

Assessment of availability, ecological feature, and habitat preference of the medicinal herb *Houttuynia cordata* Thunb in the Brahmaputra Valley of Assam, India

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Abstract *Houttuynia cordata* Thunb. is a rhizome-bearing aromatic medicinal herb and is restricted to specialized moist habitats. The plant is collected from natural habitats for local consumption and trade. The status of the species and its variations in physiological performance in different habitats were studied in selected sites of geographically different areas of Brahmaputra valley in eastern India. The surveys were conducted in two different growth stages of the plant during 2005–2007. The sites where the species was encountered were marked and a distribution map was prepared. The frequency and density of the plant was higher in the moist habitats with higher organic carbon ($0.85 \pm 0.05\%$). Generally, the density, biomass production and growth had significant ($P < 0.05$) positive relationship with the soil physicochemical properties (linear curve fit). Soil moisture was the most dependent factor for the plant growth and the optimum growth was recorded at $78 \pm 5.6\%$ ($r^2 = 0.9$; $P \leq 0.01$). The physiological performance of the plant in all the studied sites were

significantly varied ($P < 0.05$). The growth and development of *H. cordata* were also different in the flowering and senescence stages. Clay loam soil, average soil pH of 5.9, and 78% soil moisture were the favorable soil characteristics for the better growth of *H. cordata* and, hence, these data may be considered for conservation of the species.

Keywords Biomass · Ecological features · Conservation · *Houttuynia cordata* · Medicinal plant

Introduction

Houttuynia cordata Thunb (Magnoliophyta: Magnoliopsida: Magnoliidae: Piperales: Saururaceae; Watson and Dallwitz 1992) is the single species of the genus and is native to Japan, South-East Asia, and Himalayas. *H. cordata* is an aromatic medicinal herb with creeping root stock; leaves broad, ovate-cordate; flowers naked in dense spikes, subtended by four white and petaloid bracts (Bora 2001). The root, young shoots, leaves, and sometimes the whole plant is traditionally used to cure various human diseases throughout South-East Asia. *H. cordata*, the well-known traditionally used Chinese medicinal material in China and Japan is listed in the Chinese Pharmacopoeia (The Pharmacopoeia Committee of China 2005).

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Flavonoids, having a wide range of pharmacological activities, including anti-leukemic, anti-oxidative, anti-mutagenic, anti-inflammatory, and anti-viral effects as well as the ability of promoting immunologic activity, are considered as one kind of the effective components of *H. cordata* (Zhang et al. 2008). In Indo-China, the entire plant is considered for cooling, resolvent, and emmenagogue. The leaves are recommended for measles, dysentery, and gonorrhoea and are used in the treatment of eye troubles, skin diseases, hemorrhoids, and in certain diseases of women. Some recent findings on its medicinal properties are anti-inflammatory (Lu et al. 2006), anti-allergic (Kim et al. 2007), virucidal (Chiang et al. 2003), anti-oxidative (Ng et al. 2007), and anti-cancer (Chang et al. 2001; Kim et al. 2001). On steam distillation, the plant yields a light brown essential oil with a strong, somewhat disagreeable odor (Sarkar 1993). About 22 different components were identified in the essential oil, among which *n*-decanoic acid (11%), α -terpineol (13%), β -myrcene (4%), 1-decanol (4%), and methyl nonyl ketone (35%) were the major components (Lu et al. 2006).

Recently, during the period of SARS outbreak, *H. cordata* was one of the ingredients in the SARS prevention formulae recognized by the Ministry of Public Health and the State Administrative Bureau of Traditional Chinese Medicine [TCM] (2003). *H. cordata* exhibited significant inhibitory effects on SARS-CoV 3C-like protease (3CLpro) and RNA-dependent RNA polymerase (RdRp) which was non-toxic to laboratory animals following oral administration at 16 g/kg (Lau et al. 2008). The steam distillate of fresh *H. cordata* could inhibit herpes simplex virus type-1 (HSV-1), influenza virus, and human immunodeficiency virus type-1 (HIV-1) without showing cytotoxicity (Hayashi et al. 1995). Traditionally, the aerial portion was used as the medicinal part; however, the root portion has also been included recently as an additional usable part in the Chinese Pharmacopoeia (The Pharmacopoeia Committee of China 2005).

Due to its remarkable medicinal properties of *H. cordata* in traditional reports, GC–MS fingerprinting has already been undertaken for the characterization and identification of organic compounds. About 16 chemical components have

been identified by GC–MS fingerprinting from 31 samples collected from various regions of China (Meng et al. 2005). This kind of approaches unravel the pharmacological potential of *H. cordata*, which will lead to the use by modern pharmaceutical companies for the production of more efficient drugs against various diseases in the near future.

Along with such positive directions, there are some negative aspects regarding the conservation of the plant and its unique genetic pool. The World Health Organization estimates that some 80% of the developing world relies on traditional medicines and out of these, 85% people use plants or their extracts as the active substance (Sheldon et al. 1998). In India, approximately 2,000 drugs are of plant origin (Dikshit 1999). Present rapid socio-economic changes and several years of unregulated collection of the valuable medicinal plant species have resulted in the depletion of their populations and habitats in nature. Many of them have become rare and endangered and some species are on the verge of extinction (Kala 2000). About 20–25% of existing plant species in India have become endangered (Laloo et al. 2006). Ours is an era of profound changes on the surface of earth, driven by an unprecedented level of human demands on the resources of our planet (Gadgil et al. 1986). Degree of threat to natural populations of medicinal plants has increased, because more than 90% of the medicinal plant raw materials of Indian and export herbal industries are drawn from natural habitats (Dhar et al. 2002). Over 70% of the plants collected by the pharmaceutical industries involve destructive harvesting. These patterns of use possess a definite threat to the genetic stock and to the diversity of medicinal plants. Threat assessment exercises as per latest IUCN guidelines for Southern and Northern India has already listed around 200 species of medicinal plants that are rare, endangered, and threatened. It is necessary to bear in mind that, even if a particular variety of a plant is put under several million hectares of active cultivation, the species can still go extinct in the wild if its wild populations with all their inherent intra-specific diversity is not conserved. It is an established fact that the evolution of the species depends on diversity (Shankar and Ved 2003). But we can not deny the importance of

uninterrupted supply of essential medicinal plants for the existence of pharmaceutical companies for the sake of public health. So the only way to restore human health as well as to decrease overexploitation is to encourage sustainable and discrete collection of medicinal plants from the wild. For this purpose, knowledge about distribution and ecological feature of the plants are necessary.

Many plant species still have not been categorized and placed properly in the Red Data Book (RDB) of Indian plants and Conservation Assessment and Management Plan (CAMP) workshops because of inappropriate investigations, lack of ecological data, and subjective classification. Categorization of rare species in RDB has been based on herbarium collections rather than population estimation in the wild and assessment of rare species by few experts in CAMP are the major shortcomings of these documents. Moreover, in CAMP workshops, only few species are assessed, mainly those placed before experts and most species are still non-assessed. Thus, it does not provide full information on the number of taxa under threat for a specific area (Kala 2000). Presently, no quantitative information on availability in different populations of *H. cordata* is available in India, especially in Brahmaputra valley of Assam. But various tribes of Assam have been utilizing the plant as a vegetable as well as in

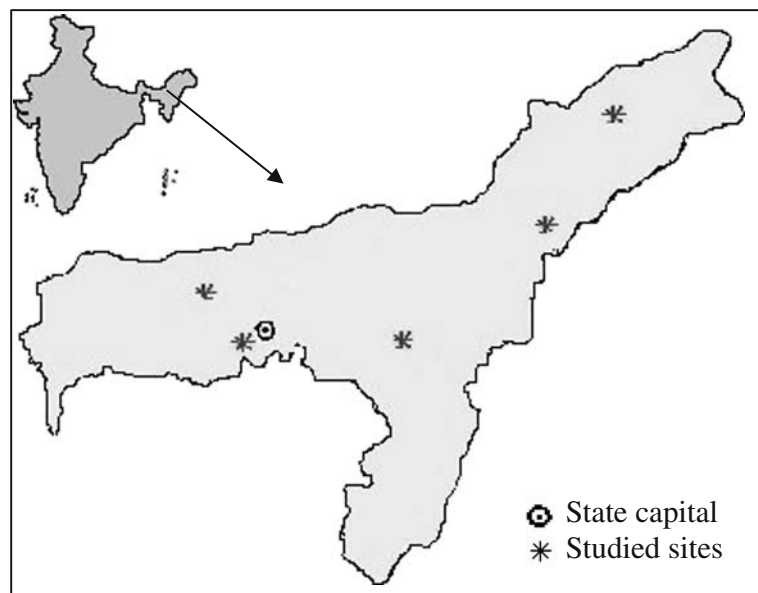
various medicinal purposes traditionally (Sarkar 1993; Bora 2001). Quantitative information on a species plays a vital role in formulating a conservation plan and in understanding the ecology of the species (Uniyal et al. 2002). Therefore, the present investigation has been attempted to provide quantitative details of *H. cordata* through (1) assessment of the distribution pattern and (2) analysis of variations in biomass among natural populations in different places.

Materials and methods

The studied sites

Five populations of *H. cordata* were selected in five different regions in the Brahmaputra valley of Assam (Fig. 1), viz. [Guakuchi, Dist.-Nalbari, 26°–27°N and 91°–97°E (NL); Lankeswar, Dist.-Guwahati, 26.21°N and 91.46°E (GH); Amolapatty, Dist.-Nagaon, 26.21°N and 92.41°E (NG); Pulibor, Dist.-Jorhat, 26.44°N and 94.10°E (JR); and Sissibargaon, Dist.-Dhemaji, 27.29°–27.48°N and 94.35°–94.54°E (DH)]. All these five sites were geographically different with foothills to marshy lands, dry lands, urban, and flood-affected areas. These sites also represent the lower, middle, and upper part of the state.

Fig. 1 The locations of study area in the state of Assam in India



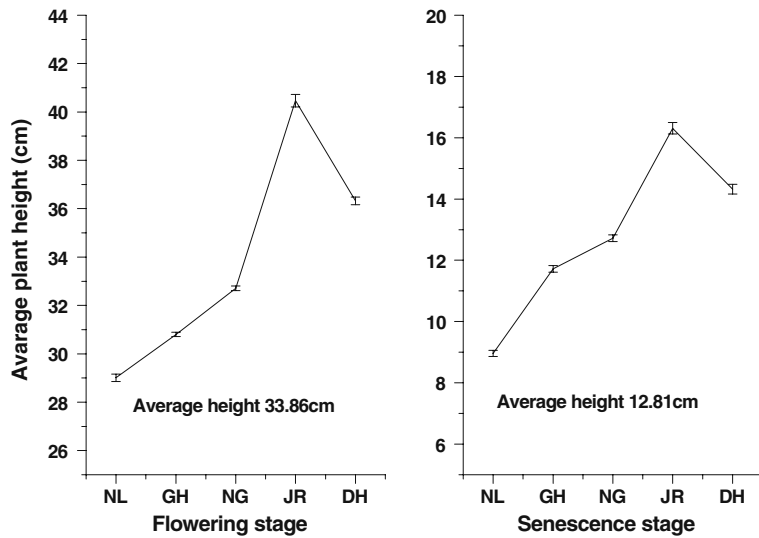
The state experiences a very hot–humid weather during summer with an average temperature of 30°C (max. 38.5°C. min. 7°C). The annual rainfall ranges between 1,500 and 2,600 mm with

moderate humidity (75%). A large part of the districts is covered by forest under a constant threat of denudation and deforestation because of the large felling of trees for timber, firewood, and

Table 1 Ecological status of *H. cordata* in the five studied populations

Area	Species name	Abundance (A)	Density	Relative density	Frequency (F)	A/F ratio
NL	<i>H. cordata</i>	57.3	57.3	18.22	100	0.573
	<i>Cyperus</i> sp.	88.9	88.9	28.27	100	0.889
	<i>Oxalis corniculata</i>	33.6	33.6	10.68	100	0.336
	<i>Cynodon dactylon</i>	43.6	43.6	13.86	100	0.436
	<i>Centella asiatica</i>	27.7	27.7	8.80	100	0.277
	<i>Hydrocotyle rotundifolia</i>	27.7	27.7	8.80	100	0.277
	<i>Elusine indica</i>	119.0	35.7	11.35	30	3.967
			Total = 314.5	Total = 100		
GH	<i>H. cordata</i>	71.2	71.2	27.22	100	0.712
	<i>Cyperus</i> sp.	62.8	62.8	24.01	100	0.628
	<i>Cynodon dactylon</i>	38.5	38.5	14.72	100	0.385
	<i>Evolvulus</i> sp.	22.9	22.9	08.75	100	0.229
	<i>Colocasia</i> sp.	5.13	4.1	01.57	80	0.064
	<i>Oxalis corniculata</i>	21.2	21.2	08.10	100	0.212
	<i>H. rotundifolia</i>	20.6	20.6	07.88	100	0.206
	<i>Elusine indica</i>	40.6	20.3	07.76	50	0.812
		Total = 261.6	Total = 100			
NG	<i>H. cordata</i>	80.2	80.2	19.87	100	0.802
	<i>H. rotundifolia</i>	23.3	23.3	5.77	100	0.233
	<i>Cyperus</i> sp.	97.8	97.8	24.23	100	0.978
	<i>Oxalis corniculata</i>	21.5	21.5	5.33	100	0.215
	<i>Cynodon dactylon</i>	54.0	54.0	13.38	100	0.540
	<i>Evolvulus</i> sp.	39.7	39.7	9.83	100	0.397
	<i>Nustertium</i> sp.	23.9	23.9	5.92	100	0.239
	<i>Centella asiatica</i>	16.6	16.6	4.11	100	0.166
		116.8	46.7	11.57	40	2.920
		Total = 403.7	Total = 100			
JR	<i>H. cordata</i>	101.0	101.0	40.43	100	1.010
	<i>Oxalis corniculata</i>	22.2	22.2	8.89	100	0.222
	<i>Cyperus</i> sp.	33.4	33.4	13.37	100	0.334
	<i>Cynodon dactylon</i>	29.4	29.4	11.77	100	0.294
	<i>Nustertium</i> sp.	9.7	9.7	3.88	100	0.097
	<i>Centella asiatica</i>	20.2	20.2	8.09	100	0.202
	<i>H. rotundifolia</i>	22.8	22.8	9.13	100	0.228
	<i>Evolvulus</i> sp.	10.5	10.5	4.20	100	0.105
		3.0	0.6	0.24	20	0.150
		Total = 249.8	Total = 100			
DH	<i>H. cordata</i>	94.3	94.3	31.99	100	0.943
	<i>Oxalis corniculata</i>	22.3	22.3	7.56	100	0.223
	<i>Cyperus</i> sp.	90.6	90.6	30.73	100	0.906
	<i>Cynodon dactylon</i>	37.7	37.7	12.79	100	0.377
	<i>Nustertium</i> sp.	20.1	20.1	6.82	100	0.201
	<i>Colocasia</i> sp.	2.7	1.6	0.54	60	0.045
	<i>Centella asiatica</i>	8.9	8.9	3.02	100	0.089
	<i>H. rotundifolia</i>	19.3	19.3	6.55	100	0.193
		Total = 294.8	Total = 100			

Fig. 2 Above ground plant height of *H. cordata* in two different growth stages of development. Error bars are the standard deviations



annual flood. The physico-chemical characteristics of soil differ from place to place. Because of the diverse climatic, topographic conditions and abundant rainfall, Assam forests support a vast variety of floral and faunal biodiversity.

Ecological features

In each population of *H. cordata*, one 20 × 20 m² plot was selected and ten numbers of 1 × 1 m² quadrates were placed randomly inside the plot. All the plant species were recorded from the quadrates. The habitat soil characteristics (soil type, pH, moisture, available NPK, etc.) of each plot were also analyzed simultaneously. The pooled quadrate information for each plot was used to analyze compositional features including frequency (*F*), density (*D*), abundance (*A*), and abundance-to-frequency ratio (*A/F*) (Misra 1968).

All the populations were visited during the active growing season, i.e., flowering stage (April to July 2006) as well as in senescence stage (November–February 2006–2007) for plant height and biomass estimation. Ten individuals from each population were selected randomly to measure the height of the aerial part of each individual at both flowering and senescence stages and their average heights were determined for each population and among all populations at both stages.

One randomly selected individual from each population was harvested at two growth stages [flowering (FL) and senescence (S)]. The harvested individuals were carefully washed to remove soil content and, later, the water adhered to the root surface was removed by pressing the plant carefully onto tissue paper. Thereafter, the entire sample was oven dried at 80°C to a constant weight. Attempts were made to determine the biomass in the two growth stages to identify the best stage for optimum and sustainable harvest. Biomass (above ground, below ground, and total) was obtained by multiplying individual dry weight

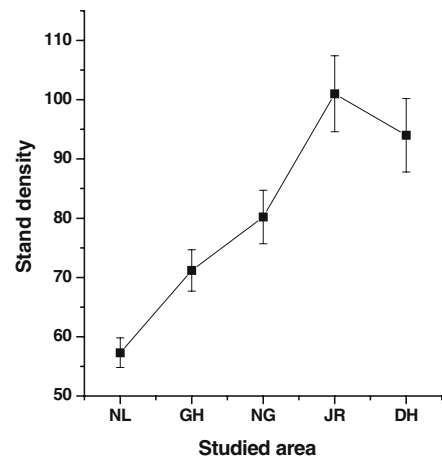


Fig. 3 Stand density of *H. cordata* in studied sites. Error bars are the standard deviations

Table 2 One-way analysis of variance of biomass production of *H. cordata* in different sites

Biomass	Source of variation	SS	df	MS	F crit
Above ground	Between groups	67,386.75	9	7,487.417	2.39 ^s
	Within groups	1,862.5	20	93.12501	
	Total	69,249.25	29		
Below ground	Between groups	12,982.15	9	1,442.461	2.39 ^{ns}
	Within groups	90.13987	20	4.506993	
	Total	13,072.29	29		
Total biomass	Between groups	126,080.5	9	14,008.94	2.39 ^s
	Within groups	2,055.872	20	102.7936	
	Total	128,136.4	29		

s significant, ns non-significant

with the stand density of the species at each stage (Airi et al. 1997).

Soil characteristics

Soil samples were collected from each studied areas. About 500–600 g of soil was collected from the rhizosphere (6 cm soil depth) of *H. cordata* at the sampling locations. The samples were air dried and packed in perforated polythene bags and were stored at room temperature (25–28°C) until further analysis. Soil texture and classification were done by the method of Piper (1944). Soil pH was determined for four replicates per sample. A soil suspension was prepared by stirring a mixture of air-dried soil (sieved through No. 8 mesh) and de-ionized water: 20% (w/v), for about 20 min. Soil pH was measured by the electrometric method using an Orion digital pH meter. Walkly and Black's Rapid Titration Method was used to determine soil organic matter and other macro elements in the soil (Jackson 1973).

Data analysis

All the data presented are the mean of replicates. The data were analyzed by Microsoft Excel program and an ANOVA was made on the height and biomass of the plant in different growth stages. A linear regression was also made ($y = a + b \times x$) to find the best fit value and the linear curve with soil characteristic and plant growth and biomass. Linear regression, graphs, and diagrams were presented with the help of statistical software program Origin 7.5.

Results

Occurrence and availability

Almost all the populations of *H. cordata* were observed in shady and well-moistened places under the canopy of horticultural trees or in the garden fencing sides. *Oxalis corniculata*, *Cynodon dactylon*, *Centella asiatica*, *Nustertium* sp., *Colocasia* sp., *Evolvulus* sp., *Cyperus* sp., and *Elusine* sp. were the common associates of *H. cordata*. The density of *H. cordata* was higher in all populations and ranged between 57.3 ± 2.4 (NL) and 101.0 ± 6.4 (JR). The relative contribution of the species to overall stand density was higher than other dicotyledonous herbaceous associates and was

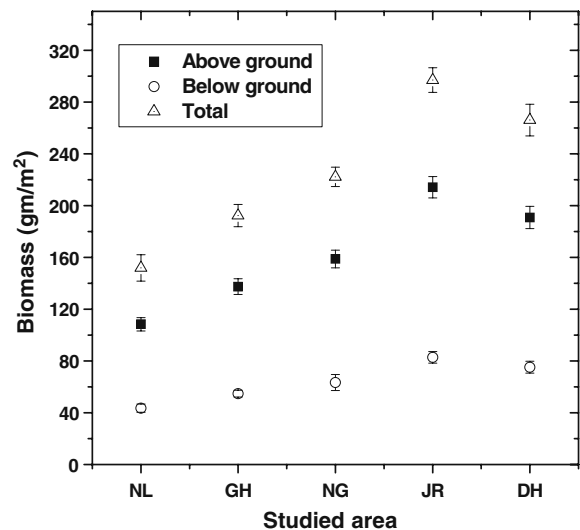


Fig. 4 Biomass production of *H. cordata* in different sites. Error bars are the standard deviations

comparable to the dominant grass species. The frequency of occurrence was also higher (100%) in all the studied populations (Table 1). Patterns of A/F ratio were quite different in the sites; however, the average A/F ratio of *H. cordata* was maximum ($n = 5$). The distribution of the herb was not common to all the areas and was restricted only to certain pockets in all the studied populations.

Variation in plant height and biomass

The average plant height of the medicinal herb showed significant variation ($P < 0.05$) in flowering and senescence stages. The mean height in flowering stage (considering all populations, $n = 5$) was 33.86 cm (± 5.58), while in senescence stage it was 12.81 cm (± 2.76) (Fig. 2). The average plant height was significantly higher in JR in both the stages (flowering, 40.47 ± 0.77 cm; senescence, 16.31 ± 0.58 cm), followed by DH (36.32 ± 0.49 and 14.32 ± 0.49 cm). While the minimum plant heights were recorded 29.01 ± 0.44 cm (flowering) and 8.96 ± 0.29 cm (senescence) in NL. The stand density of the plant was also the highest in JR (101.0 ± 6.41) and was minimum in NL (94 ± 6.15) (Fig. 3) and both sites were in the nearby area. The biomass production of the plant was significantly different ($P < 0.005$) among the populations (Table 2 and Fig. 4). The biomass production was also different in the flowering and senescence stages. The above ground biomass production was 214.12 ± 8.42 g/m² in flowering stage and 82.82 ± 2.31 g/m² in senescence stage in JR which was the maximum among the populations. The total biomass production of *H. cordata* was 296.94 ± 9.51 g/m² in the flowering stage at JR. The analysis

of variance table of the biomass production in all the populations showed significant result on above ground and total biomass production ($P < 0.005$) and non-significant result in below ground biomass production.

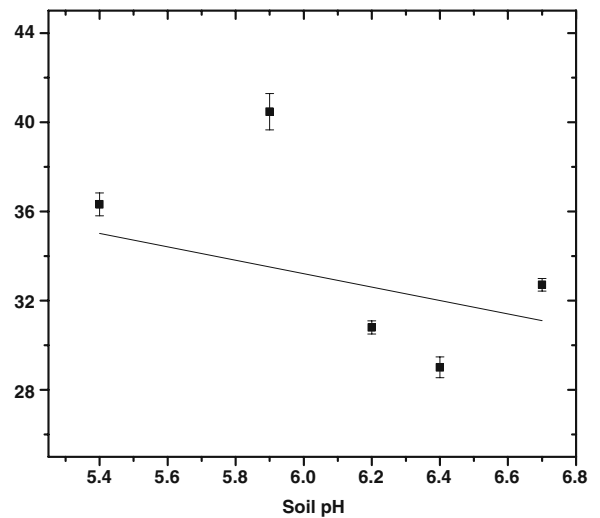
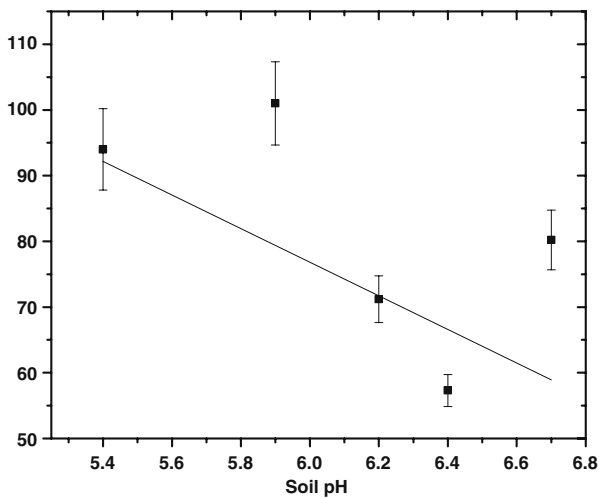
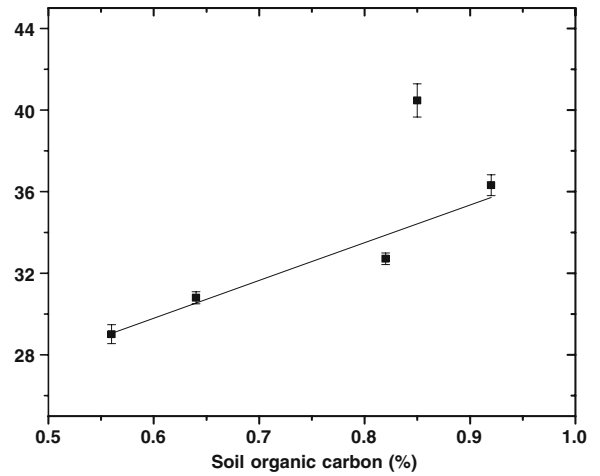
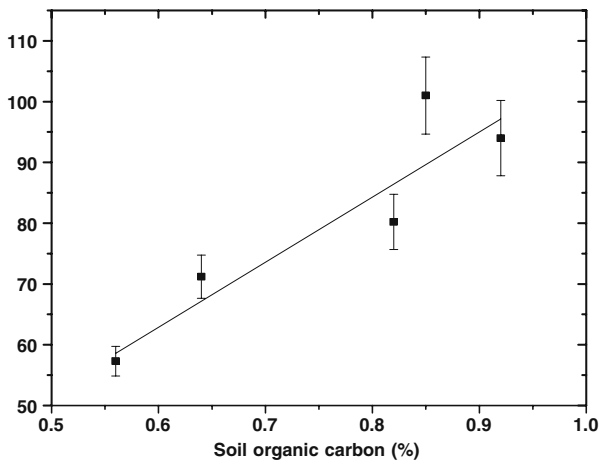
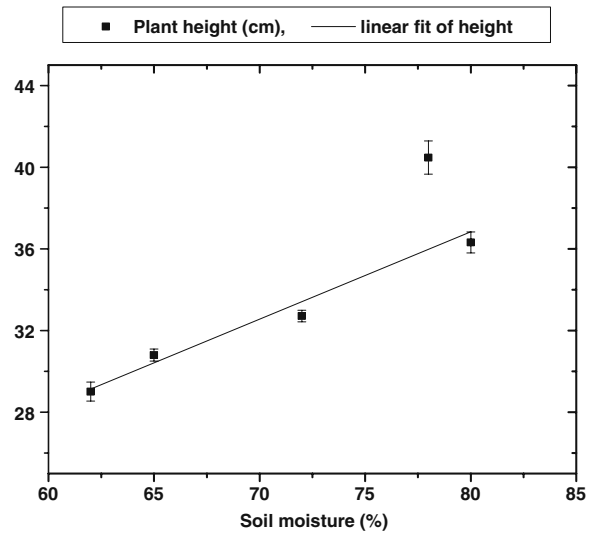
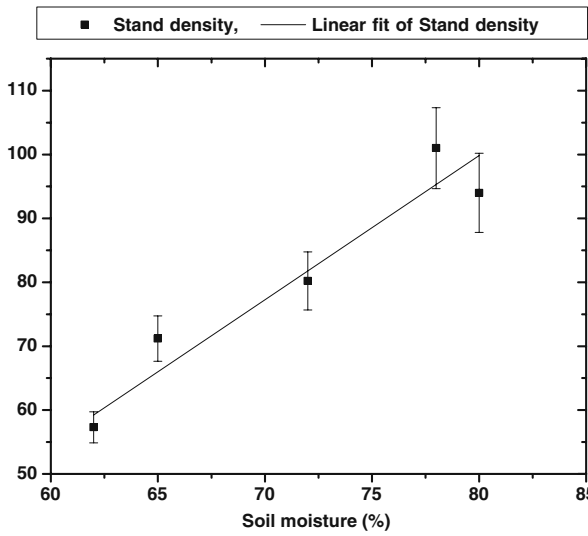
Soil characteristic and plant growth

It has been observed that *H. cordata* was restricted only to certain habitats, although the plant was available in different geographical regions. The soil characteristics were the dependent factors for the growth of *H. cordata* in all the populations. The plant was only recorded in the moist habitats and therefore the soil physico-chemical properties were analyzed. The performance of *H. cordata* was maximum in JR where the soil moisture ($78 \pm 5.6\%$) and organic carbon ($0.85 \pm 0.05\%$) were also higher than other populations (Table 3). The plant growth and soil characteristic had a significant positive correlation except in DH (linear curve fit; Fig. 5). Soil moisture was the most dependent factor of the plant growth and the optimum growth was recorded at $78 \pm 5.6\%$ soil moisture ($r^2 \geq 0.9$; $P \leq 0.01$). However, the growth of the plant was not linear in different soil pH, hence, a linear curve was not fitted ($r^2 \leq 0.33$; $P \geq 0.1$). Higher soil organic carbon also favored the growth of the plant and was adequately linear in studied sites ($r^2 \geq 0.8$; $P \leq 0.1$). These data may indicate the optimum environmental parameters for the better growth of *H. cordata* and hence may be considered for conservation of the plant. Again, the area of DH is also well known for the annual heavy flood which may affect on the growth of the species in that area. The clay loam soil with maximum moisture and slightly acidic

Table 3 Soil characteristics of *Houttuynia cordata* in five different sites

Studied sites	pH	Moisture (%)	Organic carbon (%)	Available N (%)	Available P (%)	Available (K) %	Soil type
NL	6.4 (0.42)	62 (3.42)	0.56 (0.09)	0.18 (0.04)	0.005 (0.0007)	0.004 (0.0002)	Sandy loam
GH	6.2 (0.35)	65 (4.04)	0.64 (0.024)	0.28 (0.02)	0.004 (0.0009)	0.005 (0.0005)	Sandy loam
NG	6.7 (0.40)	72 (3.08)	0.82 (0.032)	0.20 (0.03)	0.007 (0.0007)	0.005 (0.0004)	Clay loam
JR	5.9 (0.32)	78 (5.6)	0.85 (0.045)	0.32 (0.05)	0.007 (0.0004)	0.005 (0.0003)	Clay loam
DH	5.4 (0.40)	80 (4.8)	0.92 (0.051)	0.30 (0.04)	0.008 (0.003)	0.006 (0.0004)	Clay loam
SE	0.22	4.0	0.11	0.03	0.0007	0.0003	
SD	0.50	8.8	0.24	0.06	0.0016	0.0007	

Data in parentheses are standard deviation



◀ **Fig. 5** Simple linear curve fit of soil moisture, pH, and organic carbon with stand density and plant height. Error bars are the standard deviations

pH were favorable for growth and development of *H. cordata* (Fig. 6).

Discussion

The high density (57.3 to 101.0 individuals/m²), accompanied by high frequency of *H. cordata* in the surveyed populations, indicates that the species has a tendency to cover a wide space in a given area and is able to exhibit thick stocking in optimum environmental parameters, although the species was restricted to certain habitats and less-disturbed habitats in the region. This is probably because of lack of overexploitation or extensive harvesting of this medicinal herb, especially from this region. Additionally, the local people generally harvest only the aerial part of the herb to use as vegetable or as raw herbal medicine for various disorders. High density also reveals that the environment and soil quality is favorable for the luxurious growth and thick stocking of the herb in the region.

From the study, it can be assumed that the region is very much conducive for the *in situ* conservation and cultivation of the plant, if and when needed in the future. This is justified in view of the fact that luxurious availability, higher abundance and frequency as well as higher density of a species at present time do not pledge anything about its safe status in the near future. This is because of the growing demand of medicinal plants for the pharmaceutical companies. For instance, there was a large-scale commercial exploitation of medicinal plants from various districts of Himachal Pradesh (Sharma 1995). In parts of Kulu district, 85% of families adjoining the Great Himalayan National Park (GHNP) meet 65–70% of their total annual cash income by medicinal plants trade (Singh 1999). Over the last decade, there has been a substantial increase in the quantity of medicinal plants sold in the market. About 61 kg of *Aconitum violaceum* and 1,468 kg of *Picrorhiza kurrooa* were collected from the entire state in 1988–1989 (Sharma 1995), whereas a total of 5,100 kg of *A. violaceum* and 8,350 kg of *P. kurrooa* were collected only from GHNP for selling in the market by local communities in 1998–1999 (Singh 1999). Nearly 25% of the estimated 25,000 species of vascular plants in the world may become extinct within the next 50 years (Raven 1987; Schemske et al. 1994). Red Lists of threatened plants are important tools for the conservation of threatened species (Berg et al. 1994). However, comparison between assessments, before and after Rare Lists were formulated, is obscured by different categories and philosophies (Adersen 1989; Oredsson 1997).

Considering species performance of *H. cordata* across the populations, the population at JR appeared to be the best with its highest average plant height, biomass (above ground, below ground, and total), and maximum density. Performance of the herb was inferior coming down from upper to lower Assam (JR to NL). This suggests that *H. cordata* performs better in upper Assam with moist tropical climate.

In case of medicinal plants, the time of harvesting is considered critical for the optimum biomass or availability of active constituents. There was a significant variation in the total biomass during the flowering and senescence stages of *H. cor-*

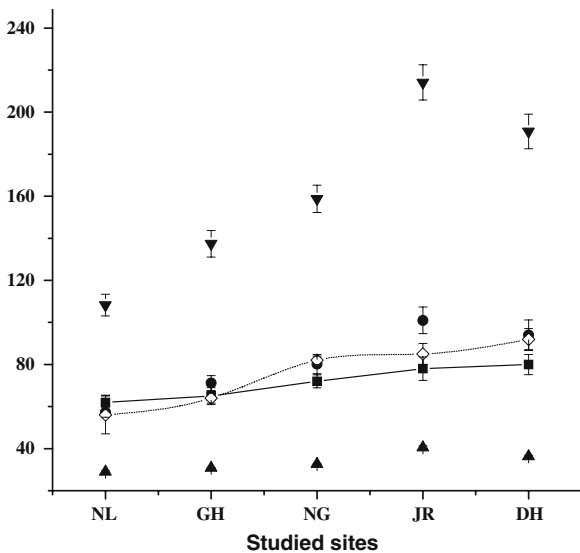


Fig. 6 Physiological performance of *H. cordata* in relation to organic carbon and soil moisture in four different sites. —■— Moisture (%); ● stand density; ▲ height (cm); ▼ above ground biomass (g/m²); —◇— organic carbon (g/10 kg). Error bars are the standard deviations

data, which indicates that the flowering or active growing stage was better for maximum biomass harvesting (fresh and dry weight basis). For long-term survival of populations, it is recommended that plants are harvested in the senescence stage when most of the reproductive stages are over (Bhatt et al. 2006). Therefore, this study suggests active cultivation of *H. cordata* in active growing season to cope with its greater demand. Otherwise, extensive harvesting for optimum biomass in active growing season, i.e., in reproductive season, may pose a threat to the existence of the species in future.

The most important conservation strategy is the protection of habitats. In some cases, conservationists have no choice but to devise sustainable harvesting techniques for wild populations (Sheldon et al. 1998), keeping in mind the demand of local people. The present data on species availability status in different populations of Assam will help in understanding the distribution and status of *H. cordata*, which will consequently help in designing sustainable harvesting strategies, leading to long-term conservation cautions for this species. The present study also recommends the active cultivation of the species in active growing season to decrease the pressure on natural population in reproductive stage to ensure the long-term sustainability of the species in this part of the world. Since the population of JR showed the highest biomass and performance, therefore a detailed study of this population is required to determine the active constituents of *H. cordata*. However, finer details of the essential oil and active compound availability in two growth stages are also needed with detailed phyto-chemical analysis.

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