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Original scientific article

DIVERSITY AND ECOLOGICAL NICHE MODELLING STUDIES IN *Trifolium repens* L. (WHITE CLOVER) IN THE REGION OF NORTH-WESTERN HIMALAYA, INDIA

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Trifolium repens L., commonly referred as white clover, is one of the important stoloniferous perennial range legume growing in temperate regions. The introduction of forage legumes in agro-ecosystem provides nitrogen enrichment in soil and mobilizes other nutrients. Further, it has a tremendous potential to help rehabilitate temperate grasslands and decrease the severe fodder shortage in the Himalayan region. In recent decades, collecting and exploration of forage species germplasm, including white clover, have been in the focus of researchers. The collected material shall act as a safe repository for different improvement programmes in future as the germplasm has been stored in the Long Term Module of the National Gene Bank. In this study, maximum entropy (MaxEnt) technique of niche modelling was used to explore probable new areas for the collection of white clover germplasm and identify favorable climate for characterization,

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cultivation, evaluation and on-farm conservation in the Indian Himalayan region, which comprises the of Jammu Kashmir and Himachal Pradesh and Uttarakhand. Significant variation was observed in plant height (15.5 to 37.6 cm), floret number per flower head (9.24 to 52.4), 100 seed weight (0.038 to 0.077), dry matter yield per plant (6.2 to 15.1 g), leaf length (15.6 to 48.4 mm), leaf width (11.2 to 39.6 mm). Very highly significant variation was also observed in 'V' marking. Dendrogram grouped the 22 accessions into two clusters based on the average linking method. Cluster I consisted of five accessions (IC-615818, IC- 615817,IC-622352, IC-615815, and IC-622362), cluster- II could be grouped into sub-cluster–IIA and sub-cluster- IIB. Cluster IIA consist of six accessions (IC- 622338, IC-622379, IC-622382, IC-622401, IC-622343 and IC-62237), whereas cluster-IIB comprise of 11 accessions (IC- 615814 IC- 615811, IC-615819, IC-622376, IC-622383, IC-615812, IC-622385, IC-615816, IC- 615817, IC-622415 and IC-622406). In this study, maximum entropy (MaxEnt) technique of niche modelling was used to explore probable new areas for the collection of white clover germplasm, identifying favorable climate for characterization, cultivation & evaluation and on-farm conservation in the Indian Himalayan region comprising the Union Territory of Jammu Kashmir and the states of Himachal Pradesh and Uttarakhand.

Key words: DIVA-GIS, fodder, germplasm, livestock, MaxEnt Analysis, white clover

INTRODUCTION

Grasslands represent 26 per cent of the land area and 70 per cent of the land under agricultural area globally (FAO, 2010). These unique ecosystems have relied on food and fodder production (CONANT, 2010; AHMAD *et al.*, 2016; SINGH *et al.*, 2018). Fodder crops are the plant species that are used as feeding material for animals (ROY *et al.*, 2019) in the form of forage (when harvested green and given as such), hay (dried out green fodder), and silage that is conserved under an-aerobically (AHMAD *et al.*, 2021).

Despite being of great importance globally, limited research has been reported on forage crops as compared with cereals, fruits, and vegetables (CAPSTOFF and MILLER, 2018; AHMAD *et al.*, 2018). The Himalayan region has a rich genetic diversity in indigenous grasses and legumes (AHMAD *et al.*, 2016; AHMAD *et al.*, 2018; MIR *et al.*, 2016). Livestock husbandry and agriculture are interconnected with the complex fabric of the society in socio-economic, religious and cultural ways (SINGH *et al.*, 2018). Out of more than 400 species of 60 genera of the Leguminosae family, 21 genera have been reported to be useful as fodder. Besides some micro-centers for certain species, the main centers of genetic diversity in forage crops are peninsular India (for tropical types), the North-Eastern and central region (for sub-tropical types), and Himalayan region (for temperate and sub-temperate types) (ROY *et al.*, 2019). Despite rich forage crops available; there is a severe shortage of fodder, particularly green, which has been a critical factor in low livestock productivity in the Himalayan region (AHMAD *et al.*, 2016; MIR *et al.*, 2016).

The introduction of forage legumes in the agro-ecosystem enhances soil health by providing high nitrogen content and further help in the mobilization of other nutrients (DEV *et al.*, 2018; SINGH *et al.*, 2019). Therefore, exploration and collection of forage legumes that are acclimatized to grow up under given locality factors and conserved in gene banks are of immense significance. Further, it can be utilized in different plant breeding programs and genetic resource conservation. The most significant areas for collection of forage germplasm include alpine and/or sub-alpine pastures, forest openings, fruit orchards, graveyards, and wastelands which have not been used for arable farming and represent the most important centers of perennial grass/legume biodiversity in the Himalayas region (AHMAD *et al.*, 2020; BHAT *et al.*, 2021). Much of the collected germplasm has been evaluated and characterized in the recent past, where some elite lines have shown excellent traits for fodder production (AHMAD *et al.*, 2021).

White clover is a perennial range legume growing under temperate eco-regions globally (TREUREN *et al.*, 2005) with its centre for origin in the Mediterranean region (GEORGE *et al.*, 2006) and grows under a wide range of edaphic and climatic conditions (AHMAD *et al.*, 2020). The worldwide distribution of white clover is presented in Fig.1 (CABI, 2021). It is a stoloniferous major cool-season short-lived perennial forage legume crop grown worldwide in the temperate regions (Fig. 2). It is one of the predominant legume species along with red clover which is found in temperate pasturelands and has often been regarded as a natural tetraploid with 2n = 4x = 32 chromosome number (VOISEY *et al.*, 2001). Some researchers (ZHANG *et al.*, 2007) have described this species as an allopolyploid and a short-lived (3 to 5 years) perennial legume. It can reach up to 18–40 cm of height, is stoloniferous and forms a shallow root system. Leaves are glabrous and generally marked with a distinct white "V" marking. Flowers are white and clustered into heads with very small seeds (PANDEY and ROY, 2011). Climatic conditions (cooler temperatures and high moisture) have been found suitable for the active growth of germinating seeds or existing plants. Having nitrogen-fixing ability, it has often been used to improve pasture quality. It is an excellent choice to be used as a companion crop in temperate grass-dominated pastures (BRINK *et al.*, 1999; JAHUFER *et al.*, 2009).

Fig.1. World distribution of white clover (*Trifolium repens*)

White clover is one of the most predominant temperate forage legumes grown in North-Western Himalayan region and is used mainly as pasture legumes as well as an important cover crop in fruit orchards.. In the modern era, continued pressure on agricultural land and food insecurity requires urgent attention to think about the future sustainable agro-ecosystems development.

White clover is a widely used quality forage legume, grown alone or in mixed stands with grasses, in rainfed or irrigated stands, moderate drought tolerant species with better biomass production on clay or loam soils than on sandy soils (BHAT *et al*., 2021). Sustainable pasture management refers to a livestock production system that produces quality products in environmentally compassionate, economically sound and socially acceptable ways (ADDEO *et al.*, 2001; REDDY *et al.*, 2015). Temperate pasturelands have suffered a lot owing to degradation, uncontrolled grazing, encroachment and lack of policy initiatives vis-à-vis rehabilitation of these distinct ecosystems (AHMAD *et al.*, 2016; AHMAD *et al.*, 2018; SINGH *et al.*, 2018). Hence, there is a need to reseed white clover and other forage legumes in these pasturelands not only to meet the increased demand for fodder in the high-altitude regions but also to rejuvenate these temperate grasslands. This could be done either by introduction of elite cultivars or by improving the productivity traits of its genotypes in traditional growing areas of the North-West Himalayan region.

White clover cultivars have been grouped into three types on the basis of size, i) prostate types (wild type) that are tolerant of heavy traffic and grazing, ii) intermediate types (New Zealand White, Dutch White, and Louisiana S-1) that show earlier precocity, drought-tolerant and iii) large types (Ladino) that possess higher biomass and large leaf size (CLARK, 2007). Maximum entropy (MaxEnt) has been frequently used in predicting occurrences and is considered one of the most accurate models, especially with incomplete information or datasets (ELITH *et al.*, 2006; HIJMANS and GRAHAM, 2006). *MaxEnt*, as a niche modelling technique, involves species distribution information to predict the long and/or medium-term distribution of a particular species. In recent decades, it has been successfully used by researchers of different works of life to predict distributions such as macro-fungi (WOLLAN *et al.*, 2008), forests (CARNAVAL and MORITZ, 2008), rare plants (WILLIAMS *et al.*, 2009), stony corals (TITTENSOR *et al.*, 2009); seaweeds (VERBRUGGEN *et al.*, 2009); sorghum (SIVARAJ *et al.*, 2016) and many other species (ELITH *et al.*, 2006). Some researchers (PHILLIPS *et al.*, 2004, 2006; ELITH *et al.*, 2011) have described its use in ecological modeling and explained the various parameters and measures involved. MaxEnt has been the most adapted statistical technique (EITZINGER *et al.*, 2013). Changes in climatic factors determine the geographical expansion of plants, fragmentation of habitats, invasion by exotic species, and pollution of soil, air and water (WANG *et al.*, 2020). Climate change, in particular, has caused significant changes in the distribution of plant species, especially in mountain regions (MA and SUN, 2020). Algorithm modeling using maximum entropy (MaxEnt) has been a popular software worldwide because it uses presence-only data (PHILLIPS *et al.*, 2006; GEBREWAHID *et al.*, 2020) and works well with incomplete data requiring small sample size (LI *et al.*, 2020; NAMEER, 2020). The MaxEnt model estimates an unknown probability distribution that "satisfies any constraints on the unknown distribution that we are aware of, and that subject to those constraints, the distribution should have maximum entropy" (PHILLIPS *et al.*, 2004). As per the information theory, entropy refers to randomness or unpredictability, meaning that the portion that is not explained by the probability distribution has no remaining information compared to the distribution of the primary data.

Fig. 2. Variability in white clover with respect to leaf size and ‘V’ marking and crop in bloom

During the last few years, exploration and germplasm collection missions of forages, including white clover have been conducted by ICAR-Indian Grassland and Fodder Research Institute, Regional Station Srinagar from different parts of Jammu and Kashmir (J & K), Himachal Pradesh (H.P.) and Uttarakhand. The main objective of collecting from these regions was to determine the variability of locally adapted white clover genotypes and whether new valuable traits could be recognized for future breeding programmes. In this study, the Maximum entropy (MaxEnt) method of niche modelling has been attempted to explore potential new areas for white clover germplasm collection, identifying suitable eco-regions for characterization, cultivation & evaluation and on-farm conservation. This study was carried out to predict the climate suitable regions for cultivation and the effects of future climatic changes on the expansion of white clover across North Western Himalayan region using the MaxEnt model, using plant distribution data for white clover and the current/future climatic data, ur results shall help the local governments and other agencies develop sustainable management practices to conserve native forage plant species. This investigation utilized the collection sites' geo-referenced occurrence locations and climatic grid data. It analyzed information about climatic conditions at the current locations of white clover in Kashmir Himalaya to predict the probability of suitable conditions that exist for this forage crop in other regions of the Indian Himalaya.

MATERIALS AND METHODS

In the present study, MaxEnt (Maximum Entropy) technique (http://www.cs.princeton.edu/~schapire/MaxEnt) has been used to know the potential distribution of white clover in the Himalayan region of India. The geographical coordinates recorded by the global positioning system (Garmin 12 GPS) for this species during survey and exploration programs conducted by the Regional Research Station (ICAR-IGFRI), Srinagar have been used as reference points for the species (Table 1). Monthly gridded datasets (e.g., maximum temperature of warmest month, minimum temperature of the coldest month, mean diurnal range, annual mean temperature, annual precipitation, and precipitation of the wettest and driest months) from the WorldClim (WC) database sourced (http://www.worldclim.org) from global weather stations was downloaded and used in this study. This data from WorldClim gives interpolated global climate using independent variables/coordinates (latitude, longitude, and altitude) and symbolizes long-term (1950-2000) monthly means of maximum, minimum, mean temperatures and total precipitation as generic 2.5 arc-min grids. Environmental dataset layers used (all continuous) for this study include: bio1 (annual average temperature); bio2 (average diurnal range); bio3 (isothermality); bio4 (temperature seasonality); bio5 (maximum temperature of warmest month); bio6 (minimum temperature of coldest month); bio7 (annual range of temperature); bio8 (average temperature of wettest quarter); bio9 (average temperature of driest quarter); bio10 (average temperature of warmest quarter); bio11 (average temperature of coldest quarter); bio12 (annual precipitation); bio13 (precipitation of wettest month); bio14 (precipitation of driest month); bio15 (precipitation seasonality); bio16 (precipitation of wettest quarter); bio17 (precipitation of driest quarter); bio18 (precipitation of warmest quarter); bio19 (precipitation of coldest quarter).

Data recording of agro-botanical traits

22 different white clover accessions collected from diverse ecological niches of Jammu and Kashmir were evaluated at the experimental farm of ICAR-IGFRI regional research station, Srinagar (33°59′ N latitude & 74°47′ E longitude with altitude of 1640 m a sl) consecutively for two years. Recommended package of practices was followed to raise a good stand. Each genotype was sown in 3 rows of 3 m in length under three replications. The data was taken on

six quantitative traits: leaf length (mm), plant height (cm), leaf width (mm), 100 seed weight (mg), floret number per flower head, dry matter yield per plant (g) (were recorded on five random plants). Nutritional parameters like crude protein (CP %), acid detergent fibre (ADF) and neutral detergent fibre (NDF) were also analyzed.

Table1. Passport data of white clover

S.No.	Accession No.	Place	District	Habitat	Latitude (ºN)	Longitude (ºE)	Altitude (masl)
1	IC-0615818	K D Farm	Budgam	IGFRI Research Farm	33.59	74.48	1640
2	IC-0622370	Kathpora	Kulgam	Roadside	33.43	75.00	1850
3	IC-0622406	Shuhama	Ganderbal	Field	34.11	74.49	1629
4	IC-0622415	Manasbal	Ganderbal	Orchard	34.15	74.40	1597
5	IC-0622382	Dialgam	Anantnag	Cultivated field	33.40	75.09	1636
6	IC-0622383	Sagam	Anantnag	Orchard	33.36	75.15	1815
7	IC-0622385	Mattan	Anantnag	Orchard	33.45	75.12	1686
8	IC-0622376	Aamnu	Kulgam	Orchard	33.38	75.02	1723
9	IC-0622343	Hirpora	Shopian	Forest	33.41	74.47	2300
10	IC-0622352	Chitragam	Shopian	Orchard	33.46	74.54	1900
11	IC-0622362	Arihal	Pulwama	Orchard	33.48	74.53	1700
12	IC-0622401	Shalimar	Srinagar	Roadside	34.08	74.52	1602
13	IC-0622379	Badura	Anantnag	Cultivated field	33.39	75.13	1702
14	IC-0622338	Devpora	Shopian	Forest	33.42	74.47	2350
15	IC-0615817	K D Farm	Budgam	IGFRI Research Farm	33.59	74.48	1634
16	IC-0615816	K D Farm	Budgam	-do-	33.59	74.48	1640
17	IC-0615819	K D Farm	Budgam	-do-	33.59	74.48	1634
18	IC-0615811	K D Farm	Budgam	-do-	33.59	74.48	1634
19	IC-0615817	K D Farm	Budgam	-do-	33.59	74.48	1634
20	IC-0615815	K D Farm	Budgam	-do-	33.59	74.48	1634
21	IC-0615814	K D Farm	Budgam	-do-	33.59	74.48	1640
22	IC-0615812	K D Farm	Budgam	-do-	33.59	74.48	1634

Statistics analysis

Statistical analysis was done using MS Excel to work out descriptive indicators and variability patterns. Multivariate analysis of quantitative traits was carried out using Statistical Package for the Social Sciences (SPSS version 19). Further, a potential distribution map was generated with DIVA-GIS version 7.5 and an input ASCI file was obtained through MaxEnt analysis (PHILIPS *et al.*, 2017).

RESULTS AND DISCUSSION

In this study, agronomical and nutritional data (mean value) recorded for white clover revealed high variability for various quantitative traits. A high coefficient of variation (CV) was observed in the case of leaf width (38.81%), followed by leaf length (34.04%), dry matter yield (24.95%), plant height (23.58%), floret number per flower head (22.13%), seed weight (19.84%) and less CV was observed in forage quality parameters, like crude protein, ADF and NDF. Plant height varied from 15.5 cm (IC-0622343) to 37.6 cm (IC-0615818), floret number per flower head from 9.24 (IC-0622338) to 52.4 (IC-0622415), 100 seed weight from 0.038 (IC-0622343) to 0.077 (IC-0615818), dry matter yield per plant from 6.2 g (IC-0622343) to 15.1 g (IC-0615818), leaf length from 15.6 mm (IC-0622343) to 48.4 mm (IC-0622415), leaf width varied from 11.2 mm (IC-0622343) to 39.6 mm (IC-0622415) (Table 2) and the Analysis of Variance for the different traits has been presented in Table 3.

Table 2. Varietal characteristics and descriptive statistics in white clover germplasm

Acc. No.	100 seed weight (mg)	Plant height (cm)	Floret no./ flower head	Leaf Length (mm)	Leaf Width (mm)	Dry matter yield (g/plant)	CP (%)	NDF (%)	ADF (%)
IC-0615818	0.077	37.6	52.4	48.4	39.6	15.1	20.24	40.26	32.45
IC-0622370	0.044	18.5	28.6	18.4	14.6	8.1	23.65	37.14	28.64
IC-0622406	0.056	26.6	40.2	24.5	18.4	11.4	22.35	38.65	29.07
IC-0622415	0.058	26.4	42.2	24.8	18.2	11.6	22.24	38.54	29.24
IC-0622382	0.046	20.5	31.5	18.6	13.8	8.4	22.25	38.24	29.25
IC-0622383	0.064	29.2	44.5	26.2	19.5	13.4	22.35	38.25	30.12
IC-0622385	0.068	29.4	48.4	24.8	18.2	13.9	21.64	39.35	30.05
IC-0622376	0.052	27.4	46.2	25.4	19.5	12.1	20.75	41.15	32.85
IC-0622343	0.042	19.6	27.4	18.2	13.4	6.7	23.45	37.25	28.15
IC-0622352	0.074	36.4	49.5	42.4	35.8	14.9	23.24	37.14	28.18
IC-0622362	0.072	35.5	50.5	39.8	32.2	14.6	21.15	39.45	30.26
IC-0622401	0.044	18.5	29.2	16.8	12.2	7.9	22.46	38.65	29.12
IC-0622379	0.048	22.4	32.3	24.5	18.4	8.2	22.24	38.74	29.25
IC-0622338	0.038	15.5	21.6	15.6	11.2	6.2	21.64	39.24	30.54
IC-0615817	0.058	26.6	44.6	25.2	18.2	11.4	22.24	38.16	29.94
IC-0615816	0.056	25.8	46.2	24.2	17.8	11.4	22.65	38.18	30.12
IC-0615819	0.062	28.5	48.6	26.2	20.4	12.6	23.12	37.25	28.08
IC-0615811	0.065	28.4	50.4	26.4	20.8	13.1	22.14	38.14	29.36
IC-0615817	0.074	37.2	50.2	45.6	36.8	14.9	21.34	39.46	30.24
IC-0615815	0.072	36.8	52.4	40.2	32.4	14.6	20.65	42.75	32.68
IC-0615814	0.062	32.4	48.2	26.4	20.5	13.4	21.45	38.94	30.24
IC-0615812	0.052	28.5	46.4	24.6	17.8	12.3	21.24	38.85	30.12

Descriptive statistics of white clover germplasm

	100 seed weight (mg)	Plant height (cm)	Floret no./ flower head	Leaf Length (mm)	Leaf Width (mm)	Dry matter yield (g) per plant	CP%	NDF	ADF
Mean	0.058	27.3	41.7	27.1	20.9	11.5	21.98	38.85	29.94
Max	0.077	37.6	52.4	48.4	39.6	15.1	23.65	42.75	32.85
Min	0.038	15.5	21.6	15.6	11.2	6.2	20.24	37.14	28.08
Sd	0.011	6.43	9.24	9.22	8.12	2.87	0.89	1.28	1.28
Skew	0.09	0.06	-0.73	1.12	1.20	-0.53	0.05	1.27	0.89
Kur	-1.09	-0.79	-0.78	0.36	0.38	-1.04	-0.43	2.86	0.82
CV (%)	19.84	23.58	22.13	34.04	38.81	24.95	4.03	3.28	4.29

Table 3. Analysis of variance for the different traits

	Sources of variations		
Traits	Replications	Genotypes	Error
	d.f. =2	21	42
100 seed weight (mg)	2.252e-05	4.073e-04**	5.970e-06
	(3.77)	(68.27)	
Plant height (cm)	1.263	129.70**	1.70
	(0.74)	(75.88)	
Floret no./ flower head	2.97	264.43**	3.98
	(0.74)	(66.30)	
Leaf Length (mm)	4.41	267.25**	1.65
	(2.67)	(161.67)	
Leaf Width (mm)	2.06	207.72**	1.05
	(1.96)	(197.82)	
Dry matter (g/plant)	0.25	24.11**	0.30
	(0.82)	(79.46)	
CP (%)	1.49	2.50**	0.99
	(1.50)	(2.50)	
NDF (%)	10.91	5.27**	2.79
	(3.90)	(1.89)	
ADF (%)	1.48	5.38**	1.90
	(0.78)	(2.83)	

Values in the () are respective F-values

Very high variation was also observed in ‘V’ marking. In some accessions, it was altogether absent or conspicuous. Consequently, based on average linking method, the dendrogram grouped 22 accessions into two clusters (Fig 3). Cluster I consist of five accessions (IC-615818, IC- 615817, IC-622352, IC-615815, and IC-622362), cluster- II can be grouped into sub-cluster–IIA and sub-cluster- IIB. Cluster IIA consist of six accessions (IC- 622338, IC-622379, IC-622382, IC-622401, IC-622343 and IC-62237), whereas cluster-IIB comprise of 11 accessions (IC- 615814 IC- 615811, IC-615819, IC-622376, IC-622383, IC-615812, IC-622385, IC-615816, IC- 615817, IC-622415, and IC-622406). Genetic divergence studies in the species have revealed high diversity among the different collections in white clover in past also, as has been evaluated by SHARMA *et al.* (2005) in the species from Himachal Pradesh from 28 collections, wherein they further noted diversity of exotic accessions as compared to the indigenous germplasm and need for genetic introgression. Attainment of heterotic vigour through hybridization between genetically distant clusters can lead to generation of promising breeding material, as suggested by BHAT *et al.* (2012).

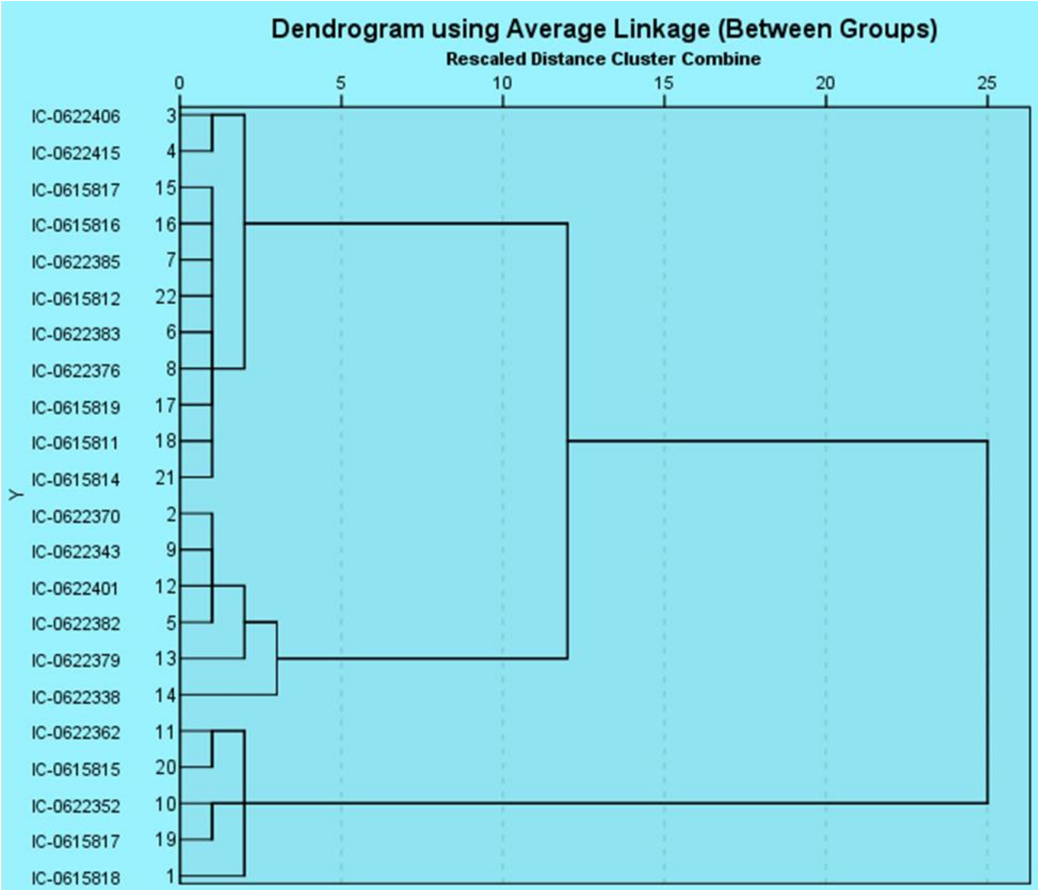

Fig. 3. Dendrogram using Average Linkage method between groups performed on plant traits

The present study provides the Ecological Niche Models generated for the current and future climatic grids using the Maximum entropy approach in Fig. 4 & 5 respectively. Niche models reveal that potential districts identified for managing white clover genetic resources in Jammu and Kashmir are Kupwara, Poonch, Rajauri, Udhampur, Baramulla, Badgam, Pulwama, Anantnag, Doda, Srinagar, and Kathua. Similarly, Chamba, Kangra, Kinnaur, Shimla, Kullu, Lahul, and Spiti are the potential districts in H.P while Pithoragarh, Chamoli, Uttar Kashi, Almora, Tehri Garhwal districts in Uttarakhand are identified. As white clover is an important forage legume of Himalayan region, it becomes imperative to find out the areas suitable for its cultivation. The site's suitability has been a vital aspect for determining the productive potential of the crop and suitability maps depict the suitable area for raising a given crop (PARTHASARATHY *et al.*, 2007). Many suitability models have already been studied extensively to predict the potential impact of future climatic conditions on the shifts in production and growing regions of different crops (TUBIELLO *et al.*, 2000, 2002).

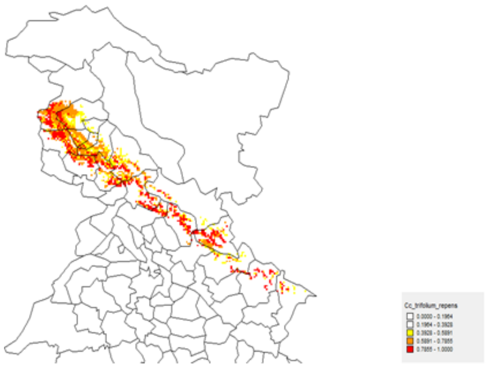

Fig. 4. MaxEnt model generated for white clover (current climate)

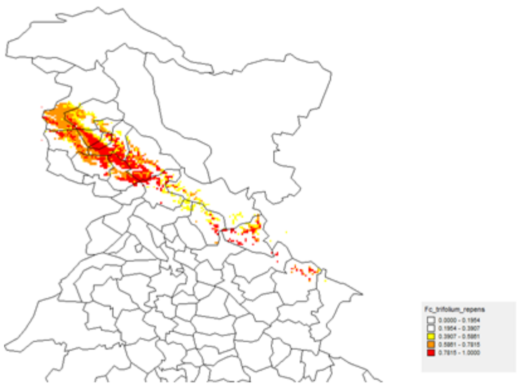

Fig. 5. MaxEnt model generated for white clover (Future climate)

The data presented in Table 4 provides estimates of relative contributions of various environmental variables to Maxent models of current and future climatic scenarios. Bioclimatic variables *viz*., annual temperature range (bio7), precipitation of driest month (bio14), average temperature of coldest quarter (bio11), precipitation of wettest month (bio13), precipitation seasonality (bio15), average temperature of wettest quarter (bio8) contributed maximum to the current climatic models with percentage values of 46.5, 10.3, 6.3, 5.1, 5.1, respectively. Interestingly, the niche model for future climate governed by the bioclimatic variables, the average temperature of warmest quarter (bio10), precipitation of wettest month (bio13), range of annual temperature (bio7), precipitation of driest month (bio14), the average temperature of driest quarter (bio 9) with percentage values of 34.0, 18.6, 18.5, 8.8 and 5.5 respectively.

Table 4. Estimates of relative contributions of the environmental variables to the MaxEnt models (Current & Future) for white clover (Trifolium repens)

Variable	Percent contribution	
	Current Climate	Future Climate
Annual mean temperature (bio1)	2.9	0.1
Mean diurnal range (bio 2)	2	0
Isothermality (bio 3)	0.5	0
Temperature seasonality (bio 4)	0	0
Maximum temperature of warmest month (bio 5)	0	0
Minimum temperature of coldest month (bio6)	4	0
Temperature annual range (bio7)	46.5	18.5
Mean temperature of wettest quarter (bio8)	4.1	4.6
Mean temperature of driest quarter (bio 9)	0	5.5
Mean temperature of warmest quarter (bio10)	3	34
Mean temperature of coldest quarter (bio11)	6.3	0.3
Annual precipitation (bio12)	3.9	3.4
Precipitation of wettest month (bio13)	5.1	18.6
Precipitation of driest month (bio14)	10.3	8.8
Precipitation seasonality (bio15)	5.1	3.2
Precipitation of wettest quarter (bio16)	2.8	0.3
Precipitation of driest quarter (bio17)	3.6	1.1
Precipitation of warmest quarter (bio18)	0	0
Precipitation of coldest quarter (bio19)	0.1	1.6

For determining the first estimate, in each iteration of the training algorithm, the increase in regularized gain was added to the contribution of the corresponding variable or subtracted from it if the change to the absolute value of lambda was found negative. As for second estimate, for each environmental variable, the values of that variable on training presence and background data were randomly permuted. As for the second estimate, for each environmental variable, the values of that variable on training presence and background data were randomly permuted. The model was re-evaluated on the permuted data, and the resultant drop in training AUC has been depicted in the Table 4, normalized to percentages. So far as the variable jackknife is concerned, variable contributions should be interpreted cautiously when the predictor variables are correlated. Regularized training gain was found to be 5.218 and 5.320 for current and future climates, respectively, while training AUC was 0.999 for both and un-regularized training gain was 6.314 and 6.454, respectively. White and red clovers have been largely used in agricultural systems as cover and forage crops. The climate change and collective demands of the society for sustainable agricultural production systems shall call for new traits or characteristics to be incorporated into these important legumes through sustained breeding efforts (EGAN *et al.* 2020). Pre-breeding efforts in minor *Trifolium* species while complementing white and red clover breeding programmes have depicted that the areas of origin of various accessions have profound effect on populations' structure (EGAN *et al.*, 2019). SINGH *et al.*, (2019) conducted a very detailed evaluation and characterization of two hundred fifty eight white clover accessions, based on 25 agro-morphological features. They concluded that such agro-morphological traits could be very well utilized for documentation, identification and grouping of white clover diverse populations.

CONCLUSION

The main focus of this study was the use of Ecological Niche Models to assess the suitability of white clover for current and potential regions across the Himalayas having diverse climatic conditions. Mean values of agronomical and nutritional data recorded during the present study revealed high variability for various quantitative traits in white clover. This study utilized the collection sites' geo-referenced occurrence locations and climatic grid data. The information was analyzed regarding environmental conditions at the given locations of white clover and for predicting the probability of suitable environmental conditions for this forage crop in various other country areas. Specific potential districts in the Union Territory of Jammu and Kashmir, states of Himachal Pradesh and Uttarakhand have been identified for further collections and *in-situ* conservation of white clover in a changing climatic scenario. The results of this investigation shall help plant breeders design appropriate strategies to improve and enrich the white clover germplasm for developing new cultivars.

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PROUČAVANJE MODELA ZA DIVERZITET I EKOLOŠKE NIŠE KOD *Trifolium repens* L. (BELA DETELINA) U REGIONU SEVERO-ZAPADNIH HIMALAJA, INDIJA

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Izvod

Trifolium repens L., koja se obično naziva bela detelina, jedna je od važnih stolonifernih višegodišnjih mahunarki koje rastu u umerenim regionima. Uvođenje krmnih mahunarki u agroekosistem obezbeđuje obogaćivanje zemljišta azotom i mobiliše druge hranljive materije. Dalje, ima ogroman potencijal da pomogne u rehabilitaciji travnjaka umerenog pojasa i smanji ozbiljan nedostatak stočne hrane u regionu Himalaja. Poslednjih decenija, sakupljanje i istraživanje germplazme krmnih vrsta, uključujući belu detelinu, bili su u fokusu istraživača. Prikupljeni materijal će služiti kao sigurno skladište za različite programe poboljšanja u budućnosti pošto je germplazma pohranjena u Dugoročnom modulu Nacionalne banke gena. U ovoj studiji, tehnika maksimalne entropije (MakEnt) niša modeliranja je korišćena za istraživanje potencijalnih novih područja za sakupljanje germplazme bele deteline i identifikovanje povoljne klime za karakterizaciju, kultivaciju, evaluaciju i očuvanje na farmi u indijskom regionu Himalaja, koji obuhvata Džamu Kašmira i Himačal Pradeša i Utarakhanda. Uočene su značajne varijacije u visini biljke (15,5 do 37,6 cm), broju cvetova po glavici cveta (9,24 do 52,4), težini 100 semena (0,038 do 0,077), prinosu suve materije po biljci (6,2 do 15,1 g), dužini listova (15,6). do 48,4 mm), širina lista (11,2 do 39,6 mm). Veoma značajne varijacije su takođe primećene u oznaci „V“. Dendrogram je grupisao 22 uzoraka u dva klastera na osnovu metode prosečnog povezivanja. Klaster I se sastojao od pet uzoraka (IC-615818, IC-615817,IC-622352, IC-615815 i IC-622362), klaster-II se mogao grupisati u pod-klaster-IIA i pod-klaster-IIB. Klaster IIA se sastoji od šest uzoraka (IC-622338, IC-622379, IC-622382, IC-622401, IC-622343 i IC-62237), dok se klaster-IIB sastoji od 11 uzoraka (IC-615814, IC-615814). 615819, IC-622376, IC-622383, IC-615812, IC-622385, IC-615816, IC-615817, IC-622415 i IC-622406). U ovoj studiji, tehnika modela maksimalne entropije (MakEnt) niša je korišćena za istraživanje mogućih novih područja za sakupljanje germplazme bele deteline, identifikujući povoljnu klimu za karakterizaciju, kultivaciju i procenu i očuvanje na farmi u indijskom regionu Himalaja koji čini Uniju teritorija Džamu Kašmira i države Himačal Pradeš i Utarakand.

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