Conservation of *Tupistra* (*Tupistra nutans* Wall. ex Lindl and *T. wattii* (C.B. Clarke) Hook.f.) aids its ecology and ethnobotany in Darla, Chhukha, Bhutan

Prabhat Kumar Mukhia, Nabin Raj Joshi, Ripu Mardhan Kunwar, Kuenzang Dhendup, Yangchen Lhamo, Thinley Choden, Rajeev Joshi, Durga Hari Kutal

Prabhat Kumar Mukhia[1], Nabin Raj Joshi[2*], Ripu Mardhan Kunwar[3], Kuenzang Dhendup[1], Yangchen Lhamo[1], Thinley Choden[1], Rajeev Joshi[4,5*], Durga Hari Kutal[6*]

[1]Non Wood Forest Products and Agroforestry Technology Research Sub-center, Department of Forests and Park Services, Ministry of Agriculture and Forests, Darla Chhukha 21010, Bhutan.
[2]Pragya Solutions for Sustainable Development, Kathmandu, Nepal.
[3]Ethnobotanical Society of Nepal, Kathmandu, Nepal.
[4]College of Economics and Management, Northwest A&F University, Yangling District, Xianyang, Shaanxi (712100), China.
[5]College of Natural Resource Management, Faculty of Forestry, Agriculture and Forestry University, Katari-56310, Udayapur, Nepal.
[6]Department of Mathematics, College of Science and Mathematics, Augusta University, GA 30912, USA.

[*]Corresponding Author: nabin2001@gmail.com , joshi.rajeev20@gmail.com, dkutal@augusta.edu

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Research

Abstract

Background: Tupistra nutans Wall. ex Lindl and *T. wattii* (C.B. Clarke) Hook.f. are useful species grown wild in Bhutan. Former has now been hailed as a climate-smart species as it grows elsewhere in transition and ruderal areas, needs little effort in cultivation, and has historically been used in rural livelihood. *T. nutans* have been extensively cultivated, collected, and used to address the current changes, urging timely documentation and conservation.

Methods: Ethnomedicinal plants and the ethnobotany and ecology of *T. nutans* were assessed following interviews with 78 household members inhabiting Darla, Chhukha, Bhutan.

Results: A linear relationship was observed between planting space and *T. nutans* inflorescence per year, as Pearson's bivariate correlation coefficient showed significant values ($r = 0.48$, $p < 0.012$). The species is now increasingly cultivated and sustainably managed in forests, resulting in growing uses for its parts in the household economy and primary health care, and supporting the theory of availability. Almost all parts (inflorescence, leaf, root, seed) of *T. nutans* are useful for ethnomedicine. A total of 83.33% of the population ($n = 65$) used *T. nutans,* followed by 59 used *Swertia chirayita* (Roxb.) Karsten and *Bergenia ciliata* (Haw.) Sternb.

Conclusions: Use value shows that *T. nutans* can be used as a source of nutrition and a future constituent of traditional medicine. Continued research on commercial cultivation and sustainable utilization of *T. nutans* should be sustained, as it is considered a potential climate-smart crop to benefit the larger society.

Keywords: Tupistra nutans, ethnomedicinal plant, food, cultivation, climate-smart, Bhutan.

Background

The climate-smart crop being defined by the Food and Agriculture Organization of the United Nations (FAO) is one that needs to be climate change resilient, adaptive, and sustainably increase production with no negative impact on food production ecosystems in climate change (Altieri *et al*. 2015, Pardo & Durán-Romero, 2022). It meets food security through the process of an amicable eco-environment and vis-à-vis acquires socio-economic benefits. Further, it emphasizes adopting indigenous and traditional measures and integrated food production systems, viz., agroforestry, agri-livestock, or agri-fishery (FAO 2013, Altieri 2015). Many traits of wild plants are climate-adaptive (Hajjar & Hodgkin, 2007).

Tupistra nutans Wall. ex Lindl. is one of the wild species that can be considered a climate-smart species since it can grow in erratic weather conditions and ruderal areas (Chettri *et al.* 2020). With limited care and nourishment, it can be cultivated and produce a good yield (inflorescence), aiding farmers in earning more economic benefits through sustainable utilization practices (Sharma 2016). *T. nutans* is an evergreen plant found in Eastern Himalaya, South Asia, South China, Sumatra, and Ambon Island in Indonesia, from Nepal to Bhutan (Thuy Linh *et al.* 2022). Bhutan is a treasure of diverse ecosystems and habitats, whose altitude ranges from 150 meters above sea level (masl) in the south to 7,700 masl in the north. It boasts many economic and climate-adaptive plant species like *T. nutans* that grow naturally in the wild (Sherub *et al.* 2021). Plant roots and flowers are used as indigenous medicine to manage diabetes and hypertension. Some researchers ascertained that this plant has a considerable amount of nutrients and minerals and can be regarded as an affluent source of natural antioxidants (Idrisi *et al.* 2010, Verma & Nath 2016, Khatoon *et al.* 2016, Tamang et *al.* 2023). Plant root decoction is cytotoxic, anti-inflammatory, antimicrobial, and antidiabetic, exhibiting a potential role in body pain and weakness (Chung *et al.* 2019). Despite the growing recognition of *Tupistra* species for their ethnomedicinal and nutritional value, significant research gaps remain. Recent ethnobotanical studies in Nepal have documented extensive indigenous knowledge, such as the 219 medicinal plant species recorded in Baglung District, Nepal (Acharya *et al.* 2025) and the rich plant biodiversity documented in Palpa District (Neupane *et al.* 2025), underscoring the need for integrated conservation and sustainable healthcare approaches across the eastern Himalaya. Specifically, while the pharmacological properties of *T. nutans* are being increasingly validated in laboratory settings (Chung *et al.* 2019, Thuy Linh *et al*. 2022), there is a notable lack of integrated studies that connect its ecological requirements with sustainable cultivation practices and community-based conservation. Recent reviews highlight that the conservation status of many Himalayan medicinal plants, including *Tupistra*, is poorly understood due to habitat loss and over-harvesting, yet few studies have quantified the success of *ex-situ* conservation efforts (Dangwal et al. 2025). Furthermore, the socio-economic role of *T. nutans* in local livelihoods, particularly its potential as a climate-smart crop in the face of climate change, remains under-documented in Bhutan. Given the importance of species in the local economy, cultivation management of *T. nutans* Wall. ex Lindl. in Bhutan is in place by the Non-Wood Forest Products and Agroforestry Technology Research Sub Centre (NWFATSc), Darla, Chhukha Bhutan. This paper communicates the conservation initiatives of *Tupistra* in Bhutan and its potential to enhance the rural economy and livelihood in the wake of climate change. The main aims of this study were to (i) catalog the local uses of *T. nutans* and its economic significance, (ii) documentation of the best practice for its optimum growth and yield in an *ex-situ* environment, and (iii) develop the measures that aid in sustainable conservation of the species for present and future uses.

Materials and Methods

Study area

Non-Wood Forest Products and Agroforestry Technology Research sub-center (NWFATSc) is located in Darla administrative block under Chhukha district, South-Western Bhutan (Fig. 1). The area lies within the geo-coordinates of 26º 51’ 18” N and 89º 33' 12" E at an elevation of 1760 masl. It covers an area of about 11.74 ha (29.02 acres).

In the peak rainy season (July), it received a maximum rainfall of ±1260 mm and a minimum of ±660 mm, respectively. Sometimes, it gets an annual mean minimum rainfall of 43.17 mm and a maximum of 169.42 mm (RNR RDSC 2007-12). Accordingly, the annual mean maximum relative humidity was recorded as 93% and a minimum of 62%. The annual mean maximum temperature observed was 17ºC, and the minimum was 12 ºC (RNR RDSC 2007-12). The soil report stated that all soils in the Darla areas are acidic and highly leached with low c*alcium* and *magnesium* content. The report suggested that adding lime to the ground helps grow many crops (BSS 2003). The vegetation region of Darla falls within the sub-tropical to warm temperate broadleaved forest. It has rich floral diversity, and to state some, they are *Alnus nepalensis* D. Don, *Casearia glomerata* Roxb., *Castanopsis hystrix* A. DC., *Castanopsis indica* (Roxburgh ex Lindl.) A. DC., *Castanopsis tribuloides* (Sm.) A. DC., *Cinnamomum bejolghota* (Buch.-Ham.) Sweet, *Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br., *Litsea cubeba* (Lour.) Pers. *Persea clarkeana* (King ex Hook. fil.) Kosterm., *Quercus glauca* Thunb., *Quercus lamellosa* Sm., *Tupistra nutans* Wall. ex Lindl. etc.

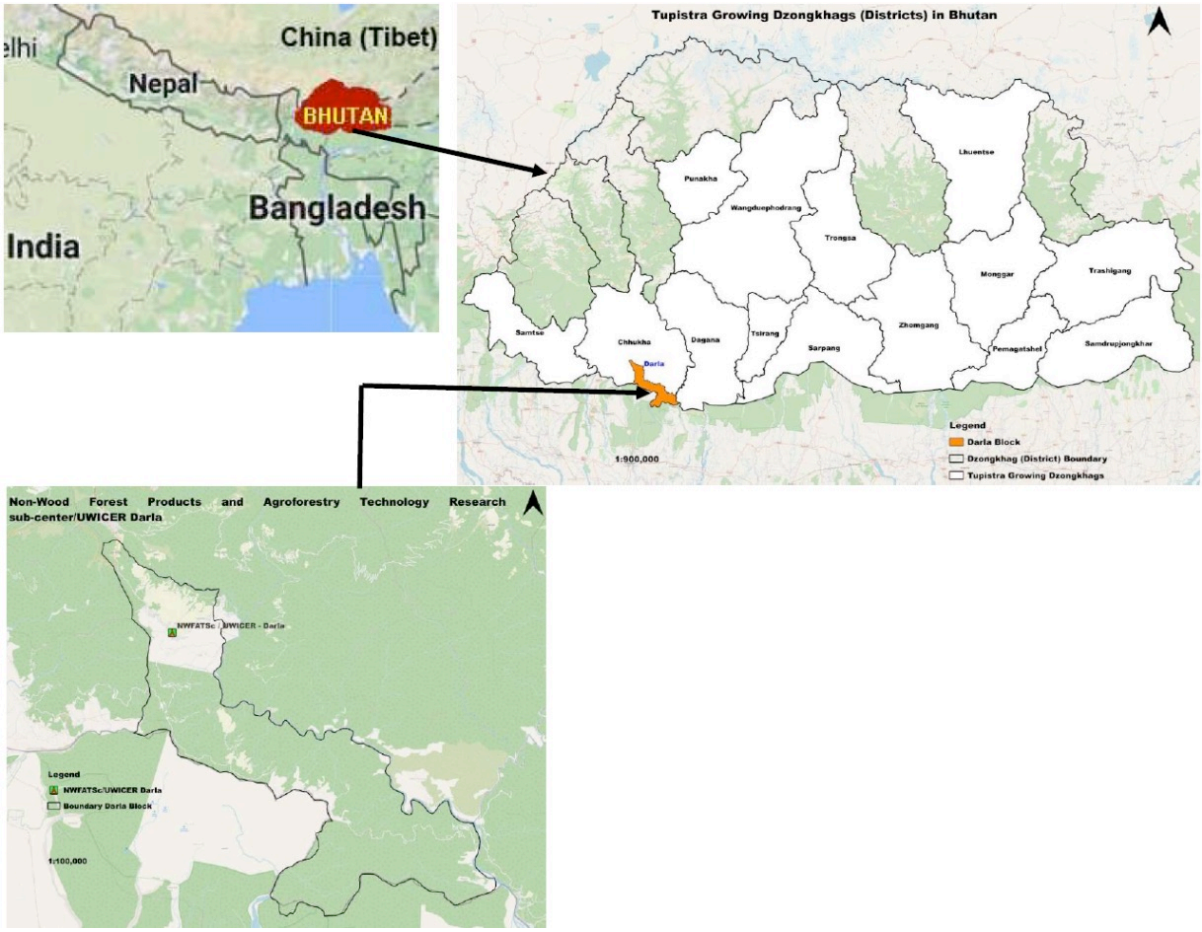

Figure 1. Location of study sites and *Tupistra* distribution map

Cultivation of *Tupistra*

The plantation of *Tupistra* was conducted on-station in different blocks (Fig. 2) of various sizes by adopting the vegetative propagation method (dividing the plant by another growing individual point). The planting materials were collected from the in-situ sites. Plantation distance (in meters) from plant to plant (i.e., clump to clump) was maintained differently in 5 different plantation trial blocks (Table 1). The harvest of fresh inflorescence had been maintained annually by recording its yield.

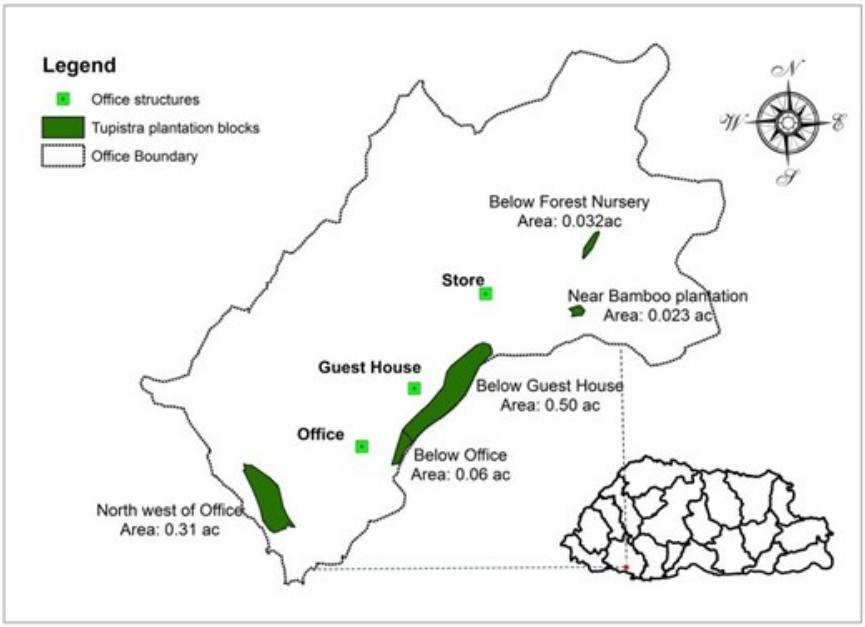

Figure 2. On-station *Tupistra* plantation trial blocks

Table 1. Details of the on-station *Tupistra* trial plantation blocks.

Block Name	Space between plant and plant (m)	Number of the plant (Clump)	Total area (m^2)	Total area (Acre)	Year of establishment
Below the forest nursery	0.7 x 0.7	264	129.50	0.032	2009
Near the bamboo plantation	1.7 x 1.7	32	93.08	0.023	2009
Below the guest house	1.7 x 1.7	700	2023.43	0.50	2017
Below office	1.1 x 1.1	200	242.80	0.06	2007
North-West of the office	2.5 x 2.5	200	1254.53	0.31	2009
Total		**1396**	**3743.34**	**0.925**	

Keeping different plantation spaces (distance from plant to plant) in different block sizes is set as a treatment for plant growth. This treatment was implemented since *Tupistra*'s growing habitat was found to be coarse areas, over the rocks, and at the cliff's edges (Fig. 3a). The manuring, weeding, and cleaning are done with consistent frequency to all plants of the on-station trial blocks (Fig 3b and 3c). At the initial stage of plantation, leaf humus as manure was applied. Weeding unwanted plants and cleaning the surroundings are done twice a year in all the blocks of the plantation.

Figure 3a. *In-situ* habitat of *Tupistra*

Figure 3b. *Tupistra* plantation in farmland (ex-situ)

Figure 3c. *Tupistra* plantation in research plot (ex-situ / on-station)

For comparison, the office had also asked one of the interested farmers to cultivate plants as on-farm trials on the farmland, giving basic training on cultivation techniques. Table 2 shows the details of the on-farm plantation block. The farmer has planted a clump comprising three vegetative individual stems collected from the wild. In this trial farmland, input treatment like manure or fertilizer was not applied at planting times (Figure 3). Weeding and cleaning had also been done only once a year, just before the harvest of the inflorescence. The plot layout and inflorescence yield data (including other input) of the trial sites and six years (2013-2018) income data (of the farmer) from the sale of the fresh inflorescence were recorded. Data analysis was done in SPSS.

Table 2. Detail of the on-farm *Tupistra* trial plantation block

Block Name	Space between plant and plant (m)	Numbers of the plant (Clump)	Total area (m^2)	Total area (Acre)	Year of establishment
Farmer's farmland	1.5 x 1.5	900	2023.43	0.50	2008

Ethnobotanical survey and analysis

The settlement area near the cultivation trial management consists of 78 (N) farm households. All the households were surveyed in February 2021 for the ethnomedicinal study. The survey was done by employing standard methods like face-to-face interviews using open-ended questions. Free prior informed verbal consent was obtained following the guidelines of the International Society for Ethnobiology (ISE) Code of Ethics. One elder member of each household was asked to participate in the discussion and share information regarding the use of all ethno-medicinal plants and cultivation measures. In total, 46 men and 32 women took part in the survey. A total of 72% of the respondents possessed non-formal education, and the rest, 28%, had a formal education at least at the primary school level (Table 3). Some participants were village shamans and local traders who were further interviewed for the details of ethnomedicinal accounts and verification. The HH interviews were accompanied by direct field observations to record the on-site situations. The most frequently used plant species was deduced through ranking based on the responses received from more than five respondents. The collected data were compiled in an MS Excel spreadsheet, tabulated, ranked, and listed the species under their family group in ascending order. We computed quantitative ethnobotany applying the Importance Value (Byg & Balslev 2001) that measures the proportion of informants who regard a species as most important. Importance Value (IV) = n_{is}/n, where n_{is} = number of informants who consider the species to be most important, n = total number of informants. Informant score method (rather than consensus): measures the proportion of informants who regard a species as most important. Values range from 0 to 1.

Statistical analysis

Quantitative data from cultivation trials were analyzed using SPSS. Descriptive statistics were calculated for yield across plantation blocks. Pearson's bivariate correlation was used to assess linear relationships between planting distance, number of clumps, and annual yield. An independent-samples t-test compared mean yields between groups with different planting distances. Linear regression modeled the relationship between harvest year and yield. Statistical significance was set at $p < 0.05$.

Table 3. Age group and education level of the household interview survey's respondents.

Age (Year) Group of Interviewees	Education level					
	NFE	PS	LS	MS	HS	Degree
20-39	6	6	0	2	2	0
40-59	25	5	2	1	0	0
60-79	23	3	0	0	0	1
80+	2	0	0	0	0	0
Total Interviewee	56	14	2	3	2	1

Results and Discussion

Tupistra plant profile and distribution

Tupistra has about 20 species recorded in its growing places, as cited earlier, and it belongs to the Asparagaceae family (Wu & Raven 2000). A total of 2 species of *Tupistra* (*T. nutans* and *T. wattii*) were found in 14 districts of Bhutan (Noltie 1994). It is found wild in the 700 - 2,800 masl elevation range forests. *T. nutans* is an evergreen plant that keeps the land surface moist throughout the year. It is confirmed through field visits that there are two species (*T. nutans* Wall. and *T. wattii* (C.B. Clarke) Hook.f.) that grow wild in the tropical and temperate forests of Bhutan (Fig. 1).

Cultivation management of *Tupistra*

According to on-station research field observation, *T. nutans* can grow without plenty of rain or humus soil. For comparison, the center has trained 39 farmers in the nearby settlement area of the research center to manage non-timber forest products, including cultivating the *Tupistra* plants in farmland with varying planting distances. According to the record, despite less acreage of land, on-farm land produced more yield than on-station trials. However, regression analysis showed that the on-station model is much better than on-farmland (Fig. 4). The farmer used to earn good money from the sale, and *Tupistra* inflorescence fetched a plausible price in the available local market compared to other crops (Fig. 5).

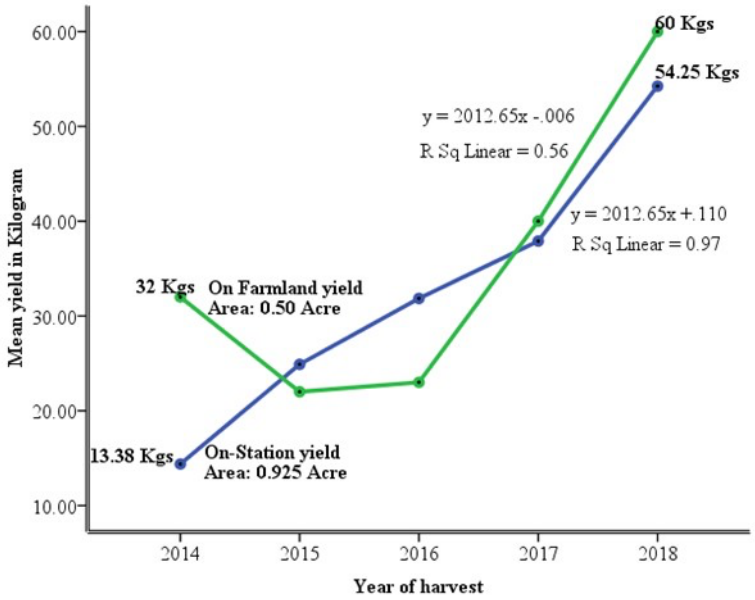

Figure 4. Linear regression line graph for yield

In 2014, the office recorded a fresh inflorescence yield of 13.38 kgs from on-station and 32 kgs from on-farmland trials, respectively. The yield trend in the on-station increased steadily without any fluctuation and recorded 54.25 kgs in 2018. Yield from on-farm land dropped in 2015 and 2016 but showed an increased yield. It produced 60 kgs in 2018, which is more than the yield from the on-station, in addition to its smaller coverage area (0.50 Acre) than the on-station (0.925 Acre). The regression analysis for yield in on-station showed, $R^2 = 0.97$, and y = 2012.65x +0.110, and for on-farmland $R^2 = 0.56$, and y = 2012.65x -0.006. It can be concluded that the regression relationship between yield and harvest year is medium to strong; as the plant (*Tupistra*) aged more years, it produced more inflorescence. In 2013 (base year), it was sold at Nu. 550.00 kg^{-1}.

The selling price was increased to Nu. 750.00 kg^{-1} in 2014 until 2017. However, in 2018, it plummeted to Nu. 600.00 kg^{-1}, slightly less than in 2014 - 2017. Yet, it was still a better price than in 2013.

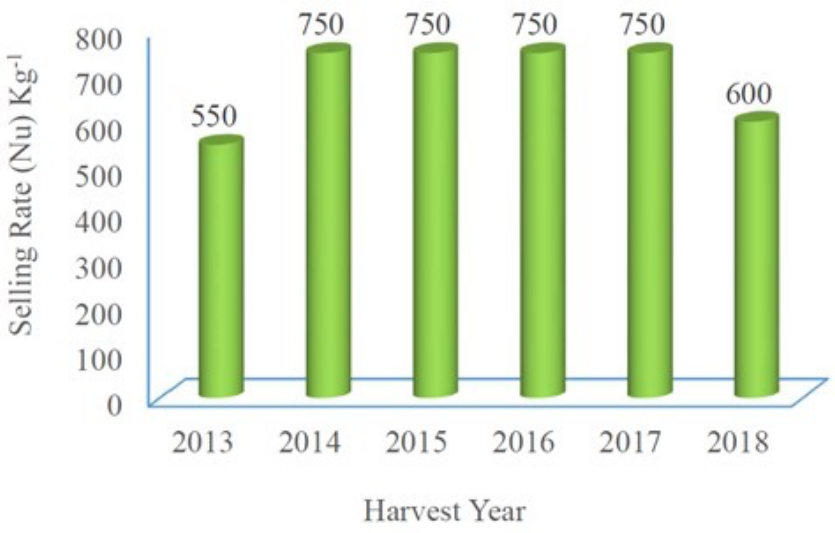

Figure 5. Year-wise selling price of the inflorescence

Bivariate Pearson's Correlation Analysis was run to determine if there is a linear relationship between the fresh yield of *Tupistra* inflorescence among different variables such as the aspect of the block, the average slope of the block, the area of the block, the distance between clump and clump, the number of clumps in block^{-1}, and yield (kg) year^{-1} block^{-1}. However, the analysis (Table 4) showed a linear relationship only among the distance between clump and clump, the number of clump block^{-1}, and yield (kg) year^{-1} block^{-1}. As such, the distance between clump and clump and yield (kg) year^{-1} block^{-1} were positively correlated; Pearson's bivariate correlation coefficient shows $r = 0.48$, $p < 0.012$, which is significant at the 0.05 level. Likewise, the distance between clump and clump and numbers of clump block^{-1} shows a medium positive linear relationship, $r = 0.621$, $p < 0.001$, and numbers of clump block^{-1} and yield (kg) year^{-1} block^{-1} also leads to a medium positive linear relationship, $r = 0.683$, $p < 0.001$ which, both are significant at 0.01 level.

Table 4. Correlations among the distance between clump and clump, number of clump block^{-1}, and yield (kg) year^{-1} block^{-1}

Variables		**Distance between clump and clump (m)**	**Numbers of clump block^{-1}**	**Yield (kg) year^{-1} block^{-1}**
Distance between clump and clump (m)	Pearson Correlation	1	0.621**	0.476*
	Sig. (2-tailed)		0.001	0.012
Numbers of clump block^{-1}	Pearson Correlation	0.621**	1	0.683**
	Sig. (2-tailed)	0.001		0.000
Yield (kg) year^{-1} block^{-1}	Pearson Correlation	0.476*	0.683**	1
	Sig. (2-tailed)	0.012	0.000	

There are five different groups of plantations that vary in the gap distance from clump to clump. Pairing them among other groups (1 & 2, 1 & 3, 1 & 4, 1 & 5, 2 & 3, 2 & 4, 2 & 5, 3 & 4, 3 & 5, and 4 & 5) respectively an independent-samples *t-test* was run to determine if plantation distance from clump to clump make any difference in yield of fresh inflorescence.

There was no significant difference in the yield score for group 1 (M = 10.63, SD = 5.94) and group 2 (M = 8.97, SD = 2.85) conditions as t (10) = 0.65, p = 0.53 (Table 5). A similar prediction was made for groups 1 and 3, i.e., no significant difference in the yield score for the group 1 (M = 10.63, SD = 5.94) and group 3 (M = 5.26, SD = 2.63) conditions as t (8) = 1.85, p = 0.10. Likewise, the analysis showed no significant difference in the yield score for group 1 (M = 10.63, SD = 5.94) and group 4 (M

= 4.21, *SD* = 2.89) conditions as *t* (8) = 2.18, *p* = 0.06. However, a highly significant difference in the yield score for the groups 1 *(M = 10.63, SD = 5.94)* and 5 *(M = 35.40, SD = 15.58)* was seen as *t (8) = 3.32, p =* 0.01. Also, there was a significant difference in the yield score for groups 2 (*M* = 8.97, *SD* = 2.85) and 3 (*M* = 5.56, *SD* = 2.63), as values were *t* (10) = 2.30, *p* = 0.05. A highly significant difference in the inflorescence yield was shown for group 2 (*M* = 8.97, *SD* = 2.85) and group 5 (*M* = 35.40, *SD* = 15.58), as t (10) was 4.47, *p* was 0.001. There was no significant difference in the yield score for group 3 (*M* = 5.26, *SD* = 2.63) and group 4 (*M* = 4.21, *SD* = 2.89) with *t* (8) = 0.60, *p* = 0.56. Meanwhile, groups 3 (M = 5.26, SD = 2.63) and 5 (M = 35.40, SD = 15.58) showed a highly significant difference in the yield score, as t (8) was 4.27, and the p-value was 0.003. Groups 4 (M = 4.21, *SD* = 2.89) and 5 (*M* = 35.40, *SD* = 15.58) also demonstrated a highly significant difference in the yield score, as t(8) was 4.40, and the p-value was 0.002.

Table 5. Independent-samples *t-test* for the yield of different plot sizes, where yield is assigned as dependent & distance between clump and clump as independent variables.

Group	**Distance between clump and clump**	**N**	***M***	***SD***	***F***	***Sig.***	***t***	***df***	***Sig. (2-tailed)***
1	1.1m × 1.1m	5	10.63	5.94	3.98	0.07	0.65	10.00	0.531
2	1.7m × 1.7m	7	8.97	2.85			0.58	5.33	0.587
1	1.1m × 1.1m	5	10.63	5.94	3.87	0.09	1.85	8.00	0.102
3	0.7m × 0.7m	5	5.26	2.63			1.85	5.51	0.118
1	1.1m × 1.1m	5	10.63	5.94	3.28	0.11	2.18	8.00	0.061
4	2.5m × 2.5m	5	4.21	2.89			2.18	5.79	0.074
1	1.1m × 1.1m	5	10.63	5.94	3.05	0.12	-3.32	8.00	0.011
5	1.5m × 1.5m	5	35.40	15.58			-3.32	5.14	0.020
2	1.7m × 1.7m	7	8.97	2.85	0.05	0.82	2.29	10.00	0.045
3	0.7m × 0.7m	5	5.26	2.63			2.33	9.21	0.044
2	1.7m × 1.7m	7	8.97	2.85	0.01	0.92	2.84	10.00	0.081
4	2.5m × 2.5m	5	4.21	2.89			2.83	8.70	0.020
2	1.7m × 1.7m	7	8.97	2.85	8.77	0.01	-4.47	10.00	0.001
5	1.5m × 1.5m	5	35.40	15.58			-3.75	4.19	0.018
3	0.7m × 0.7m	5	5.26	2.63	0.01	0.92	0.60	8.00	0.564
4	2.5m × 2.5m	5	4.21	2.89			0.60	7.93	0.564
3	0.7m × 0.7m	5	5.26	2.63	6.49	0.03	-4.27	8.00	0.003
5	1.5m × 1.5m	5	35.40	15.58			-4.27	4.23	0.012
4	2.5m × 2.5m	5	4.21	2.89	6.25	0.04	-4.40	8.00	0.002
5	1.5m × 1.5m	5	35.40	15.58			-4.40	4.27	0.010

The production is determined by the number of clumps in a block and the maintenance of appropriate space between clumps (Tables 1 & 2). Among all the maintained spacing between clump and clump, the spacing of 1.7m × 1.7m & 0.7m × 0.7m; 1.7m × 1.7m & 2.5m × 2.5m showed a significant difference in yield (Groups 2 & 3, 2 & 4 in Table 4). However, the spacing of 1.1m× 1.1m & 1.5m × 1.5m; 1.7m × 1.7m & 1.5m × 1.5m; 0.7m × 0.7m & 1.5m × 1.5m; 2.5m × 2.5m & 1.5m × 1.5m demonstrated a highly significant difference in the yield (Groups 1 & 5, 2 & 5, 3 & 5, 4 & 5 in Table 5). It was interesting to note that *T. nutans* cultivation does not need much care, such as putting manure, watering, weeding, and hoeing. It was revealed from the on-farm yield that the farmer never applied manure while planting, and weeding was done once a year, just before the harvest of the inflorescences.

Vernacular names

T. nutans is known in Bhutan by mainly three names: "wangpem meto" in Dzongkha (Bhutan National Language), “wang pemo” in Khengkha (Central Bhutan Dialect), and “nakima” in Lhotshamkha (Southern Bhutan Dialect). It is a clump-forming evergreen plant. It has dark green, sprawling, and parallelodromous leaves converging apically. The leaf length of a fully-grown plant scales up to 2 meters, with an average of ±1.50 meters. The structure of the plant resembles that of *Molineria*.

Ethnobotany of *Tupistra*

There are 53 families, 76 genera, and 78 species of wild plants that have been used ethnomedicinally. A recent study from Baglung District, Nepal, documented 219 medicinal plant species, highlighting the rich ethnobotanical diversity across the eastern Himalayan region (Acharya et al. 2025). Only 20 family groups of plants (22 genera and 22 species) had been used the most. Other common species, such as *S. chirayita, B. ciliata, V. articulatum, and A. rivularis,* were also in the top list (Table 6). These species are also frequently used in Nepal (Kunwar & Bussmann 2009). Table 6 showed that *Tupistra nutans* possessed the highest IV, followed by *Swertia chirayita* (0.75) and *Bergenia ciliata* (0.66). *Rubus ellipticus* and *Centella asiatica* were used with the least importance value (0.06 each). People of the age group (33-86 years old) have said that drinking decoction out of fresh leaves of *T. nutans* controls high blood pressure, and they never have to take allopathic medicine. Likewise, same-age group respondents have noted that consuming flowers as a vegetable contains their sugar to its normal range. People said that taking about 5 grams of roots every evening before bed can also bring the blood sugar level to its normal range.

As *T. nutans* is abundant and available in Darla, Bhutan, because of its in-situ conservation and cultivation on-station and on-farmland, the species is now emphasized in selection and collection for ethnobotanical uses. Our findings confirm that the ethnobotany of Darla is influenced by the availability of species. It is depicted that *T. nutans* is a beneficial plant species among all listed ones. Almost all parts (inflorescence, leaf, root, seed) of the *T. nutans* plant are being used for different purposes. For instance, the inflorescence is used as a vegetable, and interviewees have also said it is helpful for blood pressure, diabetes, and gout. Further, it is one of the wild plant species that can add off-farm income to rural communities. However, the above-listed wild plant species cater to the socio-economic needs of rural livelihoods. Among them, *T. nutans* is very valuable in Bhutan since its inflorescence is used as one of the Bhutanese cuisines and is believed to have medicinal properties (Supplementary File 1).

Table 6. The most frequently used ethnomedicinal plants in Darla, Bhutan.

Scientific name of the plants	**Plants’ voucher species # collected at National Herbarium, National Biodiversity Centre, Thimphu**	**Respondents’ age group (Yrs)**	**Men**	**Women**	**Importance Value (IV)**	**Used by % of HH Population**
Tupistra nutans Wall. ex Lindl.	THIM17660/BTN340	33-86	39	26	0.83	83.33
Swertia chirayita (Roxb.) Karsten	10138 & 492	20-80	41	18	0.75	75.64
Bergenia ciliata (Haw.) Sternb.	5733	20-80	31	21	0.66	66.66
Viscum articulatum Burm. f.	21965	20-80	29	20	0.62	62.82
Astilbe rivularis D. Don.	3074	33-86	25	14	0.5	50.00
Exbucklandia populnea (Griff.) R. W. Brown	7959 & 51091	34-80	21	13	0.43	43.58
Poranopsis paniculata (Roxb.) Roberty	48854	34-74	11	7	0.23	23.07
Tinospora cordifolia (Willdenow) Hook. f. & Thomson.	15419 &15420	39-80	10	6	0.2	20.51
Litsea cubeba (Lour.) Pers.	THIM15499 /BTN137	35-74	9	5	0.17	17.94
Acorus calamus L.	THIM16579 / 15	35-80	9	3	0.15	15.38

Docynia indica (Wall.) Decaisne	THIM02912	36-64	11	1	0.15	15.38
Drymaria cordata (L.) Roemer & Schultes	3514 / 7032	34-86	7	5	0.15	15.38
Engelhardtia spicata Blume	THIM00115 / 645	35-80	7	5	0.15	15.38
Rumex nepalensis Sprengel.	THIM00935 / 1283	35-73	6	6	0.15	15.38
Costus lacerus Gagnep.	2685/ 39	39-73	7	1	0.1	10.25
Myrica esculenta Buch.-Ham. ex D. Don	THIM00113/ 4563	39-73	6	2	0.1	10.25
Rhododendron arboretum Smith.	8677/ 604	34-74	3	5	0.1	10.25
Artemisia verlotiorum Lamotte.	5334	35-73	5	1	0.07	7.69
Phytolacca acinosa Roxb.	THIM00979 / 2026	50-71	6	0	0.07	7.69
Rhus chinensis Mill.	THIM04364 / 257	38-64	5	1	0.07	7.69
Centella asiatica (L.) Urban	THIM15758 / 5617	42-57	4	1	0.06	6.41
Rubus ellipticus Smith	THIM03229 / 2	43-73	4	1	0.06	6.41

The people of Darla use flowering spikes of *T. nutans* as a vegetable. Some people in Bhutan collect and use flowers as vegetables, eat fruits, and use their long leaves as fodder for livestock. It was recorded that the inflorescences of this plant are used to sell at Bhutanese currency 25/= per handful, fist bundle in the Thimphu vegetable market by the local community (Mukhia *et al.* 2022, Nepal 2023). Dagana district's NWFP report recorded that some farmers within their homesteads use the plant as an ornamental plant (Bajgai *et al.* 2023). The plant inflorescences are seen in the local market and along the roadside shops in Gedu (Ghimiray & Katwal 2013). Being widely applicable, this plant is considered a potential crop that can be domesticated and naturally grown as an income-generating species for farmers. The plant is also cultivated by the farmers of Sikkim as a crop and sold inflorescence with spikes in the market during its flowering season (Sharma 2016).

It has been revealed that *T. nutans* is also a good source of fiber and protein (Gurung *et al.* 2018). It is comparable to asparagus's nutrients (Gurung *et al.* 2018). Because of its properties, the people of Sikkim use a decoction of this plant prepared out of its roots and flowers (Hussain & Hore 2007) for diabetes (Tamang *et al.* 2013). The Lepcha tribe of north Sikkim made powder from this plant's inflorescence and mixed the powder in water thoroughly to relieve body pain (Pradhan & Badola 2008). The inflorescence of this plant is also used in managing hypertension and diabetes (Bhattacharya & Ghosh, 2014). People from south Sikkim eat its dry nakima inflorescence powder to treat diabetes and as a tonic (Idrisi *et al.* 2010). It is affirmed that inflorescence with buds and open flowers can be made into curry and taste like a button mushroom, but a bit bitter (Verma & Nath 2016). Fresh flowers and dried roots of *T. nutans* are used by people of Darjeeling to relieve food poisoning, body pain, and general weakness (Yonzone *et al.* 2012).

Pharmacological uses

Pharmacologically, the hydro-ethanolic flower extract of this plant shows that it has flavonoids (Verma & Nath 2016) and antidiabetic effectiveness (Sharma 2016, Dhugyal *et al.* 2018). The methanolic extract from the flowers of *T. nutans* exhibits the presence of flavonoids (Verma & Nath 2016). Proximate analysis of essential and non-essential elements has determined that *T. nutans* contains a significant quantity of nutrients and minerals and is a rich source of natural antioxidants. The determinants pointed out that for a healthy life, it can be added to a daily food basket (Khatoon *et al.* 2018).

Climate change adaptation

T. nutans was known by the villagers even before the record by H. Noltie for Bhutan in 1994. The flora of Bhutan (Noltie 1994) recorded *T. nutans* in the wild, but it is still being cultivated in gardens within Chhukha, Dagana, Samtse, and Gangtok (India). It grows in transition and ruderal areas and maintains ground moisture and the environment. It is a crop that aids the household economy and has significant cultivation potential under climate change. It is revealed that this wild plant has potential for many uses as fodder, vegetable, and edible fruits, and can even generate income by selling its flowering spikes/inflorescences as vegetables in the markets (Noltie 1994, Ghimiray & Katwal 2013, Verma & Nath 2016). Some

research studies confirmed that it could be adopted as a climate-smart crop and as one of the agroforestry species in agricultural farming land (Muschler 2016; Sharma 2016). In response to the impact of climate change, the Lepcha communities in Sikkim, India, began to domesticate valuable species such as *T. nutans* as one of the intercropping species in their farming land since it needs less water and shade to grow (Das *et al*. 2025).

Conclusion

T. nutans can be grown wild and cultivated on the marginal land as it demonstrated sound growth on trial cultivation on on-station and on-farmland in Darla, Bhutan. It only requires a few cultivation management techniques. The planting space (distance) of 1.5m × 1.5m between plants and plants (clump to clump) can be adopted for healthy growth and optimum production. The dry, coarse soil with scanty rainfall is better for its development. As revealed on on-station and on-farmland trials, this plant species can be grown within a homestead agroforestry practice. As the theory of availability is already reflected in ethnobotany, we found that the availability of a *Tupistra* plant influences its use and conservation, and the *T. nutans* has increasingly been used in Bhutan. The village's older people have expressed that flowers, leaves, and roots can help manage high blood pressure and diabetes, relieve food poisoning, body pain, and general weakness. Taking flowers as a vegetable maintains an individual's appetite and even helps in food digestion. Eventually, research studies of the regional places stated that the plant is a rich source of natural antioxidants. The hydro-ethanolic flower extracts of *T. nutans* can be used as medicine for diabetes through herbal therapy. Besides, it can generate income for local farmers by selling its fresh flowers/inflorescences in the available market as vegetables. Thus, it is considered a beneficial plant for socio-economy and local therapeutics.

Declarations

Ethics approval and consent to participate: Required consent was obtained from the Department of Forests and Park Services (DoFPS), Ministry of Agriculture and Forests.

Consent for publication: not applicable

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Supplementary File 1. Most frequently used of wild plants for ethno-medicinal purposes by the vicinity settlement of the research sub centre office, Darla

Plant family	**Scientific name of the plants**	**Part (s) used**	**Purpose**
Asparagaceae	*Tupistra nutans* Wall. ex Lindl.	Inflorescence, leaf, root, seed	Inflorescence is used as a vegetable, helpful in blood pressure, diabetes & gout. It is also sold in the available market, which helps to add to household income. Raw root is taken as betel nut by a diabetic person. Seed used to relieve sinusitis. Seed powders boil and drink to relief stomach-pain. Leaf used as fodder.
Gentianaceae	*Swertia chirayita* (Roxb.) Karsten	Entire	Decoction or soaked warm water is taken as tea to relieve fever, cold & cough, and to reduce high blood pressure.
Saxifragaceae	*Bergenia ciliata* (Haw.) Sternb.	Rhizome	Chew betel-nut or prepare tea and drink to relief body-pain, to normalize heavy menstrual flow. Helpful to delivery women to the relief post-delivery pain. Rhizome paste is also applied over cuts & wounds to heal.
Loranthaceae	*Viscum articulatum* Burm. f.	Entire	Paste applied over the fracture, boil and drink as tea to relief body-pain
Saxifragaceae	*Astilbe rivularis* D. Don.	Rhizome	Boil and drink as tea to relief body-pain and stomachache.
Hamamelidaceae	*Exbucklandia populnea* (Griff.) R. W. Brown	Bark	Paste applies over fractures of both human & livestock. Bark tea relief body-pain.
Convolvulaceae	*Poranopsis paniculata* (Roxb.) Roberty	Entire	Paste applies over fractures or sprains, wounds, and cuts. Taking tea out of the climber reliefs body-pain
Menispermaceae	*Tinospora cordifolia* (Willdenow) Hook. f. & Thomson.	Climber	Drinking decoction helps in diabetes, fever, body & joint-pain, high blood pressure, ulcer, jaundice, and also regularizes irregular menstruation. Climber paste is applied over the fracture for quick recovery. Feed the milch cow to enhance milk production.
Lauraceae	*Litsea cubeba* (Lour.) Pers.	Fruit / Seed	Essential oil extracted from fruit/seed. Apply oil on the forehead; swallow a little bit to relieve cold & cough, headache, fever, throat-pain, and mouth ulcer.
Acoraceae	*Acorus calamus* L.	Rhizome	Paste applies to cuts and wounds, scabies, & ring-worm. Take a little bit of rhizome to stop diarrhea, relieve food poisoning, or indigestion. Steam inhalation for relief of sinusitis, cold & cough.
Rosaceae	*Docynia indica* (Wall.) Decaisne	Bark, ripened fruit	Bark or prepared vinegar out of ripened fruit is taken to relieve diarrhea & dysentery. Raw bark helpful in piles.
Caryophyllaceae	*Drymaria cordata* (L.) Roemer & Schultes	Entire aerial parts	Used to relieve sinusitis and throat pain. Its decoction relieves early diarrhea in a child.
Juglandaceae	*Engelhardtia spicata* Blume	Bark	Paste applies over a fracture or sprain. Bark decoction relieves red urine in cattle.

Polygonaceae	*Rumex nepalensis* Sprengel.	Root, leaf	Useful for stomachaches. Leaf extract can treat a child against diarrhea. Root is helpful in jaundice, and leaf in piles. Paste can cure cuts and wounds. Foot itchiness due to mud can be cured by applying its paste.
Costaceae	*Costus lacerus* Gagnep.	Stem, root	Stem is useful in jaundice, UTI, stomachache, body-pain. Eating raw root help in gastritis. Root also used in sinusitis.
Myricaceae	*Myrica esculenta* Buch.-Ham. ex D. Don	Bark	Useful at times of diarrhea, stomachache, piles, high blood pressure, snuffling its powder relief sinusitis.
Ericaceae	*Rhododendron arboreum* Smith.	Flower	Reliefs throat-pain, diarrhea, dysentery, relief food poison
Asteraceae	*Artemisia verlotiorum* Lamotte.	Entire	Juice extract can cure minor cuts & wounds. Take bath with its extracted juice to cure scabies.
Phytolaccaceae	*Phytolacca acinosa* Roxb.	Root, tender leaf along with young shoot.	Take a small bit of root to relief stomachache & food poison. It is also helpful in eye problem. Tender leaves along with young shoot eat as vegetable.
Anacardiaceae	*Rhus chinensis* Mill.	Fruit, root	Make into vinegar which is taken to stop diarrhea / dysentery. It is also given to cattle at times of diarrhea and to goat when suffers from indigestion. Root is chewed like betel-nut.
Apiaceae	*Centella asiatica* (L.) Urban	Entire	To treat diarrhea, pneumonia & tonsillitis in child. Paste applies to cuts, useful to mouth ulcer. Paste also cures itchiness of foot due to mud.
Rosaceae	*Rubus ellipticus* Smith	Root	Useful to treat diarrhea, food poison. Root decoction relief gastritis, also used in sinusitis. Ripened fruit edible.