc.) and services *i.e.*, shelter, shade, protection of soil, water, crops, livestock and dwellings (Ball *et al.,* 2005). Due to their rapid growth they are effective for carbon sequestration. They provide employment opportunities, boost exports and contribute to social and economic development and sustainable livelihood in rural areas. The genus is distributed over wide ecological and climatic zones ranging from North America to China, excluding Australasia (Trybush *et al.,* 2008). Willow are well suited for establishment of special purpose plantations like biological control of soil erosion, nutrient cycling, phytoremediation, carbon sequestration and filtering of sewage and polluted water as it is able to grow over marshy, swampy, compacted acidic and saline soils provided the roots have sufficient moisture content (Verjwist, 2001).

In Punjab, 42.7 per cent area has poor water quality (Anonymous, 2010) and the willow based plantations can mitigate ground water related problems and address to water logging as well. It can be successfully cultivated in agroforestry systems with rice-wheat rotation, where the smaller leaf surface and narrow canopy of willow allows sufficient light penetration to the crop without affecting crop yield and are able to withstand standing water in comparison to other woody species (Saini and Sharma, 2001). But systematic research work is required for screening of genetic resources of indigenous species, import of various clones/species/hybrids/strains, etc. to evaluate them with regard to specific end uses. The essential purpose of tree improvement is to develop a suitable clone/variety that eventually brings about economic returns and related benefits to growers. Genetic and phenotypic variance in clones provide an estimate of the proportion of the variation within a population that is due to genetic or environment differenc

among individuals. Keeping in view the ever increasing demand of willow wood for various uses, twenty two clones were introduced from the University of Horticulture and Forestry, Solan and evaluated at Punjab Agricultural University Seed Farm, Ladhowal, Ludhiana to compare the growth parameters of selected clones in field condition as well as to estimate the genetic parameters of clones of *Salix* species. The emphasis was focused on growth traits to evaluate the clones for specific purposes like biofuel, agroforestry, phyto-remediation and landscaping.

Materials and Methods

The experimental plantation was raised at Punjab Agricultural University Seed Farm, Ladhowal, Ludhiana in February 2011. The pits of 1 m depth with augor hole of 15 cm diameter were prepared at 4 m x 4 m spacing and plantation was done in randomized block design in three replications. The field site is located at an elevation of 776 feet above mean sea level in the central plain zones of Punjab and lies between 30°58'N latitude and 75°45'E longitude. The area experiences severe summer during May-July and severe winter during December –February. The average annual rainfall ranges between 400-600 mm, mostly received during monsoon (July-September), winter showers are mild. Meteorological data of the site during the trial period is given in figure 1. Soil samples were collected at four depths (0-15, 15-30, 30-60 and 60-90 cm) from the site and details of the soil physico-chemical properties are presented in table 1.

Assessment of the traits: Height of the plant was measured in meters from the ground level to the apex of the leading shoot by using measuring scale. Collar diameter of the plant was measured with the help of digital caliper at the collar region *i.e.* 5 cm above the soil surface. Primary branches emerging from main stem (diameter more than 5 mm) were counted from each plant. Leaf less days were calculated from the date of completion of leaf fall to the date of leaf sprouting initiation. Leaf area of five leaves collected from the central portion of branches of each tree was calculated by multiplying the length of leaves to the mean width of leaves.

Statistical analysis: Statistical analysis was done with MVM computer package. Analysis of variance was conducted for all the traits to detect significant differences among the clones with the model for a randomized block design *i.e.*, $Y_{ik} = \mu + g_i + r_k + (g)_{ik} + e_{ik}$

Table 1. Physico-chemical properties of soil at USF, Ladhowal

Depth (cm)	Texture	N (kg/ ha)	P (kg/ ha)	K (kg/ ha)	OC (%)	EC (mm hos/ cm)	pH
0-15	Loamy sand	150.4	7.25	216.5	0.36	0.22	8.4
15-30	Loamy sand	145.6	7.50	214.0	0.35	0.22	8.3
30-60	Loamy sand	150.4	6.50	190.5	0.28	0.19	8.4
60-90	Loamy sand	148.5	7.00	210.0	0.48	0.20	8.4

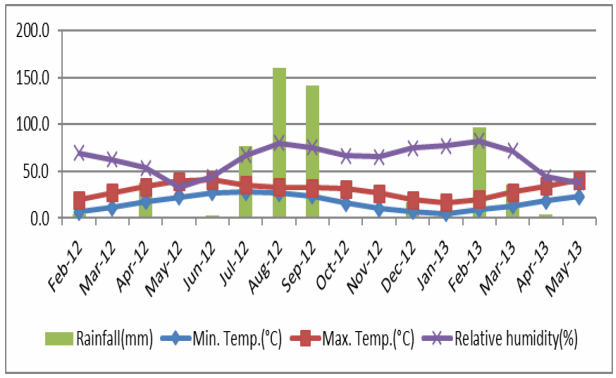

Fig 1. Meteorological data of USF, Ladhowal, Ludhiana

Where,

Y_{ik} = mean performance of genotype i in replicate k
μ = overall mean
g_i = contribution of genotype i
r_k = contribution of the replicate k
e_{ik} = residual variation of genotype i in replicate k.

Genotypic and phenotypic coefficients of variability, genotypic and phenotypic correlations were worked out as per Singh (2006) and heritability (broad sense) and genetic gain at 5 per cent intensity was calculated as suggested by Johnson *et al.* (1955).

Results and Discussion

***Growth performance*:** Plant height and diameter at breast height are the important morphological traits, which indicate the growth and development of plant. The perusal of the data in Table 2 showed that the plant height and collar diameter of different clones ranged between 2.24 - 4.00 m and 2.27 - 3.57 cm, respectively. Clone UHFS-13 registered the maximum plant height (4.00m) and collar diameter (3.57 cm). UHFS-13 was statistically at par with clone UHFS-2, UHFS-3, UHFS-5, UHFS-12, UHFS-13, UHFS-14, UHFS-17, UHFS-18 and UHFS-20.

Similarly for collar diameter clone UHFS-13 was statistically at par with clone UHFS-1, UHFS-3, UHFS-5, UHFS-9, UHFS-14, UHFS-16 and UHFS-19. Minimum plant height (2.24 m) was recorded in clone UHFS-21, whereas, minimum collar diameter was recorded in clone UHFS-10 (2.27 cm). Total number of primary branches per plant ranged between 5.33 and 22.33. Highest number of branches was found in clone UHFS-3 (22.33) and minimum number of branches was found in clone UHFS-18 (5.33). Apart from clone UHFS-18, the clones UHFS-4 (8.69), UHFS-5 (9.67), UHFS-12 (8.33) and UHFS-19 (6.67) had also less number of branches. Similarly apart from clone UHFS-3, clone UHFS-6, UHFS-13, UHFS-14 and UHFS-16 had also large number of branches. Clone UHFS-18, which had lowest number of branches was statistically at par with clones UHFS-2, UHFS-4, UHFS-5, UHFS-10, UHFS-12 and UHFS-19. Clone UHFS-3, which had highest number of branches was at par with UHFS-13 only and differed significantly from all other clones. Leaf area of different clones ranged from 8.04 cm^2 to 29.91 cm^2, clone UHFS-19 recorded the highest (29.91 cm^2) leaf area and lowest area was registered by clone UHFS-2 (8.04 cm^2). Other clones which had less leaf area included UHFS-7 (8.09 cm^2), UHFS-20 (8.78 cm^2), UHFS-4 (9.26 cm^2) and UHFS-8 (9.65 cm^2). Clone UHFS-2, which had lowest leaf area was statistically at par with clone UHFS-4, UHFS-7, UHFS-8, UHFS-9, UHFS-10, UHFS-12, UHFS-16 and UHFS-20. However, clone UHFS-19, which had highest leaf area differed significantly from all other clones. The number of leaf less days of different clones ranged between 18 UHFS-12 and 97.67 UHFS-16, but clone UHFS-16, which remained leaf less for maximum number of days was statistically at par with clone UHFS-4, UHFS-7, UHFS-9, UHFS-14, UHFS-15, UHFS-17, UHFS-20 and UHFS-22. Whereas, clone UHFS-12, which remained leaf less for minimum number of days (18 days) differed significantly from all other clones. For growing trees in combination with crops better growth performance, less number of branches, less leaf area and more number of leaf less days are required, so perusal of data in Table 2 revealed that clone UHFS-2, UHFS-5, UHFS-12 and UHFS-18 would be suitable. Whereas for biofuel or phyto-remediation better growth performance, more number of branches, large leaf area and less number of leaf less days are required, hence the clones UHFS-3, UHFS-13, UHFS-14 and UHFS-16 would be suitable. Due to drooping branches clone UHFS-10 could be used for as ornamental tree for landscape purposes.

Such a significant variation may be attributed to the distinct genetic constitution of the clones and their performance in given set of climatic and edaphic conditions. In consonance with the present study, Sharma *et al.* (2011) reported significant differences in the plant height and diameter of eighteen clones after five years of evaluation in Himachal Pradesh. Tunctaner (2002) also observed large variations in plant height (2.3 m to 6.7 m) and diameter (1.9 cm to 4.7 cm) of fifty-three willow clones after two years at Izmit nursery (Turkey), these clones were selected from different locations in Turkey. Similarly significant differences in plant height and diameter of two year old sprouting of different species and hybrids of willow were observed by Vihera-Aarnio and Saarsalmi (1994) on abandoned field in southern Finland. Arun (2009) also reported large variation in height, collar diameter, number of branches, leaf area and leaf less days of willow clones collected from different parts of the north India in his study in Punjab at nursery stage. Tharakan *et al.* (1998) also found statistically significant differences between clones of *Populus* and *Salix* for height, diameter, growth, leaf area and biomass production.

***Genetic values*:** The perusal of the data in Table 3 revealed high variability among the *Salix* clones. Phenotypic coefficient of variation (PCV) was greater than genotypic coefficient of variation (GCV) for all growth parameters. The PCV varied from 16.78 to 40.14 per cent in plant height and leaf area, respectively and GCV varied from 8.57 per cent to 36.33 per cent in collar diameter and leaf area, respectively. Sharma *et al.* (2011) also recorded phenotypic coefficient of variation more than genotypic coefficients of variation that were highest for character volume than height and diameter at breast height in 5 year old willow clones. The existence of genotypic and phenotypic differences among white willow populations for rate of growth, length of growing season, leaf characteristics and branching was reported by Kristinic (1979). Variations in plant height, leaf area and branching pattern were also reported by Tu and Pan (1984) in twenty clones of ten willow species.

The heritability (broad sense) of the traits ranged from 22.46 per cent in collar diameter to 89.15 per cent in leaf less days. Heritability is used to estimate the heritable portion of variations and the result showed the scope for improvement in these characters through clonal selection and control breeding. The outcome of the present study exhibited higher heritability for characters

Table 2. Data on growth parameters of different *Salix* clones

Clone	Plant height (m)	Collar diameter (cm)	Number of branches	Leaf area (cm^2)	Leaf less days
UHFS-1	3.24	2.87	12.67	16.03	46.67
UHFS-2	3.47	2.73	8.00	8.04	44.00
UHFS-3	3.48	3.27	22.33	14.69	49.00
UHFS-4	3.25	2.47	8.67	9.26	94.67
UHFS-5	3.30	2.90	9.67	15.99	50.33
UHFS-6	2.86	2.47	17.33	19.53	48.00
UHFS-7	2.82	2.57	11.00	8.09	92.67
UHFS-8	2.91	2.57	11.00	9.65	43.67
UHFS-9	3.21	2.97	13.33	9.95	85.67
UHFS-10	2.62	2.27	10.00	10.88	54.00
UHFS-11	3.22	2.47	12.33	15.00	47.67
UHFS-12	3.59	2.83	8.33	11.90	18.00
UHFS-13	4.00	3.57	20.33	19.87	52.00
UHFS-14	3.97	3.20	16.33	12.15	86.33
UHFS-15	3.21	2.63	11.33	13.19	85.00
UHFS-16	3.27	2.93	16.00	11.27	97.67
UHFS-17	3.48	2.73	11.33	13.37	94.67
UHFS-18	3.59	2.33	5.33	16.14	49.00
UHFS-19	3.10	3.30	6.67	29.91	67.33
UHFS-20	3.32	2.50	12.67	8.78	87.33
UHFS-21	2.24	2.63	11.67	22.51	68.00
UHFS-22	2.96	2.37	11.00	13.51	87.67
Mean	3.23	2.75	12.15	14.08	65.88
Range	2.24– 4.00	2.27– 3.57	5.33– 22.33	8.04– 29.91	18.00– 97.67
CD (P<0.05)	0.72	0.72	4.75	3.97	12.86

like height (34.05%) than collar diameter (22.46%), which was also recorded by Sharma *et al.* (2011) in eighteen tree willow clones and by Ronnberg-Wastljung and Gullberb (1999) in *Salix viminalis*. The genetic gain was recorded lowest (8.37%) for collar diameter and highest (67.73%) for leaf area. Heritability estimates in broad sense are reliable if accompanied by high genetic gain (Burton and Devane, 1953). Johnson *et al.* (1955) reported that heritability estimates along with expected genetic gain are more useful and realistic than the heritability alone predicting the resultant effect for selecting the best genotype. Kumar (2012); Bhat and Ahmed (2012) recorded high estimates of heritability and genetic advance in *Pongamia pinnata* and *Grewia optiva,* respectively.

***Correlation studies*:** The perusal of the data in Table 4 revealed that the phenotypic correlation of collar diameter was significant and positive with plant height and leaf area. Numbers of branches were significant and negat-

Table 3. Genetic parameters of different *Salix* clones

Parameter	PCV (%)	GCV (%)	Herita-bility	Genetic gain
Plant height	16.78	9.79	34.05	11.77
Collar diameter	18.08	8.57	22.46	8.37
Number of branches	39.55	31.64	64.01	52.15
Leaf area	40.14	36.33	81.92	67.73
Leaf less days	35.96	33.95	89.15	66.04

-ively correlated with leafless days. Genotypic correlation of collar diameter was significant and positive with leaf area and plant height. Genotypic correlation of leafless days was negative with all other traits, but not significant with leaf area. Maximum positive and significant phenotypic correlation coefficient was recorded for plant height with collar diameter (0.6706). These correlations indicate that improvement of one character will be accompanied by the improvement in another related character. Tunctaner (2002) and Sharma *et al.* (2011) also observed highly significant correlation between plant height and collar diameter in their study on willow clones. Positive correlation between growth traits and late leaf abscission in present study was in line with the results of Weih (2009) on six willow varieties in central Sweden. Highly positive correlation between height and collar diameter of clones and negative correlation of plant height and collar diameter with leaf less days also confirmed the earlier findings of the Arun (2009) and Robinson *et al.* (2004), but contradicts their negative relationship with other traits like leaf area and number of branches.

Conclusion

Clone UHFS-13 showed the maximum growth in plant height and collar diameter. The performance of other clones was in the order of UHFS-14, UHFS-3, UHFS-12 and UHFS-19. For agroforestry, clone UHFS-2, UHFS-5, UHFS-12 and UHFS-18 will be suitable due to less number of branches, small leaf area, more days in leaf less phase and good growth. For biofuel or phyto-remediation, clone UHFS-3, UHFS-13, UHFS-14 and UHFS -16 will be suitable due to good growth, large number of branches, more leaf area, and less days in leaf less phase. Clone UHFS-10 can be used for landscape purposes due to its dropping nature of branches.

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Table 4. Phenotypic (P) and Genotypic (G) correlation coefficients among different growth parameters

Parameters		Plant height	Collar diameter	Leaf area	Leaf less days
Collar diameter	P	0.6706**			
	G	0.3518**			
Leaf area	P	-0.0962	0.2551*		
	G	-0.1482	0.5753**		
Leaf less days	P	-0.0378	-0.2336	-0.1538	
	G	-0.2481*	-0.7311**	-0.1660	
Number of branches	P	-0.0953	-0.077	-0.2118	-0.4501**
	G	-0.0904	-0.0601	-0.2315	-0.5269**

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