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GENETIC VARIABILITY IN *HERACLEUM CANDICANS* WALL

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ABSTRACT

The roots of *Heracleum candicans* are rich source of furocoumarins, having photosensitizing property. The species showed wide range of variability for furocoumarin yield as brought out through high phenotypic, genotypic and environmental variances. In all the population collections studied at two locations, genotypic variances were higher than the environmental variances except for plant height, tap root length and secondary root length. Genotypic coefficient of variability (GCV) has showed similar trend; heritability ranged between 60.6% for root length to 98.3% for furocoumarin content. High heritability was accompanied by genetic gain of same intensity which reflects the presence of high additive genetic component for these parameters and can be utilized in selection of high furocoumarin yielding line as part of crop improvement.

Key words: *Heracleum*, variability, heritability, genetic advance, furocoumarin.

Furocoumarins are a group of secondary metabolities found in some plants of Umbelliferae (Apiaceae) and Rutaceae families. Among them xanthotoxin and psoralen have exhibited photosensitizing property and, therefore, they are extensively used in the treatment of leukoderma and in the preparation of sun-tan lotions. The roots of *Heracleum candicans* Wall., family Umbelliferae (Apiaceae), is the richest source of xanthotoxin as compared to other allied species such as *Heracleum canescens, H. pinnatum* and *H. thomsoni* [1]. At present, the raw material is collected from the wild source, but indiscriminate collection has drastically reduced its frequency of distribution. Therefore, there is need to bring it under cultivation to ensure sustained supply of good quality raw material to the user industries and also the species is conserved in its habitat. Before taking up its cultivation, it is considered desirable to broadly identify selection index to pin point superior genotypes.

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Collection of population sample from forests suggested that *Heracleum candicans* exhibited large variations in root characters, viz., number of secondary roots, secondary root length, root diameter and active contents. Since these characters contribute towards total furocoumarin content, it may control the expression of this trait [2, 3]. Therefore, improvement for furocoumarin content and root yield led us to study the inherent variability present in the collection for different yield contributing characters taken for selection. The variability (genotypic and phenotypic) along with heritability is used in predicting genetic gain for a given selection intensity which may give us an idea of the extent to which possible improvement can be made in a character under selection. Consequently, the present investigation has been undertaken to assess the extent of variability present in some of the collections made from Sangla (Kinnaur) and Manali (Kullu) forest ranges of Himachal Pradesh, so that to ultimately introduce the selected lines into commercial cultivation in Himachal Pradesh.

MATERIALS AND METHODS

The study reported was carried out during the year 1990–1993 period at two locations: at the experimental farm of the Department of Forest Products, Dr. Y. S. Parmar University of Horticulture and Forestry, Solan (30° 51'N, 76° 11'E, 1300 m above sea level) and at the Regional Horticulture Research Station, Bajaura (31° 8'N, 76° 3'E, 1090 m above sea level), Kullu district. The material consisted of eight collections of *Heracleum candicans* made from Sangla (Kinnaur) and Manali. Both experiments were laid out in randomized block design with three replications and eight treatments (collections) with the plot size 2.25 m x 1.8 m. Seeds were sown in lines at the spacing of 45 cm x 45 cm on December 6, 1990. Observations were recorded on 14 growth and yield characters. The roots were harvested from two experimental sites on January 6, 1993. Total furocoumarin content was estimated in dried roots by the TLC-spectrophotometric method [4]. Observations were recorded on five random plants in each plot.

RESULTS AND DISCUSSION

Studies on variability were carried out on selected characters, which was expressed as range, mean, phenotypic and genotypic variances, heritability, genetic advance and gain.

VARIABILITY ESTIMATES AND GENETIC STUDIES (SOLAN)

The data collected from Solan revealed considerable variation for almost all the characters studied (Table 1). The values of phenotypic variability was higher than genotypic variability. However, plant height showed larger environmental variances than genotypic one which is due to the influence of environment on the expression of this trait. Genotypic

Table 1. Variability estimates for important furocoumarin contributing parameters in *Heracleum candicans* Wall. at Solan

Character	Mean	SE	Variance			Coefficient of variability (%)		
			pheno-typic	geno-typic	environ-mental	pheno-typic	geno-typic	environ-mental
Plant height (cm)	56.6	6.5	118.8	55.8	63.0	19.3	13.2	14.0
No. of leaves/plant	18.0	1.4	20.1	17.2	2.9	25.0	23.1	9.5
Leaf area (cm^2)	170.4	7.9	2587.5	2493.9	93.6	29.8	29.3	5.7
Fresh leaf yield/plant (g)	80.7	2.2	832.3	825.1	7.2	35.7	35.7	3.3
Days to flowering	182.6	4.3	56.7	29.5	27.3	4.1	3.0	2.9
Root length (cm)	29.7	2.0	13.5	7.3	6.2	12.4	9.1	8.3
Root diameter (mm)	37.7	1.5	8.4	4.8	3.7	9.0	6.5	5.7
No. of secondary roots/plant	34.7	1.3	22.0	19.5	2.5	13.5	12.7	4.6
Secondary root length (cm)	19.7	1.5	25.1	21.8	3.3	25.4	23.7	9.2
Fresh root yield/plant (g)	231.0	11.0	5095.2	4912.1	183.0	30.9	30.3	5.9
Fresh root yield/ha (q)	118.9	14.5	1480.2	1166.0	314.2	32.4	28.7	14.9
Dry root yield/ha (q)	47.7	5.9	230.5	178.3	52.2	31.8	28.0	15.1
Furocoumarin content in roots (%)	6.6	0.3	4.5	4.4	0.1	31.9	31.6	4.6
Furocoumarin yield (kg/ha)	329.4	132.6	31547.0	29957.0	1590.2	53.9	52.5	12.1

variation was also high for leaves per plant, leaf area, fresh leaf yield/plant, number of secondary roots per plant, secondary root length, fresh root yield/plant, yield in q/ha, dry root yield, furocoumarin content, and yield (kg/ha), indicating large amount of genetic component for these characters which can be easily exploited for selection of superior lines in this crop [5]. The genotypic coefficient of variability (GCV) was in the range of phenotypic coefficient of variability (PCV), but greater GCV has been found to be associated with higher genetic variances. GCV ranged from 6.5% in root diameter to 52.5% for furocoumarin yield. Similarly, broad sense heritability was above 50% for all characters, except for plant height, where it is only 46.9% (Table 2). Maximum heritability of 99.1% has been found in fresh leaf yield, followed by furocoumarin content (97.8%) and fresh root yield per plant (96.4%), whereas maximum genetic gain was obtained for furocoumarin yield (105.4%), followed by fresh leaf yield (72.9%) and furocoumarin content (64.1%). This trend clearly indicate that these characters contain good amount of heritable additive genetic component which can

easily be exploited for further improvement. Although the characters fresh root yield, days to flowering and secondary root length registered heritability above 50% but the expected genetic gain is very low, indicating that these characters, in addition to additive genetic components, also have higher order of interactions, which is interfering in the expression of these characters.

Table 2. Estimates of genetic parameters studied in *Heracleum candicans* Wall. at Solan

Character	Heritability (%)	Genetic advance	Genetic gain (%)
Plant height	47.0	10.5	18.6
No. of leaves/plant	85.4	7.9	43.9
Leaf area	96.4	100.9	59.3
Fresh leaf yield/plant	99.1	58.9	72.9
Days to flowering	51.9	8.1	4.4
Root length	54.3	4.1	13.8
Root diameter	56.6	3.4	10.0
No. of secondary roots/plant	88.4	8.5	24.6
Secondary root length	86.8	9.0	45.4
Fresh root yield/plant	96.4	141.7	61.4
Fresh root yield/ha	78.8	62.4	52.5
Dry root yield/ha	77.4	24.2	50.7
Furocoumarin content roots	97.8	4.3	64.2
Furocoumarin yield/ha	95.0	347.2	105.4

VARIABILITY ESTIMATES AND GENETIC STUDIES (BAJAURA)

The results obtained from the experiment conducted at Bajaura broadly gave similar trend, where, primary and secondary root length registered environmental variance higher than the genotypic ones which shows influence of environment on the expression of these two characters (Table 3). High genetic variation were obtained for furocoumarin yield, fresh root yield/plant, fresh leaf yield, leaf area and fresh root yield, indicating the presence of larger amount of genetic component for these characters which can be successfully exploited in the improvement of this crop. The GCV was in the range of PCV and this trend was associated with higher genetic variances as well. However, root length and secondary root length showed higher environmental coefficient of variability than the GCV. Heritability was more than 80% for all the characters except primary and secondary root length, where it was only 40 and 41% respectively (Table 4). High heritability to the extent of 99% was recorded for furocoumarin yield and dry root yield, followed by fresh root yield, furocoumarin content, number of secondary roots per plant, plant height, and leaf area. These high values of heritability are also reflected in higher genetic gains for these characters, but not for days to flowering, leaf area, plant height and root diameter.

VARIABILITY ESTIMATES AND GENETIC STUDIES BASED ON POOLED DATA OF BOTH LOCATIONS

In the pooled analysis also, similar trend was observed for all characters as observed at Solan and Bajaura separately (Table 5). However, the estimates are slightly low and vitiating, which may be due to the balancing effect caused by pooling of the values.

Table 3. Variability estimates for important furocoumarin contributing parameters in *Heracleum candicans* Wall. at Bajaura

Character	Mean	SE	Variance			Coefficient of variability (%)		
			pheno-typic	geno-typic	environ-mental	pheno-typic	geno-typic	environ-mental
Plant height (cm)	64.6	2.8	115.3	103.9	11.4	17.0	16.0	5.0
No. of leaves/plant	24.4	2.3	43.4	35.4	8.0	27.1	24.0	12.0
Leaf area (cm^2)	170.9	5.5	402.0	355.1	46.9	11.7	11.0	4.0
Fresh leaf yield/plant (g)	80.5	6.9	513.5	440.9	75.5	28.0	26.0	11.0
Days to flowering	208.1	5.1	285.6	247.2	38.4	8.1	8.0	3.0
Root length (cm)	30.9	2.4	14.3	5.8	8.6	12.0	8.0	9.0
Root diameter (mm)	30.6	2.1	37.9	31.5	6.4	20.0	18.0	8.0
No. of secondary roots/plant	26.1	2.0	70.2	64.1	6.0	32.0	31.0	9.0
Secondary root length (cm)	16.3	1.9	9.2	3.8	5.4	19.0	12.0	14.0
Fresh root yield/plant (g)	103.9	4.7	1613.6	1580.1	33.5	39.0	38.0	6.0
Fresh root yield/ha (q)	51.5	2.4	395.4	387.2	8.3	39.0	38.0	6.0
Dry root yield/ha (q)	25.7	1.1	172.9	170.9	1.9	51.0	51.0	5.0
Furocoumarin content in roots (%)	7.1	0.3	2.3	2.2	0.1	21.0	21.0	5.0
Furocoumarin yield (kg/ha)	191.6	10.5	15949.0	15783.0	165.9	66.0	66.0	7.0

Unlike the two sites considered individually, none of the characters showed conspicuous environmental effects in pooled analysis. High genotypic variances were observed for all the traits at individual location, but the remaining characters showed genotypic variances in the same range as phenotypic variances. Coefficient of variability (CV) at phenotypic, genotypic and environmental levels also showed similar trends where dry root yield, furocoumarin content and number of leaves/plant showed higher values.

As regards heritability (Table 6), the values ranged between 60.6% for root length to 98.3% for furocoumarin

Table 4. Estimates of genetic parameters studied in *Heracleum candicans* Wall. at Bajaura

Character	Heritab-ility (%)	Genetic advance	Genetic gain (%)
Plant height	90.1	19.9	30.9
No. of leaves/plant	81.5	11.1	45.4
Leaf area	88.3	36.5	21.3
Fresh leaf yield/plant	85.9	40.5	49.8
Days to flowering	86.6	34.8	16.7
Root length	40.0	3.1	10.1
Root diameter	83.0	10.5	34.4
No. of secondary roots/plant	91.0	15.7	60.1
Secondary root length	41.0	2.6	15.6
Fresh root yield/plant	98.0	81.1	78.0
Fresh root yield/ha	98.0	40.1	78.0
Dry root yield/ha	99.0	26.8	104.2
Furocoumarin content in roots	95.0	3.0	41.5
Furocoumarin yield/ha	99.0	257.6	134.3

Table 5. Variability estimates for important furocoumarin contributing parameters in *Heracleum candicans* Wall. based on pooled data of both locations

Character	Mean	SE	Variances			Coefficient of variability (%)		
			pheno-typic	geno-typic	environ-mental	pheno-typic	geno-typic	environ-mental
Plant height (cm)	60.6	4.0	103.6	79.0	24.4	16.8	14.7	8.2
No. of leaves/plant	21.2	1.7	28.9	24.4	4.5	25.3	23.3	9.9
Leaf area (cm^2)	170.5	5.1	1165.4	1126.5	38.9	20.0	19.7	3.7
Fresh leaf yield/plant (g)	80.6	3.7	603.6	583.5	20.1	30.5	30.0	5.6
Days to flowering	195.5	3.8	134.5	113.0	21.5	5.9	5.4	2.4
Root length (cm)	31.0	1.5	8.7	5.2	3.4	9.7	7.5	6.1
Root diameter (mm)	32.2	1.3	12.4	9.7	2.7	11.0	9.7	5.1
No. of secondary roots/plant	30.4	1.0	25.0	23.6	1.5	16.5	16.0	4.0
Secondary root length (cm)	18.0	1.3	9.7	7.1	2.6	17.3	14.8	8.9
Fresh root yield/plant (g)	167.5	6.1	1642.3	1587.1	55.2	24.2	23.8	4.4
Fresh root yield q/ha (q)	85.4	6.5	464.0	401.5	62.5	25.2	23.5	9.3
Dry root yield/ha (q)	36.7	2.8	102.3	90.8	11.6	27.5	25.9	9.3
Furocoumarin content in roots (%)	6.9	0.2	2.9	2.8	0.1	24.7	24.5	3.8
Furocoumarin yield/ha (kg)	262.7	18.7	14586.0	14060.0	526.0	45.8	45.1	8.7

content. Except for plant height, root diameter, and secondary root length all other characters registered above 84.0% heritability. This high heritability values did not contribute much to genetic advance and subsequent genetic gain. However, only furocoumarin content dry root yield, and fresh leaf yield showed medium genetic gain. Other characters like leaf area, days to flowering and number of secondary roots per plant, despite high heritability, did not show the expected genetic gain and thus can be said to have more nonadditive genetic effects than the additive genetic effects [6–9].

It was also observed that furocoumarin content and yield, fresh

Table 6. Estimates of genetic parameters studied in *Heracleum candicans* Wall. based on pooled data of both locations

Character	Heritability (%)	Genetic advance	Genetic gain (%)
Plant height	76.5	16.0	26.5
No. of leaves/plant	84.4	9.4	44.0
Leaf area	96.6	68.0	39.9
Fresh leaf yield/plant	96.6	48.9	60.7
Days to flowering	84.0	20.1	10.3
Root length	60.6	3.7	12.0
Root diameter	78.4	5.7	17.7
No. of secondary roots/plant	94.2	9.7	31.9
Secondary root length	73.4	4.7	26.2
Fresh root yield/plant	96.6	80.7	48.2
Fresh root yield/ha	86.5	38.4	44.9
Dry root yield/ha	88.7	18.5	50.3
Furocoumarin content in roots	98.3	3.4	50.0
Furocoumarin yield/ha	96.4	239.8	91.3

root yield, number of leaves per plant, leaf area and number of secondary roots per plant had high heritability coupled with high genetic gain even at 5% selection pressure. Thus, these characters can form good selection index for evolving strains with high root and furocoumarin yield per unit area of the land in this species.

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