DOMESTICATION AND CONSERVATION OF ENDANGERED MEDICINAL PLANTS AT TWO AGRO-ECOLOGICAL ZONES OF PAKISTAN

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ABSTRACT

Northern Pakistan is known for its rich medicinal flora however, more than 150 species are at a greater risk of becoming endangered; mainly due to natural disaster, climate change, nomadic grazing and over harvesting for its ethno-botanical uses. Proper domestication and conservation measures are necessary to conserve the medicinal flora. Experimental trials were conducted to examine the growth of medicinal plants in Swat and Chitral. Plants were studied in wild habitats by using fertilizers. Data showed that various treatments significantly affected plant height (cm), plant density m^{-2}, root yield (kg ha^{-1}) and net income in both the locations. The analysis of the data revealed that maximum income for *Glycyrrhiza glabra* (840,000 PKR ha^{-1}) and *Trillium govanianum* (481,325 PKR ha^{-1}) was recorded in NPK treated plots. Simlalry, minimum (220,000 PKR ha^{-1}) for *Glycyrrhiza glabra* and (104,854 PKR ha^{-1}) was recorded for *Trillium govanianum* in their wild habitats. Growth and yield of the medicinal plants grown in Swat valley was higher than Chitral. Furthermore, the production of the medicinal plants in wild habitat was comparatively lower and thus improved production technology is suggested to get higher yield. The findings revealed that Swat valley is most suitable and productive for the cultivation of medicinal plants as compared to Chitral. In addition, growing medicinal plants need to be popularized among the farming communities of the area and the gerplasm of these endangered species should be conserved.

Keywords: Medicinal plants, Endangered wild flora, domestication, cultivation, conservation.

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INTRODUCTION

Medicinal plants that grow naturally are a good source of new drugs (Jamshidi-Kia et al. 2018). Peoples are interested in using organic medicines due to the side effects of the allopathic medicines. Over centuries, cultures around the world have learned how to use plants to fight illness and maintain health. The ethnobotanical medicines form the basis of an accessible and affordable health and a basic source of income for indigenous inhabitants. Ethnobotanist have been explored the potential of classical Ayurvedic and Unani uses compared to modern findings and applications, together with their pharmacology and therapeutic principles in an evidence-based approach (Khare et al., 2004; Wangensteen et al., 2013). According to the World Health Organization (WHO) approximately 65-80% of the world is dependent on the medicinal plants for caring their health (Asiminicesei et al. 2020). With the recent advancement in all areas of science and technology, herbal medicine is growing rapidly (Tang et al. 2021). Wild medicinal plants are already being affected by anthropogenic, climate change, and its rapid onset is limiting the ability of many species to adapt to their environments (Hussain et al., 2012). Moreover, due to the excessive use and non-judicious collection, medicinal plants are vanishing from their natural habitats (Hussain et al., 2012). Lack of conservation of the natural habitats, the indigenous plants are depleting day by day from the Northern regions of Pakistan (Lope, 2012). Over construction is a menace for natural habitats of medicinal plants (Malik et al. 2015).

Improper collection of these medicinal plants is a serious threat to its conservation. The foremost issues for reduction of indigenous plants are overgrazing of animals and deforestation (Wang and Nixon. 2001; Tareen et al. 2010). The intended use of wild plants for medicinal purpose are in a greater risk to become endangered at the Sothern Himalayan region of Pakistan where conservation is necessary (Qureshi and Ghufran, 2005). To conserve the natural habitats of endangered medicinal plants and spread it into other areas which are adequate for its farming are the main aim of conservation (Srivastava et al. 2018). Here are some critical endangered medicinal plants species of District Swat and Chitral area.

Glycyrrhiza glabra L., known as sweet wood and licorice belongs to family Leguminoceae. The scientific name of *G. glabra* L. is derived two Greek word i.e. *glukys* which means sweet and *rhiza* which means root. That is why it's called sweet wood and in local Pushto language it's called (*Khwaga zailai*) which also means sweet root. It is naturally found in Asia and Mediterrerian region of the world and is cultivated in the sub-tropical and temperate region. It is propagated from rhizomes. England and Spain are the its largest commercial producers (Zaigham et al. 2019). It can be easily grown on light loamy and smooth textured soil. It can be propagated from roots cuttings having two to three buds and runners as well. It contains glycyrrhizin which is used as remedy for Anaemia, asthama sexual debility, cough, skin treatments and fever (Walter and Gillett 1998; Visput et al. 2011). Moreover, it permotes the hormone production in andrenal glands and also used in the curing liver cirrhosis and chronic hepatitis (Baghdadi 2005; Noshahi et al. 2019; Hasan et al. 2021).

Trillium govanianum Wall. is one of the most important plant of the higher altitudes of Pakistan.Its a member of family Trilliaceae localy known Matarzala in Khyber Pakhtunkhwa, Pakistan (Rahman et al. 2016). Its rhizome is used for medicinal purpose i.e healing wounds, skin infections, dysentery and sexual disorders (Mahmood et al. 2013). Different studies have revealed *T. govanianum* having ani cancer and antifungal activities (Rahman et al. 2015). *T. govanianum* having ability to inhibit the production of reactive oxygen species

(Rahman et al. 2016). It contains antioxidant compounds that suppress the release of toxic compounds in human body which is widely used for the treatment of cancer, AIDS and arthritis (Rahman et al. 2017). The rhizome contains steroids and saponins which is usd in anti-inflammatory medicines and localy used in pain treatment (Rahman et al. 2015; Ismail et al. 2015).

Saussurea lappa Clarke. is perennial herb belongs to family Asteraceae and found at higher altitudes.It is cultivated in higher altitudes of Kashmir and Chenab valley. Roots are used in medicines (Khan et al. 2013). It contains Cynaropicrin, costunolide having anticancer activity (Yaeesh et al. 2010; Kamalpreet et al. 2019). Dehydrocostus lactons are found in *S. lappa* having suppressive effect on hepatitis B antigen. Moreover drugs are isolated from root as anti-HBV drugs for use (Gautam and Asrani 2018). *S lappa* extracts had significant inhibitory effect on the human pathogens (Chen et al. 1995; Khan et al. 2013).

Thymus vulgaris L. is perennial herb having volatile oil and mostly cultivated in Europe. It is used as pot herb. Leaves are used in the dairy farm products and the oil is used for flavoring in different products. It is used as carminative, anti microbial, antiseptic and disinfectant medicinal drug. It is used in curing intestinal infections. It works as anti inflammatory agent, antiviral, antioxidant and insecticidal activities (Prasanth et al. 2014).

Valeriana jatamansi L. is an important Hamalayan medicinal plant commonly cultivated in USA. It is used for sleeping disorder, skin treatment, releaf pain and also have anti inflammatory activities (Agnihotri et al. 2011). Flavonoids found in *V. wallichii* exibit antioxidant activities (Uttara et al. 2009; Thusoo et al. 2014). Due to the presence of iridoid esters it has strong antifungal and antileishmanial activity. Antimicrobial, antiviral and insecidial activities are also reported in *V. Wallichii* (Khuda et al. 2012).

Fagopyrum esculentum Moench is commonly know as Buckwheat. It was originated from Siberia and domesticated plant species of Polgoneace family. It contains variety of useful compounds that were found vital components of human diet. Buckwheat flour is consumed in certain regions of the world (Campbell, 2004; Suvorova and Zhou, 2018). It is more digestible in comparison to other flour. Its also used as sauce and served with potatoes. Plenty of products including baking products and confectionaries are avalible in market prepared from *F. esculentum* flour (Bhatta, 2021).

All these endangered medicinal plants plays a vital role in health care therefore, proper conservation of these plants are necessary. The study aimed to conserve the endangered medicinal flora from genetic erosion and to demonstrate the growth response of medicinal plants to NPK fertilizer at different agro-ecological zones.

MATERIALS AND METHODS

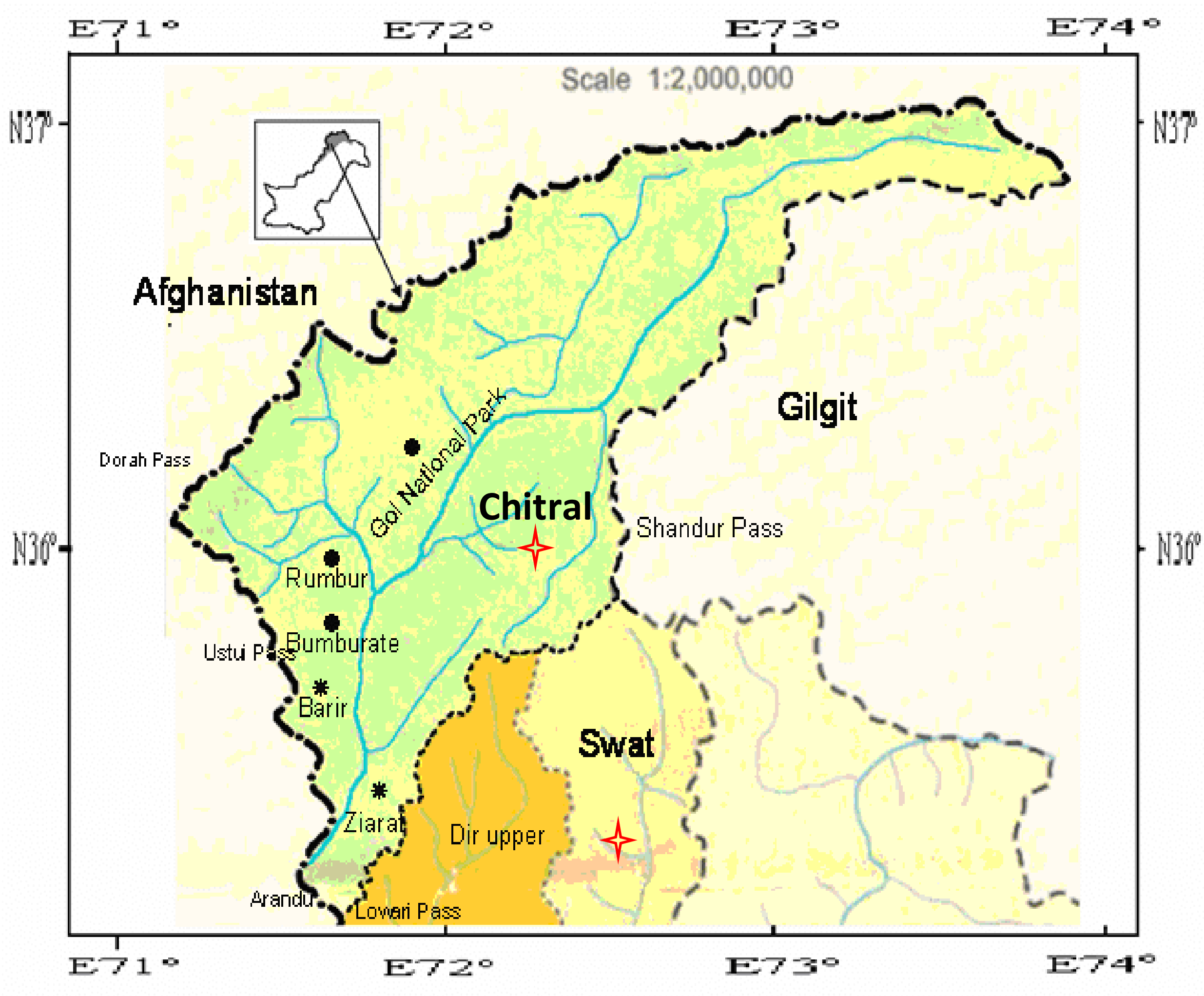
Study area description

District Swat is situated in the Northern region and cold temperate zone of Khyber Pakhtunkhwa Pakistan having wet mountains. The average monthly rainfall is 235 mm in summer and 116 mm in winter. The soils consist of silt loams to silty clays. A small area is under rainfed agriculture but most of it is under forest. District Chitral is located in Northern Dry Mountains zone of Khyber Pakhtunkhwa Pakistan. The average monthly rainfall is 25 to 75 mm in winter and 10 to 20 mm in summer. The valley soils are deep and clayey. Most of the area is used for grazing. Both the agro-ecological produce economically and medicinally important wild plants, which were at higher risk of becoming extinction in future if properly not conserved.

Keeping in view the economic and medicinal importance, endangered plant species viz; *Glycyrrhiza glabra*, *Valeriana jatamansi, Saussurea costus, Trillium govanianum, Fagopyrum esculentum, Thymus vulgaris, Viola odorata* and

Caralluma tuberculata were selected (Table 1). Field trials were conducted to evaluate the growth performance of wild medicinal plants in field and natural habitats. The plants growth performance was evaluated in response to NPK fertilization and compared with both the control plots and plants at wild habitats. The plant population were increased and the germplasm for each specie was preserved for future research in multiplication.

Figure 1. Study area map



Experimental Design

The experiments were laid out in Randomized Complete Block Design (RCBD) in two different locations i.e. District Chitral and District Swat (Pakistan). The plants collected from the wild habitates were cultivated in two plots at both the location one was maintained with fertilizer (NPK) and weed control pratices and the other was maintained without fertilizer. Rate of fertilizer was 100 kg N ha^{-1} along with 60 kg P_2O_5 and 150 kg K_2O ha^{-1}. Moreover, nitrogen was applied in split doses i.e 50 kg ha^{-1} after two weeks of transplantation and 50 kg ha^{-1} at maturity. The experimental data were recorded on plant height (cm), plants m^{-2}, root/biomass yield kg ha^{-1} and income Rs ha^{-1}.

Statistical analysis

Analysis of variance techniques (ANOVA) for all the parameters was carried out by using Statistix 8.1 software (Analytical Software, Tallahassee, FL, USA). wherever, the F-value was found significant, LSD was computed at 5 % level of probability and means were separated by using multiple comparasion test.

RESULTS AND DISCUSSION

1. Growth response of *Glycyrrhiza glabra* to NPK at two agro-ecoligcal zones

The analyzed data (Table-2) shows various parameters regarding the growth and yield of. The means of the data were found significantly (*$P \leq 0.05$*) different due to the soil and agro climatic conditions of the locations. Maximum plant height (150.67 cm), plants density (12 plants m^{-2}), root yield (3360.0 kg ha^{-1}) and income (840000 Rs ha^{-1}) was recorded in the plots where NPK was applied, agronomic and weed management practices were applied to the field in Swat. Minimum root yield (949.7 kg ha^{-1}) and income (220000 Rs ha^{-1}) was recorded in Chitral in control plot and 4.66 plants m^{-2} was noted in the wild habitat at Swat. Maximum values attained in the NPK applied plot at Swat was due to the availability of appropriate nutrients, proper weed management and moisture content in the soil. The *G. glabra* growth at Swat and NPK applied plot was better as compared to the growth at wild habitat in Swat and minimum at Chitral in fertilized plots and in the control. Whereas, the agro-climatic condition of Swat was found more suitable for the growth of *G. glabra.* Minimum value recorded in the Chitral in control plot was due to no management practices, no NPK application and due to the dry condition of the soil for *G. glabra* plants that found with retarded growth therefore proper conservation is needed (Lope, 2012).

2. Growth response of *Viola odorata* to NPK at two agro-ecoligcal zones

The statistically analyzed data in (Table-3) showed that the means of the data were found significantly ($P \leq 0.05$) different due the soil and agro climatic condition of the locations. Means of the data showed that maximum plant height (15.00 cm), plants density (270.67 plants m^{-2}), biomass yield (4860.02 kg ha^{-1}) and income (194,407 Rs ha^{-1}) was computed in the plots where NPK was applied, agronomic and management practices were applied to the field at Swat. Shorter plants (9.33 cm), plants density m^{-2} (20.67 plants m^{-2}), biomass yield (202.8 kg ha^{-1}) and income (8113 Rs ha^{-1}) was recorded at Chitral in control plots. The *V. odorata* growth at Swat was maximum as compared to the wild habitat and minimum at Chitral both in the NPK applied plot and the control plots. During the trial it was found that the *V. odorata* need more water, shady and moist place for growth and survival. The dry leaves of *V. odorata* are sold at 40 Rs kg^{-1}. Therefore, conservation of medicinal plants of northern areas will strengthen the socio economic condition of the inhabitants of the area (Qureshi and Ghufran, 2005).

3. Growth response of *Thymus vulgaris* to NPK at two agro-ecological locations

The statistically analysis of data showed that response of *T. vulgaris* to NPK at two agro-ecological locations were found significant (*P≤0.05*) as shown in Table-4. Variation in *T. vulgaris* was due the moist soil condition and appropriate agro climatic condition of the locations. Data revealed that maximum plant length (50 cm), plant density (200.3 plants m^{-2}) and root yield (5670.1 kg ha^{-1}) and income (453,609 Rs ha^{-1}) was recorded in the plots where NPK, agronomic and management practices were applied to the field at Swat. Minimum plant height (15.33 cm), plants density (22.67 plants m^{-2}), and yield (1989.1 kg ha^{-1}) and income (159,124 Rs ha^{-1}) was recorded at Chitral in control plots. Higher numerical values noted in the NPK applied field at Swat was probably due to the availability of appropriate nutrients, proper weed management and moisture content in the soil. *T. vulgaris* growth at Swat was higher as compared to the wild habitat and minimum was noted at Chitral, both in the NPK applied field and the control plots. *T. vulgaris* is sold at the rate of 80 Rs kg^{-1} by the local collectors. It can grow in the area having less water where the soil texture is sandy clay with pebbles. *T. vulgaris* is one of the endanger plant and it is cultivated in the European countries and essential oil are extracted from it (Prasanth et al. 2014).

4. Growth response of *Saussurea costus* to NPK at two agro-ecoligcal zones

Data presented in Table-5 showed that *Saussurea costus* growth was significantly (*P≤0.05*) affected by NPK at two agro-ecological locations. Means of the data showed that maximum plant height (144.00 cm), plant density (8.33 plants m^{-2}) root yield (8736.3 kg ha^{-1}) and income (698,905 Rs ha^{-1}) was recorded in the plots where NPK, agronomic and management practices were applied to the field at Swat. Minimum plant height (51.67 cm), root length (212.67 cm), plant density (5.00 plants m^{-2}) and (3047.4 kg ha^{-1}) and income (243793 Rs ha^{-1}) was recorded at Chitral in control plots. *S. costus* is a shady and humid loving plant which was mostly found near the streams. The plants were found with vigorous growth at Miandam, Swat because of favorable condition for its growth. Retarded growth was found at Chitral because Chitral has dry climatic condition. *S. costus* was sold at the rate of 80 Rs kg^{-1} by the local collectors. It is also found that *S. costus* as endangered plant documented in Appendix I of convention of International Trade Endangered species of Wild Fauna and Flora. In a previous study it was also reported that *S. costus* is one of the endangered plant specie out of 37 endangered plants. Therefore, proper conservation of *S. costus* is highly recommended for in situ and ex situ conservation (Kuniyal et al. 2019).

5. Growth response of *Valeriana jatamansi* to NPK at two agro-ecoligcal zones

Valeriana jatamansi plant was frequently found at the wild habitat of Swat.The statistically analyzed data showed significant (*P≤0.05*) difference in growth and yield of *Valeriana jatamansi* at different locations (Table-6). Means of the data showed that maximum plant height (26.00 cm), plants density (15.00 m^{-2}), weight $plant^{-1}$ (0.06 kg), biomass (3557.3 kg ha^{-1}) and income (719,200 Rs ha^{-1}) was recorded in the plots where NPK, agronomic and weed management practices were applied to the plots at Swat. The minimum plant height (18.00 cm), plants density (4.00 plants m^{-2}), and yield (670.7 kg ha^{-1}) and income (134133 Rs ha^{-1}) was recorded at Chitral in control plots.The indigenous peoples sell *V. jatamansi* at 200 Rs kg^{-1}. Moreover, *V. jatamansi* growth was siginificanlty improved with NPK application at Swat Valley. *V. jatamansi* is also shade and moist loving plant. Minimum value was recorded in the Chitral in control plots. Hence NPK application is recommended to improve growth of *V. jatamansi.* Moreover, *V. jatamansi* is a rare plant in the locality with high medicinal value (Sudhanshu 2012). Furthermore, *V. jatamansi* is at greater risk to become extinct and the prevailing environmental conditions also affect its growth. Therefore, in light of our findings it is suggested that proper conservation and cultivation of the *V. jatamansi* with improved production technology need to be popularized among the indegenous farmers.

6. Growth response of *Fagopyrum esculentum* to NPK at two agro-ecoligcal zones

Fagopyrum esculentum growth was found significantly ($P \leq 0.05$) different due the soil and agro climatic condition and management practices (Table-7). Analyzed data depicted that tallest plants (53.00 cm), plants m^{-2} (69.66) and seed yield (228.51 kg ha^{-1}) was recorded in the plots where NPK, agronomic and management practices were applied to the field at Swat. On the other hand, shorter plants (23.00 cm), plants density (19.66 plants m^{-2}) and seed yield (64.51 kg ha^{-1}) and income (193,52 kg ha^{-1}) was recorded at Chitral in control plots. The local people sell the *F. esculentum* at 300 or 350 Rs kg^{-1}. *F. esculentum* as a high nutritious plant and thus conservation and cultivation of this plant is suggested (Bhatta, 2021). Higher morphological data recorded in the NPK applied plots at Swat was due to the availability of appropriate nutrients and the lower values recorded in the Chitral in control plots were due to no proper management practices and due to dry condition of the soil *F. esculentum* growth was retarded. The results indicated that suitable weather condition and adequate agronomic practices improve buckwheat growth. Therefore, the improved growth of buckwheat in the Swat Valley could be due to its greater adaptability to the climatic conditions, whereas stunded plant growth in Chitral was because of dry weather. In a similar study, Dar et al. (2021) reported that high altitudinal regions and low temperatures exhibits improved adaptability growth of buckwheat and increased the nutritional quality of buckwheat.

7. Growth response of *Trillium govanianum* to NPK at two agro-ecoligcal zones

The statistically analyzed data presented in Table-8 showed various parameter regarding the growth and yield of *Trillium govanianum* as affected at different locations and treatments. Data showed that taller plants (15.00cm), plant density (30.66 plants m^{-2}) and yield of 59.00 kg ha^{-1} and income of 481,325 Rs ha^{-1} was observed in the plots where NPK, agronomic and management practices were used at Swat. While shorter plants (11.00), minimum plant density (5.00 plants m^{-2}, rhizome yield of 12.66 kg ha^{-1}, 104854 Rs ha^{-1} of income was recorded in the wild habitat. *T govanianum* is one of the rare plants which was found in the snow covered mountains of Miandam and its growth at Swat was better as compared to the wild habitat and minimum at Chitral. The market rate of the *T. govanianum* was 8000 Rs kg^{-1}. *T. govanianum* is very important because of its higher market ethnobotanical use (Sher et al. 2014; Rahman et al. 2015).

The areas near the snow covered mountains are found to be the most suitable for growth of *T. govanianum*. It cannot grow well in the dry areas like Chitral whereas, higher altitude region of Swat Valley are more suitable for the conservation and cultivation of *T. govanianum*. Moreover, *T. govanianum* have shown vulnerability to over-exploitation, particularly improper collection, habitat disturbances and climate change (Chauhan et al. 2019). Similarly, Ordonez et al. (2016) also reported that survival of high altitude medicinally important species are at greater risk of Climate change. Therefore, the present study revealed that adequate agronomic practices signficanlty increased the growth of *T. govanianum* in Swat Valley and the area could be recommended for cultivation of *T. govanianum* .

CONCLUSION

The endangered plants collected from their native habitat responded positively to fertilizer (NPK) application and agronomic practices at Miandam (Swat) region. The agro climatic conditions of Swat are more suitable for cultivation of these plants as comapred to Chitral which has dry climatic condition and the plants growth was retarded. All the above mentioned medicinal plants gave better yield and could be easily cultivated. Moreover, NPK application with proper irrigation practices improved plants growth in both the locations. Therefore, growing medicinal plants could be popularized among the indigenous farming community of Pakistan and the gerplasm of these endangered species should be conserved for future use. In addition, proper legesltation about the collection, conservation and marketing of endangered medicinal plants is suggested for their sustainable production.

Table-1 List of endangered medicinal plants of the studied area.

S.No.	**Scientific Names**	**Common name**	**Family**	**Uses in diseases**
1	*Glycyrrhiza glabra* (L.)	Liquorice	Fabaceae	Asthama and cough
2	*Valeriana jatamansi* (L.)	Wallichii	Valerianaceae	Sleeping disorders
3	*Saussurea costus* (L.)	Costus/kuth	Asteraceae	Hepatitis
4	*Trillium govanianum* (Wall.)	Trillium	Melanthiaceae	Cancer and arthritis
5	*Fagopyrum esculentum* (Moench.)	Buckwheat	Polygonaceae	Diabetes
6	*Thymus vulgaris* (L.)	Thyme	Lamiaceae	Intestinal infections
7	*Viola odorata* (L.)	Common violet	Violaceae	Cough and flue

Table.2. Comparison of *Glycyrrhiza glabra* growth parameters at different locations to various fertilizers.

Locations	Plant Height (cm)	Plants density m^{-2}	Yield kg ha^{-1}	Income Rs ha^{-1}
Wild Habitat (Swat)	144.00 a	4.66 c	880.0 c	220000 c
Fertilizer NPK (Swat)	150.67 a	12.00 a	3360.0 a	840000 a
Control plots (Swat)	137.67 a	10.00 ab	2332.7 b	583175 b
Fertilizer NPK (Chitral)	100.00 b	11.00 a	2528.7 b	632175 b
Control plots (Chitral)	95.67 b	5.33 bc	949.7 c	237425 c
LSD(0.05)	19.10	0.45	215.47	53867.5

Means followed by different letters are statistically different from each other at $P \leq 0.05$.

Table. 3. Growth response of *Viola odorata* to NPK fertilizer at different locations.

Locations	Plant Height (cm)	Plants density m^{-2}	Biomass kg ha^{-1}	Income Rs ha^{-1}
Wild Habitat (Swat)	14.33 ab	90.67 c	1355.0 c	54200 c
Fertilizer NPK (Swat)	15.00 a	270.67 a	4860.2 a	194407 a
Control plots (Swat)	14.80 a	231.00 b	3572.7 b	142907 b
Fertilizer NPK (Chitral)	10.66 bc	39.33 d	447.5 d	17900 d
Control plots (Chitral)	9.33 c	20.67 e	202.8 e	8113 e
LSD(0.05)	3.75	17.58	123.32	4932.6

Means followed by different letters are statistically different from each other at $P \leq 0.05$.

Table.4. Growth response of *Thymus vulgaris* to NPK fertilizer at different locations.

Locations	Plant length (cm)	Plants density m^{-2}	Yield kg ha^{-1}	Income Rs ha^{-1}
Wild Habitat (Swat)	13.33 c	22.67 d	3169.3 c	253540 b
Fertilizer NPK (Swat)	50.00 a	200.33 a	5670.1 a	453609 a
Control plots (Swat)	42.00 b	157.00 b	5010.1 a	400811 a
Fertilizer NPK (Chitral)	17.00 c	50.00 c	3142.9 b	251431 b
Control plots (Chitral)	15.33 c	17.00 d	1989.1	159124 c
LSD$_{(0.05)}$	5.53	22.06	835.73	66658

Means followed by different letters are statistically different from each other at $P \leq 0.05$.

Table. 5. Growth response of *Saussurea costus* to NPK fertilizer at different locations.

Locations	Plant Height (cm)	Root Length (cm)	Plants density m^{-2}	Yield kg ha^{-1}	Income Rs ha^{-1}
Wild Habitat (Swat)	131.67 a	43.66 a	3.00 c	1549.0 e	123920 e
Fertilizer NPK (Swat)	144.00 a	45.66 a	8.33 a	8736.3 a	698905 a
Control plots (Swat)	132.33 a	44.00 a	8.00 a	7337.4 b	586990 b
Fertilizer NPK (Chitral)	66.00 b	39.00 ab	6.33 ab	4105.5 c	328440 c
Control plots (Chitral)	51.67 c	29.66 b	5.00 bc	3047.4 d	243793 d
LSD$_{(0.05)}$	14.13	9.68	2.79	500.23	40018

Means followed by different letters are statistically different from each other at $P \leq 0.05$.

Table. 6. Growth response of *Valeriana jatamansi* to NPK fertilizer at different locations.

Locations	Plant Height (cm)	Plants densitym^{-2}	Root weight $Plant^{-1}$ (kg)	Yield kg ha^{-1}	IncomeRs ha^{-1}
Wild Habitat (Swat)	20.00 ab	4.00 d	0.043 b	694 c	138933 c
Fertilizer NPK (Swat)	26.00 a	15.00 a	0.060 a	3557.3 a	719200 a
Control plots (Swat)	20.00 ab	12.00 b	0.048 b	2396.0 b	479200 b
Fertilizer NPK (Chitral)	19.00 b	9.00 c	0.029 c	2040.0 c	208000 c
Control plots (Chitral)	18.00 b	6.66 c	0.025 c	670.7 c	134133 c
LSD(0.05)	6.07	2.39	0.01	442.01	88402

Means followed by different letters are statistically different from each other at $P \leq 0.05$.

Table. 7. Growth response of *Fagopyrum esculentum* to NPK fertilizer at different locations.

Locations	Plant Height (cm)	Plants density m^{-2}	Yield kg ha^{-1}	Income Rs ha^{-1}
Wild Habitat (Swat)	50.00 a	45.66 b	149.79 b	44936 b
Fertilizer NPK (Swat)	53.00 a	69.66 a	228.51 a	68552 a
Control plots (Swat)	45.33 a	65.00 a	213.20 a	63960 a
Fertilizer NPK (Chitral)	24.00 b	22.33 c	73.25 c	21976 c
Control plots (Chitral)	23.00 b	19.66 c	64.51 c	19352 c
LSD (0.05)	8.89	10.46	34.31	10293

Means followed by different letters are statistically different from each other at $P \leq 0.05$.

Table. 8. Growth response of *Trillium govanianum* to NPK fertilizer at District Swat.

Locations	Plant Height (cm)	Rhizome Weight (g)	Plants density m^{-2}	Yield kg ha^{-1}	Income Rs ha^{-1}
Wild Habitat (Swat)	13.66 a	5.93 a	5.00 c	12.66 c	104854 c
Fertilizer applied (Swat)	15.00 a	6.13 a	30.66 a	59.00 a	481325 a
Control plots (Swat)	11.00 b	5.06 a	14.66 b	34.66 b	280010 b
LSD (0.05)	1.51	2.47	7.2	5.75	10723

Means followed by different letters are statistically different from each other at $P \leq 0.05$.

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AUTHORS CONTRIBUTIONS

MAK designed and supervised the study. HU and MF conducted experiments and wrote the manuscript. AM, TZC, SH and HU helped in writing this manuscript. All authors read and approved the final masnucript.

REFERENCES CITED

Agnihotri, S., S. Wakode and M. Ali. 2011. Chemical composition, antimicrobial and topical anti-inflammatory activity of *Valeriana jatamansi* Jones. essential oil. *J. Essential Oil Bearing Plants,* 14 (4): 417-422.

Asiminicesei, D.M., I.C. Vasilachi and M. Gavrilescu. 2020. Heavy metal contamination of medicinal plants and potential implications on human health. Revista de Chimie. 71(7): 16-36.

Bhatta, A. 2021. Effect of malted buckwheat on the sensory and nutritional profiles of sel-roti (Doctoral dissertation, Department of Food Technology Central Campus of Techn. Inst. of Sci. and Techn. Tribhuvan University, Nepal. PhD thesis.

Campbell, C.G. 2004. Present state and future prospects for buckwheat. Proceedings of the 9th International Symposium on Buckwheat, Prague 2004. Buckwheat. 26-29.

Chauhan, H.K, A.K. Bisht, I.D. Bhatt, A. Bhatt and D. Gallacher. 2019. Trillium toward sustainable utilization of a biologically distinct genus valued for traditional medicine. The Botanical Review, 85(3): 252-272.

Chen, H.C., C.K. Chou, S.D. Lee, J.C. Wang and S.F. Yeh. 1995. Active compounds from *Saussurea lappa* Clarks that suppress hepatitis B virus surface antigen gene expression in human hepatoma cells. *Antiviral Res*. 27(1-2): 99-109.

Dar, F.A., I. Tahir and R.U. Rehman. 2021. Morphological Characterization Reveals High Intraspecies Diversity in Fagopyrum esculentum Moench and Fagopyrum sagittatum Gilib from North-Western Himalayan Regions. Agric Res. 1-12. https://doi.org/10.1007/s40003-021-00581-9.

Gautam, H., and R.K. Asrani. 2018. Phytochemical and pharmacological review of an ethnomedicinal plant: Saussurea lappa. Vet Res Int. 6: 1-9.

Hasan, M.K., I. Ara, M.S.A. Mondal and Y. Kabir. 2021. Phytochemistry, pharmacological activity, and potential health benefits of *Glycyrrhiza glabra*. Heliyon. 7;7(6) e07240. 1-10. https://doi:10.1016/j.heliyon.2021.e07240.

Baghdadi, I.H. 2005. Al Mukhtarat Fit Tib (Urdu Translation). Vol. II. New Delhi: Central Council of Research in Unani Medicine (CCRUM). 109-296.

Hussain, W., J. Hussain, R. Ali, Z.K. Shinwari, I.A. Nascimento and W.A. Lope. 2012. Tradable and conservation status of medicinal plants of Kurram valley, Parachinar, Pakistan. J. Appl. Pharm. Sci. 2(10): 65-70. https://doi:10.7324/JAPS.2012.21013.

Ismail, M., M.R. Shah, A. Adhikari, I. Anis, M.S. Ahmad and M. Khurram. 2015. Govanoside A, a new steroidal saponin from rhizomes of *Trillium govanianum*. Steroids. 104: 270-275. https://doi.org/10.1016/j.steroids.2015.10.013.

Jamshidi-Kia, F., Z. Lorigooini and H. Amini-Khoei. 2018. Medicinal plants: Past history and future perspective. J. Herb Pharm. 7(1): 1-7. http://eprints.skums.ac.ir/id/eprint/6978.

Kamalpreet, L.K., A. Singh, J. Kaur and N. Kaur. 2019. A brief review of remedial uses of *Saussurea lappa*. J Pharmacog. Phytochem. ISSN: 2349-8234. 8(3): 4423-4430.

Khan, M.A., A. Alam, S. Husain, S. Ahmed, M. Nazamuddin and Z.Q.

Ahmed. 2013. A potent herb of Unani medicine: a review. Int. J. Curr. Pharmacol. Res. 5: 1-4.

Khare, C.P. 2004. Encyclopedia of Indian medicinal plants: Rational Western Therapy, Ayurvedic and other traditional usage, Botany: Springer & Media. ISBN. 3-540-01026-21-391.

Khuda, F., Z. Iqbal, A. Khan and F. Nasir. 2012. Antimicrobial and anti-inflammatory activities of leaf extract of *Valeriana wallichii* DC. Pak. J. Pharm. Sci. 25 (4): 715-719.

Kuniyal, C.P., J.T. Heinen, B.S. Negi and J.C. Kaim. 2019. Is cultivation of *Saussurea costus* (Asterales: Asteraceae) sustaining its conservation? J. Threat. Taxa, 11(13): 14745-14752.

Kuniyal, C.P., Y.S. Rawat, S.S. Oinam, J.C. Kuniyal and S.C. Vishvakarma. 2005. Kuth (*Saussurea lappa*) cultivation in the cold desert environment of the Lahaul valley, northwestern Himalaya, India: arising threats and need to revive socio-economic values. Biodivers. Conser. 14 (5): 1035-1045.

Mahmood, A., A. Mahmood, R.N. Malik and Z.K. Shinwari. 2013. "Indigenous knowledge of medicinal plants from Gujranwala district, Pakistan." J. Ethnopharma. 148 (2): 714-723.

Malik, Z.A., J.A. Bhat, R. Ballabha, R.W. Bussmann and A.B Bhatt. 2015. Ethnomedicinal plants traditionally used in health care practices by inhabitants of Western Himalaya. J. Ethnopharmacol. 172: 133-144.

Noshahi, U.F., M.A. Nawaz and M. Hussain. 2019. A review of the medicinal values and health effects of plant *Glycyrrhiza glabra* (Licorice). Zeits Chrift Fur Arznei-& Gewurzp flanzen, 24(3): 121-127.

Petr, J., J. Kalinova, J. Moudry and A. Michalova. 2004. Historical and current status of buckwheat culture and use in the Czech Republic. Proceedings of the 9th International Symposium on Buckwheat, Prague. Adv. Buckwheat Res. 30. 524-528.

Prasanth, R.V., V.K. Ravi, P.V. Varsha and S. Satyam. 2014. Review on *Thymus vulgaris* traditional uses and pharmacological properties. Med. Aromat Plants. 3: 164.

Qureshi, R.A. and M.A. Ghufran. 2005. Medicinal value of some important roses and allied species of Northeren Area of Pakistan. M. Hashmi. Pictorial Printers (Pvt.). Ltd. Islamabad, 24-29.

Rahman, S.U., M. Ismail, M. Khurram and I.U. Haq. 2015. Pharmacognostic and ethnomedicinal studies on *Trillium govanianum*. Pak. J. Bot. 47: 187-192.

Sher, H., A. Aldosari, A. Ali and H.J. De-Boer. 2014. Economic benefits of high value medicinal plants to Pakistani communities: an analysis of current practice and potential. J. Ethnobiol. Ethnomed. 10 (1): 71.

Srivastava, A.K. 2018. Significance of medicinal plants in human life. In Synthesis of medicinal Agents from Plants. Elsevier. 1-24. https://doi.org/10.1016/B978-0-08-102071-5.00001-5.

Sudhanshu, N.R., M. Sandhya and M. Ekta. 2012. Evaluation of antioxidant properties of Valeriana wallichi to scavenge free radicals. Asian J. Pharm. Clin. Res. 5: 238-240.

Suvorova, G., and M. Zhou. 2018. Distribution of cultivated buckwheat resources in the world. In Buckwheat germplasm in the world. Academic Press. Book Chapter three. 21-35. https://doi.org/10.1016/B978-0-12-811006-5.00003-3.

Tang, F., Yan, H.L, L.X. Wang, J.F. Xu, C. Peng, H. Ao and Y.Z. Tan. 2021. Review of Natural Resources With Vasodilation: Traditional Medicinal Plants, Natural Products, and Their Mechanism and Clinical Efficacy. Frontiers. Pharmacol. 12: 257.

https://doi.org/10.3389/fphar.2021.627458.

Tareen, R.B., T. Bibi, M.A. Khan, M. Ahmad, M. Zafar and S. Hina. 2010. Indigenous knowledge of folk medicine by the women of Kalat and Khuzdar regions of Balochistan, Pakistan. Pak. J. Bot. 42(3): 1465-1485.

Thusoo, S., S. Gupta, R. Sudan, J. Kour, S. Bhagat, R. Hussain and M. Bhagat. 2014. Antioxidant activity of essential oil and extracts of *Valeriana jatamansi* roots. BioMed. Res. Inter. 1-4. https://doi.org/10.1155/2014/614187.

Rahman, S., A. Adhikari, M. Ismail, M.R. Shah, M. Khurram, M. Shahid, F. Ali, A. Haseeb, F. Akbar and M. Iriti. 2016. Beneficial effects of *Trillium govanianum* rhizomes in pain and inflammation. Molecules. 21(8): 1095. https://doi.org/10.3390/molecules21081095.

Rahman, S., M. Ismail, M. Khurram, I. Ullah, F. Rabbi and M. Iriti. 2017. Bioactive steroids and saponins of the genus Trillium. Molecules, 22(12): 2156. https://doi.org/10.3390/molecules22122156

Uttara, B., Singh, A.V, P. Zamboni and R, Mahajan. 2009. Oxidative stress and neurodegenerative diseases: a review of upstream and downstream antioxidant therapeutic options. Current Neuropharmacol. 7(1): 65-74.

Visput, S. and A. Khopade. 2011. *Glycyrrhiza glabra* Linn.- Klitaka: a review. Int. J. Pharma. Bio. Sci. 2 (3):42-51.

Walter, K.S. and H.J Gillett. (Eds.). 1998. 1997 IUCN Red list of threatened plants: IUCN.

Wang, Z.Y. and D.W. Nixon. 2001. Licorice and cancer. Nutrition and Cancer no. 39 (1): 1-11.

Wangensteen, H., L. Klarpås, M. Alamgir, A.B. Samuelsen and K.E. Malterud. 2013. Can scientific evidence support using Bangladeshi traditional medicinal plants in the treatment of diarrhoea? A review on seven plants. *Nutrients* 5(5): 1757-1800.

Yaeesh, S., Q. Jamal, A.J. Shah and A.H. Gilani. 2010. Antihepatotoxic activity of Saussurea lappa extract on Dgalactosamine and lipopolysaccharide induced hepatitis in mice. Phytotherapy Res. 24(S2): S229-S232.

Zaigham, M., M. Hamiduddin and M. Ikram. 2019. Aslussoos (*Glycyrrhiza glabra* Linn): A root with immense pharmaceutical potential and its utilization in Unani system of medicine. IJHM, 7(5): 27-34.