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ORIGINAL PAPER

Quantification of genetic variability and stable genotype selection over the years in the germplasm of critically endangered Prishanparni (*Uraria picta* Desv.)

Priyanka Prasad · Nashra Aftab · Ram Kishor · Himanshu Kumar Kushwaha · Vagmi Singh · Aishwarya Srivastava · Karuna Shanker · R. K. Lal · Birendra Kumar

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Abstract Prishanparni (*Uraria picta* Desv.), a critically endangered annual shrub belonging to the family 'Papillionaceae'. It is widely distributed throughout India, Sri Lanka, Bangladesh, Tropical Africa, Malay Islands, and the Philippines. The consistent performances of *U. picta* accessions based on ten economic traits studied were identified as P-12, P-16, P-21, P-22, P-31, P-47, and P-48. These accessions could be used for commercial cultivation in northern Indian plains. Among the total twenty-three studied accessions P-50, P-21, P-48, and P-47 were found superior for rhoifolin content in their aerial as well as root part, which may have various therapeutic potentials used in traditional and modern systems of medicines. These accessions can be exploited for commercial cultivation or in a hybridization program for further crop improvement. Wide range cultivation of the selected accessions in the Indo-Gangetic plains will fit in the existing cropping systems of this region, resulting in comparatively better supplementation of herb to the pharmaceutical and herbal drug industries and reducing the pressure on the wild populations.

Keywords Bioactive compounds · Dashmoola · G × E interactions · Prishanparni · Stability

Introduction

Prishanparni is the popular name for *Uraria picta* Desv. (2n = 22), a severely endangered annual plant in the Papillionaceae family. It can be found in India, Sri Lanka, Bangladesh, Tropical Africa, the Malay Islands, and the Philippines (Kirtikar et al., 1993; Yusuf et al., 1994; Thong-on et al., 2013). It is one of the constituents in Dashmula, which is utilized in the indigenous system of medicine. The Dashmula drug is a combination of the root of ten medicinal plants, involving Bilva (*Aegle marmelos*), Agnimantha (*Premna integrifolia*), Shoynaka (*Oroxylum indicum*), Gambhari (*Gmelina arborea*), Patla (*Sterospermum suaveolens*), Shalaparni (*Desmodium gangeticum*), Prishnaparni (*Uraria picta*), Brahati (*Solanum indicum*), Kantkari (Solanum *xanthocarpum*), and Gokshuran (*Tribulus terrestris*), utilized in the treatment of general fatigue, oral sores, and several gynecological disorder. Almost every part of *U. picta* has medicinal value; the fruits and pods are used to cure mouth sores, while the roots are used to treat chills, cough, and fever

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P. Prasad · N. Aftab · R. Kishor · H. K. Kushwaha · V. Singh · A. Srivastava · R. K. Lal · B. Kumar (✉)
Seed Quality Lab, Genetics and Plant Breeding Division, CSIR-Central Institute of Medicinal and Aromatic Plants, Lucknow, Uttar Pradesh 226015, India
e-mail: b.kumar@cimap.res.in

K. Shanker
Chemical Sciences Division, CSIR-Central Institute of Medicinal and Aromatic Plants, Lucknow, Uttar Pradesh 226015, India

(Kirtikar et al., 1993; Yusuf et al., 1994). The major biologically active flavonoid, rhoifolin exhibits a wide range of activities exhibiting effectiveness against vasorelaxing (Yadav et al., 2009), hypodynamic (Occuhiuto et al., 1990), pulmonary hypertensive cases (Occuhiuto and Limardi, 1994). It also exhibits anti-inflammatory, anti-thrombotic, anti-hepatic properties and is used in treatment of Alzheimer's disease due to their free radical scavenging activity (Yadav et al., 2009).

It is classified as threatened shrub by the IUCN Red Data Book because of unplanned extensive collection from natural sources for pharmaceutical/herbal medication businesses. The quality of ayurvedic formulations such as Dashmoolarisht, Sudarshanchuran, and others has been harmed by an uneven quality profile reported in the chemical ingredient of the plant. Hence, there is a need for organized commercial cultivation of this shrub to meet its high market demand (Prasad et al., 2012; Rakotondralambo et al., 2013). The quality and efficacy of the herb have been established based on biologically active marker compound rhoifolin (Apigenin-7-O-neohesperidoside) analyzed through liquid chromatographic analysis (Yadav et al., 2009). The ultrasonic extraction (30 min at 40 °C) with methanol solvent is a highly optimized extraction method for screening of rhoifolin in raw material of *U. picta* and in the herbal products (Yadav et al., 2009).

Since biomass production and biosynthesis of secondary metabolites in medicinal herbs are significantly influenced by genotype (G), environment (E), and genotype (G) × environmental (E) interactions. Thus, a multi-environment trial was conducted to study the performance of genotypes across a range of environmental conditions, genotype × environment interaction (GE), and genotype stability. The result of study would be recommending stable genotypes having relatively consistent performance for commercial cultivation in a particular environmental niche (Rahajanirina et al., 2012; Randriamampionona et al., 2007; Thomas et al., 2010).

No breeding strategies on stability of genotype × environment interaction have been conducted on *U. picta*. The goal of this study is to analyze the Indian Prishnaparni germplasm based on field experiments and identify those accessions (s) which are widely accepted for cultivation in the Indo-Gangetic plains (Fig. 1).

Materials and methods

Planting and experimental lay-out

The twenty-three accessions of *U. picta* used in this study were originally collected from different geographical regions of Uttar Pradesh and Uttarakhand i.e., Lucknow, Padrauna, Basti, Ambedkar Nagar districts of Uttar Pradesh and Dehradun and Nainital (Haldwani) districts of Uttarakhand, respectively (Table 4). The experiments were conducted at the experimental field station of CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow, India (northern Indo-Gangetic plains; 25.5^{o}N latitude, 80.5^o E longitude, an altitude of 128 m above mean sea level (amsl)). The seeds were exposed to presowing conditions to break the dormancy mechanism imposed by keeping the seeds at room temperature in a glass bottle. Seeds were sown at a depth of 3 cm, during the month of July in each year 2017 and 2018. Seedling emergence and germination in the field were recorded at regular intervals from 7th day of sowing. Four-week-old seedlings with 6–8 leaflets were transplanted during the last week of August each year 2017 and 2018 in the experimental plot (20 m^2 plots). With the row to row and plant to plant spacing of 15 × 15 cm^2 in a randomized block design (RBD) for each consecutive year (2017 and 2018) with three replications per accession. Before transplanting, the soil was fertilized with a standard fertilization regime of 50 kg N + 80 kg P_2O_5 + 80 kg K_2O/ha, respectively. The texture of soil at the experimental location is sandy-loam with pH 7.8. The climate of the experimental site is demonstrated as semi-arid subtropical with severe hot summer and cool winter. The mean maximum (32.9, 32.3) and minimum (23.8, 23.0) temperature (Fig. 2a), mean maximum (83.3, 79.6) and minimum (59.2, 60.3) relative humidity (Fig. 2b) in 2017 and 2018, respectively. The onset of monsoon in this region occurs from the month of June to the month of September. The average rainfall for the planting season is 5.4 and 5.1 mm for each year 2017 and 2018, respectively (Fig. 2c). The soil was subsequently irrigated at 7–10 days intervals as per requirement of the field.

On full maturation, five plants were uprooted from each accession for recording morpho-metric and yield attributing data in November (150 days from sowing) in both years: 2017 and 2018 involving eight

Fig. 1 I. Leaf morphological variation at nursery stage (**a**: P-2, **b**: P-47, **c**: P-48, **d**: P-51, **e**: P-52, **f**: P-50); II. Leaf morphological variation at mature stage (**a**: P-21, **b**: P-16, **c**: P-25, **d**: P-50), III. Mature leaf of P-50; IV. Seed colour variation (**a**: P-31, **b**: P-50, **c**: P-10, **d**: P-52, **e**: P-22, **f**: P-51); V. Plant height variation (**a**: P-50, **b**: P-47, **c**: P-4, **d**: P-22)

economical traits viz. plant height (cm), root length (cm), inflorescence length (cm), number of leaves per plant, leaf length (cm), leaf width (cm), fresh aerial part yield per plant (gm), and fresh root yield per plant (gm).

HPLC analysis for Rhoifolin

The dried uprooted plants were used to determine the percentage of rhoifolin content in aerial and root parts for the aforementioned accessions using the HPLC method following the protocol of Yadav et al. (2009) for both succeeding years (2017 and 2018).

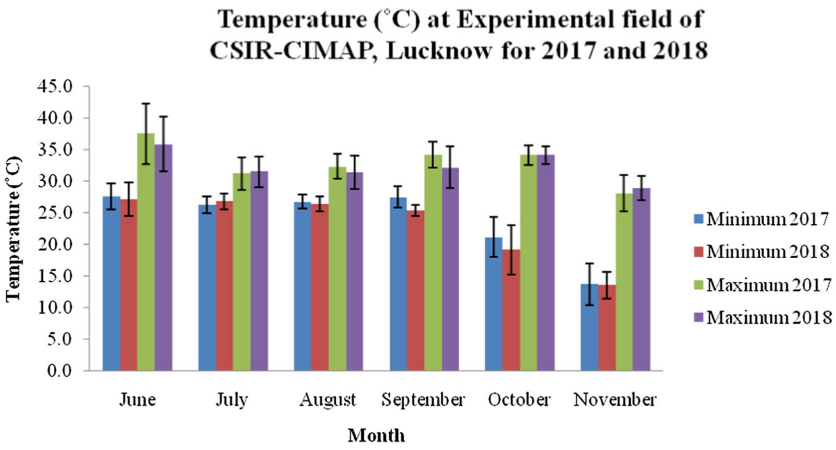
Statistical analysis

The year-wise analysis of variance (ANOVA), pooled mean analysis of variance (ANOVA), and mean performance of ten traits of the twenty-three accessions for the two consecutive years (2017 and 2018) were done using statistical analysis software ver. 3.0 available at the Department of Genetics and Plant Breeding of CSIR-CIMAP, Lucknow based on Panse and Sukhatme (1967) and Singh and Chaudhary (1985). All the values at $p < 0.01$ and $p < 0.05$ were considered significant.

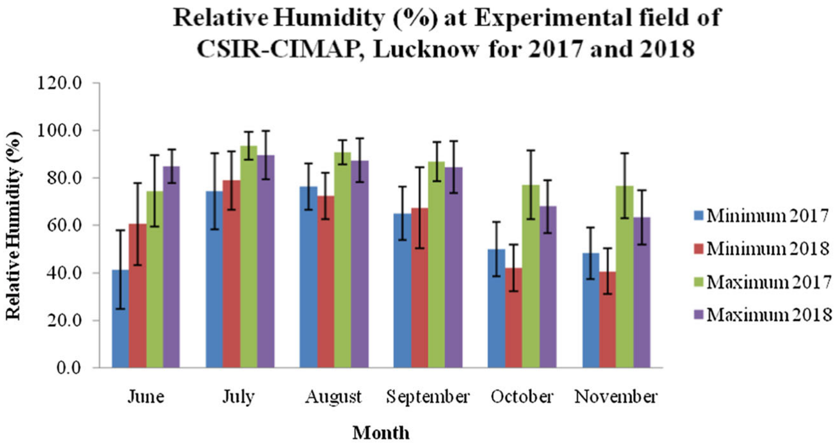
Results and discussion

Analysis of variance revealed that the mean sum of squares due to genotype showed highly significant for all the quantitative and qualitative characters in both years (Tables 1 and 2). The pooled ANOVA for genotype, year, and genotype × year interactions were found to be significant ($p < 0.01$) for all the

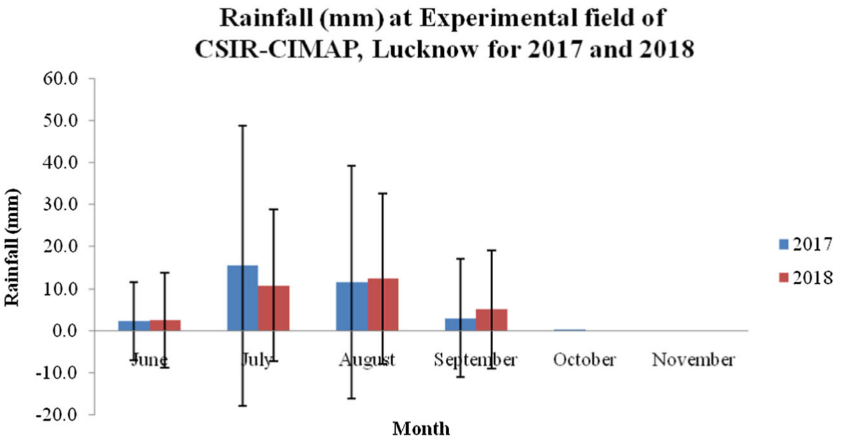
Fig. 2 **a** Temperature (°C) at Experimental field of CSIR-CIMAP, Lucknow from the month of June to November of 2017 and 2018. **b** Relative Humidity (%) at Experimental field of CSIR-CIMAP, Lucknow from the month of June to November of 2017 and 2018. **c** Rainfall (mm) at Experimental field of CSIR-CIMAP, Lucknow from the month of June to November of 2017 and 2018



(a) Temperature (˚C) at Experimental field of CSIR- CIMAP, Lucknow from the month of June to November of 2017 and 2018.



(b) Relative Humidity (%) at Experimental field of CSIR-CIMAP, Lucknow from the month of June to November of 2017 and 2018.



(c) Rainfall (mm) at Experimental field of CSIRCIMAP, Lucknow from the month of June to November - of 2017 and 2018.

Table 1 Analysis of variance (ANOVA) for different morpho-chemical traits on 23 genotypes of *U. picta* grown for Ist year (2017) at CSIR-CIMAP, Lucknow

Source of Variation	df	Mean sum of squares (MSS)									
		Plant height	Root length	Inflorescence length	No. of Leaves	Leaf length	Leaf width	Aerial part weight	Root weight	Rhoifolin in aerial part	Rhoifolin in root part
Replication	2	17.9258	4.0537	7.242	3.5801	8.749	0.0632	2.5147	0.558	0.0172	0.0001
Treatment	22	884.65**	67.7519**	100.9008**	248.715**	23.216**	0.0751**	57.34**	3.982**	0.1557**	0.0074**
Error	44	9.7003	6.1165	22.1974	20.458	1.6721	0.0289	1.7599	0.2885	0.0126	0.0008

Table 2 Analysis of variance (ANOVA) for different morpho-chemical traits on 23 genotypes of *U. picta* grown for IIst year (2018) at CSIR-CIMAP, Lucknow

Source of Variation	df	Mean sum of squares (MSS)									
		Plant height	Root length	Inflorescence length	No. of Leaves	Leaf length	Leaf width	Aerial part weight	Root weight	Rhoifolin in aerial part	Rhoifolin in root part
Replication	2	34.281	23.869	8.0146	0.8828	3.178	0.036	0.193	1.647	0.0007	0.0001
Treatment	22	492.407**	49.775**	73.666**	215.333**	16.723**	0.121**	8.668**	4.747**	0.1124**	0.0006**
Error	44	50.517	16.97	8.2417	18.596	2.327	0.03	0.709	0.599	0.007	0.0001

Table 3 Pooled Analysis of variance (ANOVA) of G × Y interaction for different morpho-chemical traits on 23 genotypes of *U. picta* grown for two consecutive years (2017 and 2018) at CSIR-CIMAP, Lucknow

Source of Variation	d.f	Mean sum of squares (MSS)									
		Plant height	Root length	Inflorescence length	No. of Leaves	Leaf length	Leaf width	Aerial part weight	Root weight	Rhoifolin in aerial part	Rhoifolin in root part
Replication	2	21.531	22.355	4.225	0.609	0.689	0.03	0.885	1.681	0.008	0.0001
Treatment	45	774.565**	77.682**	125.84**	228.175**	24.263**	0.094**	35.039**	4.296**	0.129**	0.005**
Years	1	5334.516**	987.746**	1948.133**	286.961**	237.397**	0.019	159.584**	5.544**	0.057*	0.059**
Genotype	22	637.65**	67.602**	1504.91**	359.1**	20.638**	0.146**	40.27**	6.897**	0.162**	0.004**
Genotype × Year	22	739.416**	49.926**	2335.578**	104.949**	19.302**	0.051	25.739**	1.833**	0.106**	0.004**
Error	90	30.188	11.413	1361.383	19.179	2.205	0.031	1.248	0.446	0.01	0.00041

studied economic traits except for leaf width which showed non-significance at year and genotype × year interaction (Table 3). Interaction of rhoifolin content in aerial part at year level was significant at $p < 0.05$. Evaluation trials were conducted in two years to study the effect of G × E interaction. For the same reason, the data about environmental variations in the morpho-metric traits and rhoifolin content in aerial and root part (%) of the twenty-three accessions under Lucknow agro-climatic conditions are summarized in Tables 4. The data suggest that significance among treatments at genotype level could be due to collection of genotypes from different geo-climatic zonal distribution and genotype by environment interaction (Gupta, 2018a, 2018b; Lal, 2013; Lal et al., 2019; Shukla et al., 2018). While the significant difference at year and genotype × year interactions could be attributed to change in humidity, precipitation, climatic conditions, soil condition, or other cultivation practices pursued during the cropping season (Prasad et al., 2014, 2016; Yadav et al., 2018a, 2018b).

Yield and its components are polygenic traits strongly influenced by the environment in *U. picta*. Summarizing the mean data of the morpho-metric traits and rhoifolin content of twenty-three accessions for each consequent year 2017 and 2018 are presented in Table 4. It was prominently elucidated the significant variation among the genotype, year, and genotype × year interactions studied. Among the genotypes studied, the most stable plant height was obtained by P-31 (27.66 cm in both years) followed by P-21 (31.33 cm in 2017 and 31.66 in 2018); while the highest plant height was recorded for P-50 (90 cm in 2018), followed by P-51 (87.66 cm in 2017). With regard to root length, the most superior and stable performance was attained by the genotype P-50 (28.33 cm) followed by P-5 (21.66 cm), P-31 (19.33 cm), and P-4 (21.66 cm in 2017 and 22.00 cm in 2018). Plant height and root length are the most sensitive to environmental fluctuations. It is indicated that the relative inconsistent performance of other genotypes was marked due to genotype and environment interaction. For the inflorescence length, the genotype P-50 (35.00 cm in 2018) followed by P-44 (34.33 cm in 2017) projected the highest inflorescence length which could be directly correlated with larger seed formation. The most stable inflorescence length was achieved by P-16 (16.66 cm)

Table 4 Morphological and bioactive compound comparison of *U. picta* accessions for two consecutive years (I = 2017 and II = 2018) under agro-climatic conditions of Lucknow

Accession no	Origin/places of collection	Plant height (cm)		Root length (cm)		Inflorescence length (cm)		No. of Leaves		Leaf length (cm)		Leaf width (cm)		Aerial part weight (gm)		Root weight (gm)		Rhoifolin in aerial part (%)		Rhoifolin in root part (%)	
Year		I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
P- 1	Lucknow	22.00	44.33	17.33	21.66	25.00	13.33	25.66	25.00	10.66	5.93	1.40	1.50	5.91	4.09	1.47	3.08	0.37	0.40	0.06	0.00
P- 2	Dehradun	25.00	32.00	18.33	26.66	20.33	13.33	20.00	23.66	17.16	6.36	1.36	1.43	5.70	1.63	1.47	1.08	0.20	0.36	0.01	0.01
P- 4	Haldwani	27.00	39.66	21.66	22.00	31.33	11.66	27.00	19.66	12.66	6.10	1.50	1.66	3.76	2.31	1.36	1.92	0.61	0.33	0.03	0.02
P- 5	Haldwani	25.33	44.33	21.66	21.66	31.00	13.66	32.33	22.33	11.33	6.33	1.33	1.50	2.17	1.78	2.42	3.84	0.35	0.20	0.06	0.01
P-11	Haldwani	23.33	42.33	19.83	16.66	24.66	13.00	33.66	40.00	11.33	6.40	1.50	1.66	2.43	1.81	1.23	1.34	0.38	0.47	0.18	0.02
P-12	Haldwani	21.33	40.00	20.17	17.33	25.00	12.33	29.00	22.66	14.00	8.00	1.56	1.33	3.73	2.37	2.10	1.61	0.43	0.57	0.04	0.03
P-16	Haldwani	20.00	52.00	17.83	20.66	16.66	16.66	24.33	27.33	9.09	9.00	1.33	1.33	3.53	2.82	2.20	1.66	0.36	0.24	0.03	0.02
P-17	Haldwani	25.66	41.66	19.33	28.00	24.66	16.00	30.00	23.00	7.63	9.00	1.16	1.46	5.79	2.38	2.54	2.59	0.09	0.23	0.01	0.01
P-21	Haldwani	31.33	31.66	20.16	24.33	29.00	15.66	32.33	31.00	12.16	9.33	1.46	1.33	3.71	1.94	2.52	2.43	0.27	0.73	0.14	0.03
P-22	Haldwani	23.00	56.66	16.33	21.00	21.66	18.33	30.00	30.00	12.66	13.00	1.43	1.36	5.73	1.62	1.37	1.52	0.46	0.69	0.05	0.05
P-25	Haldwani	21.00	38.33	12.33	21.66	19.66	15.66	30.00	17.66	10.50	10.00	1.30	1.56	3.55	1.62	1.32	1.73	0.75	0.48	0.03	0.02
P-29	Haldwani	22.66	50.33	17.83	24.33	19.00	13.66	24.33	29.00	9.59	10.66	1.66	1.50	4.69	3.15	1.70	2.00	0.33	0.20	0.03	0.05
P-31	Haldwani	27.66	27.66	19.33	19.33	17.00	17.00	31.66	31.66	10.66	10.66	1.66	1.16	4.93	4.92	2.54	2.53	0.34	0.27	0.03	0.02
P-34	Haldwani	31.66	47.33	28.33	31.33	26.00	13.00	31.33	26.33	15.66	8.33	1.46	1.40	6.33	4.23	2.72	2.96	0.16	0.51	0.06	0.04
P-39	Haldwani	27.66	46.66	17.33	22.00	24.33	11.00	37.66	26.00	9.50	10.33	1.26	1.33	2.93	3.29	1.72	2.08	0.60	0.49	0.10	0.01
P-41	Haldwani	28.00	40.66	20.33	30.33	22.00	13.00	30.00	26.33	11.83	10.33	1.36	1.36	3.16	3.05	1.66	2.63	0.22	0.45	0.03	0.01
P-44	Haldwani	64.66	45.00	20.33	26.66	34.33	17.00	60.00	35.00	14.66	12.00	1.56	1.66	5.07	2.95	2.31	2.32	0.69	0.34	0.03	0.01
P-47	Haldwani	25.33	42.33	20.83	19.33	21.33	21.00	28.33	24.00	12.86	10.66	1.63	1.40	2.22	2.53	1.16	1.98	0.67	0.39	0.19	0.02
P-48	Haldwani	22.33	53.33	16.33	27.66	25.33	15.66	30.00	31.66	12.50	13.00	1.46	1.36	2.60	4.21	1.52	0.87	0.78	0.12	0.09	0.01
P-49	Haldwani	18.66	51.66	9.43	28.33	11.16	19.00	16.66	31.66	8.83	9.00	1.13	1.43	1.24	5.94	0.73	3.62	0.24	0.18	0.05	0.01
P-50	Padrauna	52.33	90.00	28.33	28.33	22.66	35.00	50.33	58.33	14.43	14.66	1.73	2.10	17.28	8.87	5.75	7.27	1.01	0.75	0.07	0.00
P-51	Basti	87.6	28.33	12.33	22.33	29.00	10.66	36.33	22.00	19.33	9.60	1.50	1.13	19.42	1.87	4.53	2.67	0.43	0.67	0.01	0.02
P-52	Ambedkar Nagar	57.66	31.00	9.00	25.33	12.00	14.66	21.66	22.00	10.66	10.66	1.33	1.26	5.43	2.47	3.43	1.61	0.39	0.09	0.02	0.01

I = Ist Year = 2017; II = IInd Year = 2018 followed by P-31 (17.00 cm) and P-47 (21.33 cm for 2017 and 21.00 for 2018).

Plant height, leaf, and seed morphological variation are the primary descriptor for characterization of germplasm. However, very few attempts have been conducted on characterizing the germplasm/accessions based on descriptor data in *U. picta*. In the present study plant, seed, and leaf descriptor data for diverged accessions in the collection is represented in Fig. 1. These descriptor data are important for the identification and categorization of new or existing clones, identification of duplicate accessions, determining relative relationships among accessions, establishment of core collections, and selecting parental materials in breeding programs (Huaman, 1992). Leaf morphological characteristics reflected wide range of diversity among collected germplasm of *U. picta*. In relation to the number of leaves, it was observed that P-22 (30.00 cm) and P-31 (31.66 cm) demonstrated the most stable trait for the two years studied followed by P-21 (32.33 cm for 2017 and 31.00 for 2018). While in reference to leaf length, the stable performance was presented by P-31 (10.66 cm) followed by P-16 (9.09 cm in 2017 and 9.00 cm in 2018) and in case of leaf width, genotype P-16 (1.33 cm) followed by P-41 (1.36 cm) was recorded stable in the study.

Aerial part weight and root part weight are the major economic traits and are important for successful agronomic practices and industrial demand. Thus, exploiting the highest aerial part weight was observed in genotype P-51 (19.42 gm in 2017) followed by P-50 (17.28 gm in 2017 and 8.87 gm in 2018), whereas for root part weight, genotype P-50 (5.75 gm in 2017 and 7.27 gm in 2018) was recorded highest. While the most stable genotype for aerial part weight was recorded in P-31 (4.93 gm in 2017 and 4.92 gm in 2018) followed by P-41 (3.16 gm in 2017 and 3.05 gm in 2018), and root part weight was revealed by genotype P-44 (2.31gm and 2.32 gm) followed by P-31 (2.52 gm and 2.53 gm) and P-17 (2.54 gm and 2.59 gm) in 2017 and 2018, respectively.

WHO and modern pharmacopeia give strong emphasis on the content (%) of biologically active compounds for determining the quality and efficacy of medicinal plants (Saxena et al., 2016; Sharma et al., 2010; Vasudevan, 2009). The pooled mean percentage of rhoifolin content in aerial parts and root parts of the twenty-three accessions ranged from 0.16% to 1.01% and 0.12% to 0.75% in aerial parts and from 0.01% to 0.19% and 0.00% to 0.05% in root parts for 2017 and 2018, respectively (Fig. 3). The accession P-50 (1.01%) was recorded to establish the highest rhoifolin content (%) in aerial parts followed by accession P-48 (0.78%) and P-25 (0.75%), while the highest rhoifolin content in the root part was depicted by P-47 (0.19%) followed by P-11 (0.18%) and P-21 (0.14%) (Table 4 and Fig. 4). A superior trend of rhoifolin content in both aerial and root part were observed in P-50 (1.01% and 0.07% in 2017), P-21 (0.73% in 2018 and 0.14% in 2017), P-48 (0.78% and 0.09% in 2017) and P-47 (0.67% and 0.19% in 2017), respectively. Rhiofolin content is higher in the aerial part than in the root part suggesting that the harvesting of aerial parts would be helpful for sustainable exploitation of herb and natural

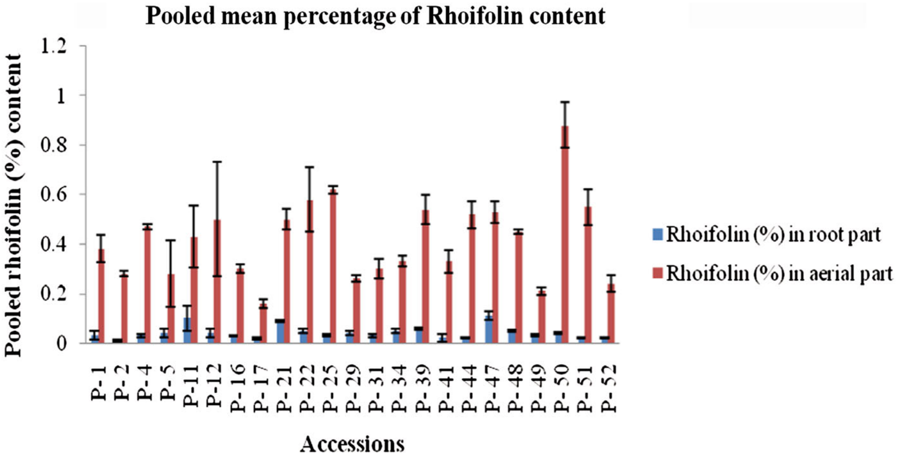
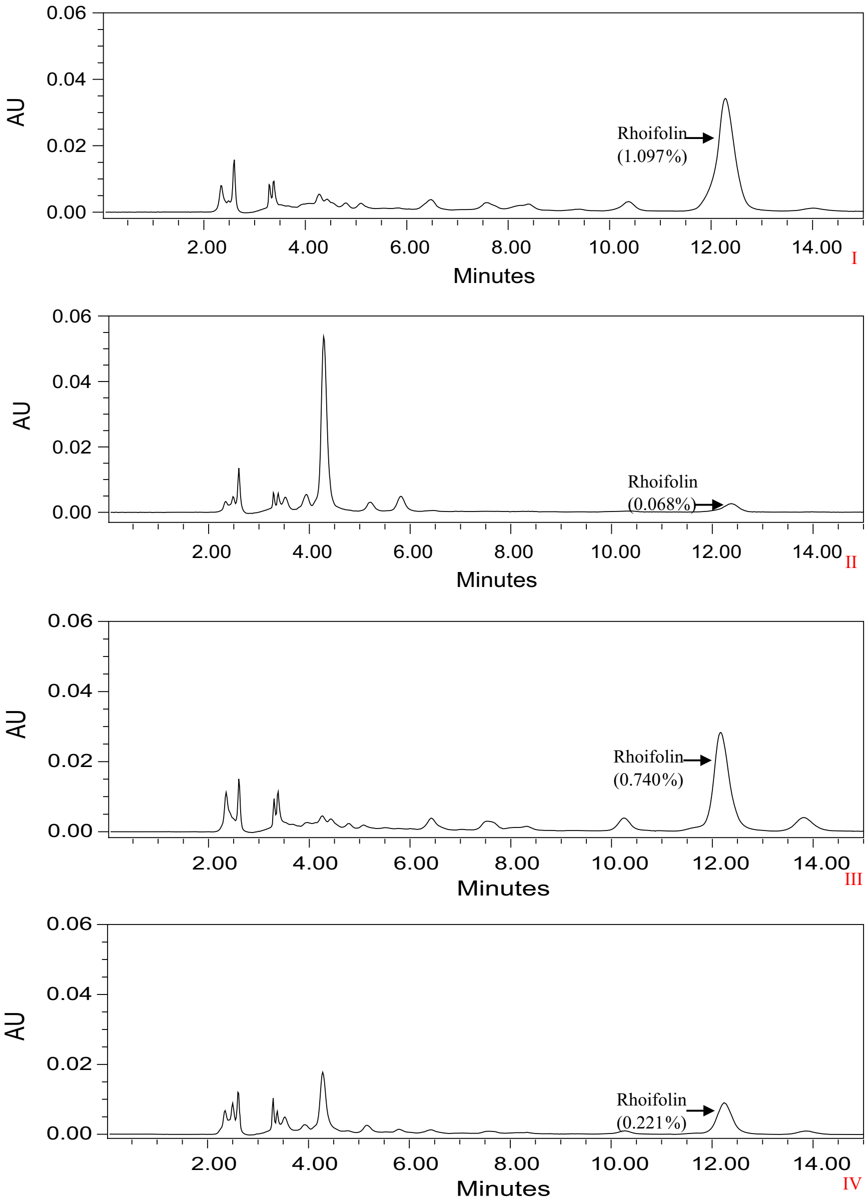


Fig. 3 Pooled mean percentage of rhoifolin content in aerial parts and root parts for two consecutive years (2017 and 2018)

Fig. 4 Representative HPLC chromatograms for peak and percentage content of rhoifolin in (I) aerial part of P-50 (II) root part of P-50 (III) aerial part of P- 47 (IV) root part of P-47



conservation. Few accessions, on the other hand, demonstrated inconsistent rhoifolin content throughout two years, which was most likely due to the consequence of polygenic control, environmental or nongenetic influences, and their combined interaction (G × E interaction). (Kang, 1998; Lal et al., 2018; Prasad et al., 2014; Sarkar & Lal, 2018).

When the performance of the traits was compared between the two years, it was clear that the accessions performed superior for different morpho-metric and yield attributing traits viz., inflorescence length, leaf length, aerial part weight, rhoifolin content in aerial parts, and rhoifolin content in root part in the first year (2017). The accessions performed superior for plant height, root length, and root weight characters in the second consecutive year (2018), while leaf width exhibited non-significant performance for both years.

Overall based on the ten morpho-chemical attributes, the accessions P-12, P-16, P-21, P-22, P-31, P-47, and P-48 displayed a comparable consistent performances pattern in the agro-climatic conditions of the Indo-Gangetic plains for the two consecutive years studied (Table 4). P-50, P-21, P-48, and P-47 had higher rhoifolin content in both aerial and root parts. Other genotypes responded differently in terms of yield-attributing traits in both the years. The result revealed that the genotype-by-environment interaction complicates the process of crop variety generation, reduces the effectiveness of a breeding program aiming at yield improvement (Ahmad et al., 2011). Nonetheless, eight accessions, P-12, P-16, P-21, P-22, P-31, P-47, P-48, and P-50, may be utilized for continued commercial cultivation on a large scale based on mean performances and stability.

Conclusion

To conserve resources, broad adaptation and performance reliability across a variety of situations are commendable goals. To achieve greater success, researchers have focused on the phenomena of genotype environments (G × E) interaction, which allows them to distinguish genotype performance in various settings and to selectively target appropriate genotypes for commercial cultivation to certain environmental niches. P-12, P-16, P-21, P-22, P-31, P-47, and P-48 were found as the consistently performing *U. picta* accessions based on ten morpho-chemical attributes studied. These accessions might be employed for commercial production under the agro-climatic conditions of the Indo-Gangetic plains. Accession P-50, P-21, P-48, and P-47, which have higher rhoifolin content in aerial and root parts, have therapeutic potential and could be used in traditional and modern medicine to treat weariness, oral sores, anti-thrombotic, hepatoprotective, and a variety of gynecological problems.

These accessions can help in commercial cultivation, hybridization, and agricultural enhancement. Wide-scale cultivation of selected accessions in the Indo-Gangetic plains will fit well within the region's managed agricultural cropping systems, ensuring a sustainable and far better supplementation of herb to the industry while reducing the impact of unregulated exploitation of wild populations.

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Author contributions BK and RKL designed the study; PP, NA, RK, HKK, VS, wrote the first draft; AS, wrote the revised draft; KS, chemical analysis and its interpretation; all authors participated in the data collection, elaborated and analyzed the data and critically revised the manuscript.

Data availability The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have no conflict of interest.

Consent to participate All authors have read and agreed with their participation.

Consent to publish All authors have read and agreed to the published version of the manuscript.

Human and animal rights No animals were harmed in this research.

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