Int.J.Curr.Microbiol.App.Sci (2019) *8*(4): 1179-1189

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 04 (2019)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2019.804.135

In-situ Assessment of Morpho-physiological Traits and Ecological Niche Modelling Studies on *Sesamum mulayanum* Nair

Nilamani Dikshit[1*], Natarajan Sivaraj[2], Sunanda Dikshit[3], Venkateswaran Kamala[2], Dinesh Chand[1] and Sunil Gomashe[1]

[1]ICAR-National Bureau of Plant Genetic Resources, Regional Station, Dr. PDKV Campus, Akola-444104, India
[2]ICAR-National Bureau of Plant Genetic Resources, Regional Station, Rajendranagar, Hyderabad-500030, India
[3]Department of Mathematics, RLT College of Science, Akola -444 001, Maharashtra, India

**Corresponding author*

Keywords

DIVA-GIS, MaxEnt, Niche modelling, Maharashtra, *Sesamum mulayanum*

Article Info

Accepted:
10 March 2019
Available Online:
10 April 2019

A B S T R A C T

Ecological niche modelling or Predictive habitat distribution modelling framework for *Sesamum mulayanum* Nair, an important wild relative of oilseed crop Sesame has been analyzed using Maximum Entropy method. Based on the Ecological Niche model generated using the presence points only from Maharashtra state, potential states identified for the distribution wild sesame species (*S. mulayanum*) in India are Andhra Pradesh, Chhattisgarh, Karnataka, Kerala, Goa, Gujarat, Madhya Pradesh and Maharashtra. These states of India could be targeted for future exploration missions based on climate suitability and for identifying in-situ conservation areas to conserve this important wild species. In-situ assessment of morphological traits viz., plant height, no. of ramifications, length of lower leaves, width of lower leaves, length of upper leaves, width of upper leaves, root length, root shoot ratio, corolla length, corolla width, petiole length lower leaves, petiole length upper leaves, first Internode length, second internode length, capsules per plant, seeds per capsule, capsule length and width indicated good variability exists among wild accessions of *S. mulayanum*. Results of the physiological traits studied viz., chlorophyll content index (CCI), photosynthetically active radiation (PAR) and leaf area index (LAI) are also presented in this paper.

Introduction

S*esamum mulayanum* Nair (2n=26) is a drought tolerant wild relative of sesame (*Sesamum indicum* L.). The genus *Sesamum* L. belong to the family Pedaliaceae and contains about 23 species in the world and only eight species are available in India. It grows in wild state in a wide range of soil conditions in the states of Maharashtra, Goa, Andhra Pradesh, Odisha, Telangana, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh and Uttarakhand. It is a medium tall type plant and grows vigorously under favourable conditions depending upon the availability of organic carbon in the soil. It is resistant to phyllody and *Fusarium* wilt (Mehetre *et al.*, 1993), viable F1 hybrids resembling wild parent in crosses between *Sesamum indicum* and *S. Mulayanum* (Biswas and Mitra, 1990, Nimmakalaya *et al.*, 2011). Seed oil content and fatty acid composition in six wild species of sesame including *S. mulayanum* exhibited variation in oil content (20.3-33.9 %) and palmitic and stearic acid contents. Higher stearic acid content was also reported in all the wild species than the cultivated sesame species (Hiremath *et al.,* 2007). Characterization of *Sesamum mulayanum* Nair using morpho-physiological traits has not been attempted earlier. Understanding the morphological and physiological behaviour that helps to withstand diverse eco-edaphic conditions might be useful for crop improvement programme.

Ecological niche models of crop wild relatives (CWRs) would be of great help in locating probable distribution of species populations and to identify *in-situ* conservation areas for managing genetic resources effectively.

In order to predict the potential distribution of *Sesamum mulayanum* in India, an attempt has been made to generate ecological niche model using Maximum Entropy species distribution modelling approach so as to manage the genetic resources essentially in the climate change regime.

Materials and Methods

Experimental material consisted of wild populations of *S. mulayanum* occurring in open ground, roadsides and waste places of Akola, Maharashtra. Agro-morphological traits were recorded as per the Minimal descriptors of NBPGR and IBPGR descriptors developed for cultivated sesame. Five randomly selected plants were used for recording of observations. In addition to the morphological characters, 19 quantitative and 5 physiological traits were recorded. Procedures followed for recording of physiological characteristics and instruments used are mentioned below:

Physiological characteristics

CCI (Chlorophyll Content Index) was measured with SPAD 502 instrument. The observations were recorded during the day time between 11.00 AM and 12.00 PM. For recording the observations, three representative plants were selected from which three representative leaves (from bottom, middle and top portion of the plant were randomly selected. Mean values of chlorophyll content index of these three leaves and three plants were calculated.

Photosynthetically active radiation, often abbreviated PAR, designates the spectral range (wave band) of solar radiation from 400 to 700 nanometers that photosynthetic organisms are able to use in the process of photosynthesis. The irradiance of PAR can be measured in energy units (W/m^2), which is relevant in energy-balance considerations for photosynthetic organisms.

Leaf Area Index (LAI) $= \frac{\text{Total Leaf Area of the Plant}}{\text{Land area occupied by the plant}}$

Ecological niche modelling

In the present ecological niche modelling study, we analyzed the potential distribution of *Sesamum alatum* using the Maximum Entropy (MaxEnt) approach (http:// www.cs.princeton.edu/ ~schapire/ MaxEnt).

The geographical coordinates recorded for the *S. mulayanum* from Maharashtra state are used as presence points for the species. Geographical coordinates were recorded using the Global Positioning System (Garmin

12 GPS) during the germplam explorations conducted by the ICAR-NBPGR Regional Station, Akola. For the current climate (baseline) of India we used monthly data from the World Clim (WC) database sourced from global weather stations.

The variables, including annual mean temperature, mean diurnal range, maximum temperature of warmest month, minimum temperature of coldest month, annual precipitation, and precipitations of the wettest and driest months were downloaded from the World Clim dataset (http://www. worldclim.org).

The World Clim data provides interpolated global climate surfaces using latitude, longitude and elevation as independent variables and represents long term (1950-2000) monthly means of maximum, minimum, mean temperatures and total rainfall as generic 2.5 arc-min grids.

Environmental layers used (all continuous): bio1 (Annual mean temperature); bio2 (Mean diurnal range);bio3 (Isothermality); bio4 (Temperature seasonality); bio5 (Max temperature of warmest month); bio6 (Min temperature of coldest month); bio7 (Temperature annual range); bio8 (Mean temperature of wettest quarter); bio9 (Mean temperature of driest quarter);bio10 (Mean temperature of warmest quarter); bio11 (Mean 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). DIVA-GIS version 7.5 was used to generate the potential distribution map with input ASCI file obtained in Max Ent analysis.

Results and Discussion

Botanical description

Sesamum mulayanum

Nair, Bull. Bot. Surv. India 5:251-253. 1963; Kulkarni. J. Bomb. Nat. His. Soc. 68(2): 495-496. 1971; Bennet, Indian For. 100(11): 691. 1974; Mitra& Biswas. Sci. Cult. 49: 40-48. 1983; Kawase, J. Trop. Agr. 44: 115-122. 2000.

Morphological characteristics

The plant height varied from 67.2-150.1cm with an average of 104.53cm. Length and width of lower leaves varied from 5.5-14.2 cm and 3.4-7.0 respectively (Table 1). Stem and branches in their upper part quadrangular with furrowed sides, pubescent becoming glabrescent, rarely pilose, stem colour yellowish, inter nodal length short, leaves heteromorphic, lower leaves opposite, palmate, 3-foliate, 3-lobed, petiole upto 12 cm, leaflets lanceolate, ovate, acute-acuminate, serrate or coarsely dentate, upper leaves alternate, petiole shorter upwards, linear or lanceolate, acute or acuminate, entire. lower leaves long petioled, pubescent, leaf glands present, petiole 2 to 12cm, flowers solitary in the axils of higher leaves, pedicel short 0.2 to 0.5cm long with 2 sessile yellow glands each in the axil of a bract, calyx persistent, Calyx persistent, 0.4 to 0.7 cm, segment oblong-lanceolate, pubescent, acute or obtuse. Corolla colour pink, lower tip of flower violet, Stamens 4, epipetalous, didynamous. Filament upto 1cm, anthers upto 0.3 cm long, dorsi fixed. Style glabrous, 0.8 to 2.5 cm long, white style length short, extra floral nectary present, capsule erect, oblong quadrangular, 4-grooved, rounded at the base, acuminate into a beak at the apex 2 to 2.5 cm long, 0.6 cm broad, pubescent to pilose, finally spitting down to the base, beak 0.3 to

0.5 cm, seeds brownish black, reticulate, broadly ovate with thick testa.

Physiological traits

Mean canopy temperature recorded was more during 11.00 AM compared to 2.00 PM. There was not much difference in the leaf conductance (CCI) and below PAR recorded at 11.00 AM and 2.00 PM. Striking differences was observed in above PAR recorded during 11.00 AM and 2.00 PM. The leaf area index (LAI), defined as the ratio between the sum of the foliar area and the unit of soil surface, is a key variable for characterizing different plant canopies because it is related to light and energy capture (Watson, 1947).. LAI was 2.43 at 11.00 AM and 1.01 at 2.00 PM. Chlorophyll Content Index gives the chlorophyll content which will give the rough trend of chlorophyll content which is important for photosynthesis process. Photo synthetically active radiation corresponds more or less with the range of light visible to the human eye. Adequate PAR is required for measurement of productive farmland. Hence the uses of PAR range from agriculture, forestry to oceanography. LAI [m2/m2] represents the amount of leaf material in an ecosystem and is geometrically defined as the total one-sided area of photosynthetic tissue per unit ground surface area. Monitoring the distribution and changes of Leaf Area Index (LAI) is important for assessing growth and vigour of vegetation. The Leaf Area Index (LAI) of plant canopies plays an important role in controlling the interactions between terrestrial environments and atmospheric variables (Gobron *et al.*, 1997). It controls the links between the biosphere and atmosphere through various processes such as photosynthesis, respiration, transpiration and rain interception. Hybridisation studies in cultivated sesame with *Sesamum mulayanum* had been attempted by many researchers (Mehetre *et al.*, 1993; Kawase, 2000 and Nimamakalaya *et al.*, 2011). Morphological studies on *Sesamum mulayanum* would help understand the variability in different traits for future crop improvement programmes.

Ecological niche modelling

In Maharashtra, *Sesamum mulayanum* are distributed in Akola, Alibag, Amaravati, Aurangabad, Bir, Buldana, Dharni, Dhule, Jalgaon, Kolhapur, Nashik, Pune, Raigad, Ratnagiri, Satara districts. The presence points of *S. mulayanum* are provided in Figure 1.

Bioclimatic variables (BC) are often used in ecological niche modelling and they represent annual trends, seasonality and extreme or limiting environmental factors. Bioclimatic variables are generally selected based on species ecology (Roura-Pascual *et al.*, 2009). Maximum Entropy (Max Ent) is a niche modelling approach that has been developed linking species distribution information built only on identified presences and is a general-purpose method for making predictions or inferences from incomplete information. MaxEnt can take the environmental conditions at occurrence locations and produce a probability distribution that can then be used to assess every other location for its likely occurrence. The result is a map of the probability of conditions being favourable to occurrence. It estimates target probability distribution of *Sesamum mulayanum* in India by finding the highest probability of distribution of the maximum entropy (i.e., most spread out or closest to uniform with indication to a set of bioclimatic variables).

Figure 2 depicts the Max Ent model for potential distribution of *S. mulayanum* in India based on the present climate scenario in Maharashtra State. Warmer colours indicate the highest probability of occurrence of *S.*

mulayanum in India. Andhra Pradesh, Chattisgarh, Karnataka, Kerala Goa, Gujarat, Madhya Pradesh and Maharashtra are the states with potential distribution of this important crop wild relative species of Sesame. Highest probability of distribution of this species occurs in West Coast of India covering Western Ghats region. Figure 3 shows the omission rate and predicted area as a function of the cumulative threshold. The omission rate is calculated both on the training presence records, and (if test data are used) on the test records. The omission rate should be close to the predicted omission, because of the definition of the cumulative threshold.

Table.1 *In-situ* assessment of Morpho-physiological traits of *Sesamum mulayanum* Nair

Morphological traits	**Range**	**Mean**
Plant height (cm)	67.2-150.1	104.53
No. of ramifications	0-4.0	3.0
Length of lower leaves (cm)	5.5-14.2	9.76
Width of lower leaves (cm)	3.4-7.0	4.92
Length of upper leaves (cm)	3.3-7.2	5.52
Width of upper leaves (cm)	0.42-0.9	0.64
Root length (cm)	9.5-12.5	10.66
Root shoot ratio	9.5-12.5/80-136	10.6/102.06
Corolla length (cm)	2.5-4.0	3.48
Corolla width (cm)	0.5-1.5	1.24
Petiole length lower leaves (cm)	0.4-13.2	6.46
Petiole length upper leaves (cm)	0.5-6.3	1.76
First Internode length (cm)	5.5-6.5	6.0
Second internode length (cm)	5.0-10.0	8.17
Capsules per plant (no.)	7.0-72.0	25.5
Seeds per capsule (no.)	36.0-59.0	49.73
Capsule length (cm)	2.2-4.5	3.58
Capsule width (cm)	0.5-0.8	0.685
1000 seed weight (g)	2.1-2.3	2.19
Physiological parameters		
	11.00 AM	**2.00 PM**
Parameters	**Range**	**Range**
Canopy temperature	37.5-39.73	25.8-37.27
CCI (Leaf conductance)	24.8-30.4	26.27-34.6
Above PAR	1854.66-1892.66	928.0-1008.67
Below PAR	451.66-485.66	416.66-477.0
Leaf Area Index	2.12-2.64	0.95-1.13

Table.2 Estimates of relative contributions of the environmental variables to the MaxEnt model for *Sesamum mulayanum*

Bioclimatic Variable	Percent contribution	Permutation importance
Precipitation of driest month	34.1	76.3
Precipitation of driest quarter	19.8	0
Precipitation seasonality	15.2	12.6
Mean temperature of coldest quarter	12.5	0.5
Mean diurnal range	9.3	6
Precipitation of wettest month	3.5	0.2
Mean temperature of warmest quarter	1.5	0
Precipitation of warmest quarter	1.4	0.1
Mean temperature of driest quarter	1.1	0
Temperature seasonality	0.6	0
Annual precipitation	0.3	0
Mean temperature of wettest quarter	0.2	0
Isothermality	0.2	4.4
Annual mean temperature	0.1	0
Precipitation of coldest quarter	0.1	0
Temperature annual range	0	0
Min temperature of coldest month	0	0
Max temperature of warmest month	0	0
Precipitation of wettest quarter	0	0

Fig.1 *Sesamum mulayanum* wild species presence points in Maharashtra state, India

Fig.2 Ecological niche model generated using maximum entropy species distribution modelling

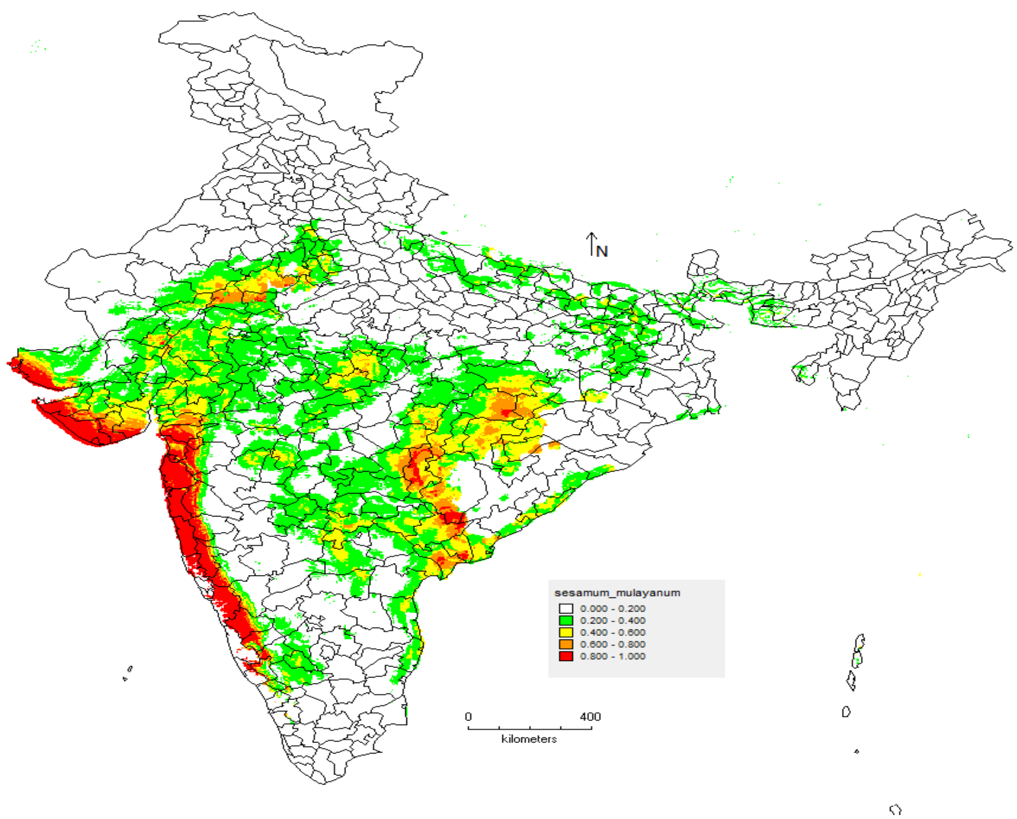

Fig.3 Omission and predicted Area for the wild species *Sesamum mulayanum* Nair

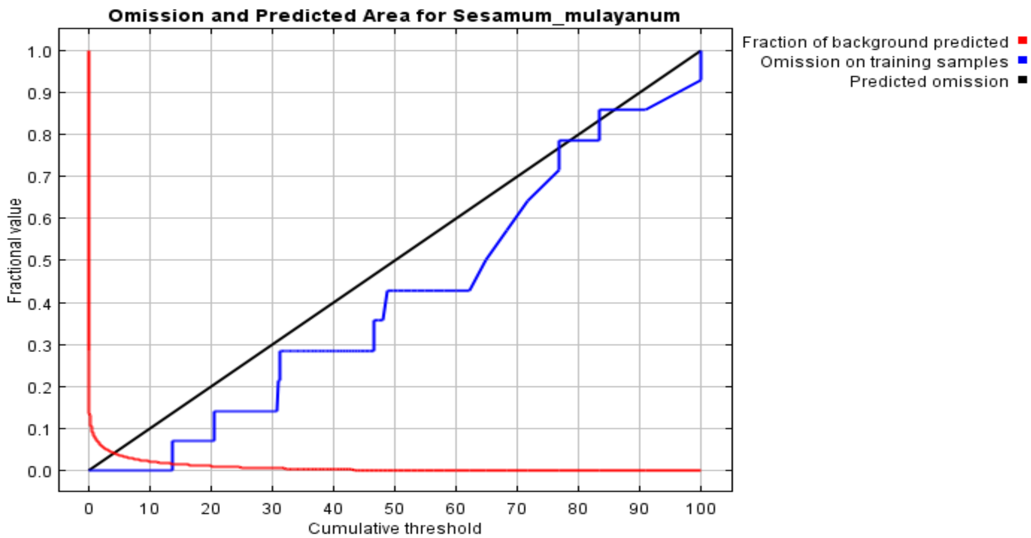

Table 2 gives estimates of relative contributions of the environmental variables to the MaxEnt model generated for *S. mulayanum*. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted. The model is re-evaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. Out of the 19 bioclimatic variables studied, only nine variables viz., Precipitation of driest month (34.1%), precipitation of driest quarter (19.8%), precipitation seasonality (15.2%), mean temperature of the coldest quarter (12.5%), mean diurnal range (9.3%), precipitation of wettest month (3.5%), mean temperature of warmest quarter (1.5%), precipitation of warmest quarter (1.4%) and mean temperature of the driest quarter (1.1%) contributing to the ecological niche model generated using Max Ent approach.

Maximum entropy (Max Ent) is considered as the most accurate model performing extremely well in predicting occurrences in relation to other common approaches (Elith *et al.*, 2016; Hijmans*et al.*, 2006; Phillips *et al.*, 2006) especially with incomplete information. Max Ent is a niche modelling method that has been developed involving species distribution information based only on known presences. Max Ent has been successfully used by many researchers earlier to predict distributions such as stony corals (Tittensor *et al.*, 2009; macrofungi (Wollan *et al.*, 2008) seaweeds (Vebruggen *et al*.,2009) forests (Carnaval and Moritz 2008), rare plants (Williams *et al.*, 2009) and many other species Elith *et al.*, 2006). In India, Ecological Niche modelling had been successfully studied by many for assessing climate suitability and species distribution in crops *viz*., *Andrographis paniculata* (Raina *et al*., 2016), Banana (Sivaraj *et al.*, 2016 a, b, c), blackgram (Abraham *et al*., 2015), bottle gourd (Dikshit *et al*.,2015), Ceylon spinach (Reddy *et al.*, 2015 a), Roselle (Reddy *et al.*, 2015 b), Sorghum (Sivaraj Reddy *et al.*, 2016), Sorrel (Reddy Reddy *et al.*, 2015 c), wild safflower (Sarath Babu *et al.*, 2016) and wild sesame

Sesamum alatum (Sarath Babu *et al.,* 2016). The identified states in India mainly Western Ghats region and west coast states could be targeted for future exploration missions. Also, based on climate suitability and for identifying in-situ conservation areas, and for managing other related genetic resources activities the present model would help to a greater extent.

Acknowledgement

Authors are highly grateful to the Head, Department of Agricultural Botany, Dr. PDKV, Akola for providing physiological instruments and Director, ICAR-NBPGR and Head, Division of Germplasm Evaluation, ICAR- NBPGR, New Delhi for encouragement during the course of investigation.

References

Babu Abraham, Vanaja M, Raghu Ram Reddy P *et al.,* 2015. Cluster Analysis and Maxent Modelling of Black gram [*Vignamungo* (L.) Hepper] genotypes from Andhra Pradesh, India. *Vegetos* 28(3):119-126.

Bennet SSR 1974. Occurrence of *Sesamum mulayanum* Nair in Goa forest. *The Indian Forester* 100(11): 691.

Biswas AK, Mitra A K1990. Interspecific hybridization in three species of *Sesamum. Indian Journal of Genetics and Plant Breeding*, 50: 307-309.

Carnaval A C, Moritz C, 2008. Historical climate modelling predicts patterns of current biodiversity in the Brazilian Atlantic forest. *Journal of Biogeography*, 35: 1187–1201.

Dikshit N, Sivaraj N, Nizar M A, Dinesh Chand 2015. In-situ diversity in bottle gourd [*Lagenaria siceraria* (Mol) Stand.] germplasm and crop modelling predictions. *International Journal of Agricultural and Statistics Sciences*, 11 (1): 17-24.

Elith J, Graham CH., Anderson RP*et al.*, 2006. Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, 29:129-151.

Elith J, Phillips SJ, Hastie T *et al.*, 2011. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, 17: 43-57.

Gobron N, Pinty B, Verstraete M M, Govaerts Y, 1997. A semidiscrete model forthe scattering of light by vegetation. *Journal of Geophysical Research-Atmospheres*, 102: 9431–9446.

Hijmans RJ, Graham C, 2006. The ability of climate envelope models to predict the effect of climate change on species distributions. *Global Change Biology*, 12: 2272-2281.

Hiremath SC, Patil CG, Patil KB, Nagasampige M H, 2007. Genetic diversity of seed lipid content and fatty acid composition in some species of *Sesamum* L. (Pedaliaceae). *African Journal of Biotechnology*, 6 (5): 539-543.

http:// www.cs.princeton.edu/ ~schapire/ MaxEnt.

http://www.worldclim.org.

Kawase M, 2000.Genetic relationship of the resderal weed type and the associated weed type of *Sesamum mulayanum* Nair distributed in Indian subcontinent to cultivated Sesame, *Sesamum indicum* L. *Journal of Tropical Agriculture* 44:115-122.

Kulkarni AR, 1971. Notes on the distribution of *Sesamum mulayanum* Nair in Maharastra. *Journal of the Bombay Natural History Society,* 68(2): 495-496.

Mehetre S, Chatge R D, Lad SK, 1993. Wild *Sesamum mulayanum*: a source of multiple disease resistance. *Annals of*

Agricultural Research, 15: 269-276.

Mitra AK, Biswas AK, 1983.New record of *Sesamum mulayanum* Nair in West Bengal. *Science and Culture*, 49: 40-48.

Nair NC, 1963.A new species of *Sesamum* Linn.from northern India. *Bulletin of the Botanical Survey of India*, 5: 251-253.

NimmakalayaP, Perumal R, Muluri S, Reddy U K, 2011. Sesame. In: C.Kole (ed.).*Wild Crop Relatives: Genomic and Breeding Resources, Oilseeds*, DOI 10.1007/978-3-642-14871-2-16.

Phillips S J, Anderson R P, Schapire RE, 2006. Maximum entropy modelling of species geographic distributions. *Ecological Modelling*, 190: 231-259.

Raina A P, Sivaraj N, AshokKumar 2016. Chemical diversity among *Andrographis paniculata* Nees (Kalmegh) and assessing climate suitable regions for elite germplasm distribution in India. *Medicinal Plants* 8(4):267-275.

Reddy MT, Begum H, Sunil N, *et al.*,2015a. Mapping the Climate Suitability Using MaxEnt Modeling Approach for Ceylon Spinach (*Basella alba* L.)Cultivation in India. *The Journal of Agricultural Sciences*, 10(2): 87-97.

Reddy MT, Begum H, Sunil N, *et al.*,2015b. Assessing Climate Suitability for Sustainable Vegetable Roselle (*Hibiscus sabdariffa* var. *sabdariffa* L.)Cultivation in India Using MaxEnt Model. *Agricultural and Biological Sciences Journal*, 1(2):62-70.

Reddy MT, Begum H, Sunil N, *et al.*,2015c. Predicting Potential Habitat Distribution of Sorrel (*Rumex vesicarius* L.) in India from Presence-Only Data Using Maximum Entropy Model. *Open Access Library Journal*, 2: e1590. http://dx.doi.org/10.4236/ oalib.1101590.

Roura-Pascual N, Brotons L, Peterson AT, Thuiller W, 2009. Consensual predictions of potential distributional areas for invasive species: a case study of Argentine ants in the Iberian Peninsula. *Journal of Biological Invasions*, 11: 1017–1031.

SarathBabu B, Dikshit N, Rameash K, Sivaraj N, 2016. Maximum entropy modelling for predicting the potential distribution of wild sesame, *Sesamum alatum* Thonn.in India. *Journal of Oilseeds Research*, 33(1):45-50.

SarathBabu B, Sultan S M, Rameash K, Sivaraj N, 2016. Predicting the potential distribution of *Carthamus lanatus* L. (Saffron thistle) using Maximum Entropy model in India. *International Journal of Applied & Pure Science and Agriculture*, 2(3):114-120.

Sivaraj N, Rameash K, SarathBabu B, 2016a. Maximum Entropy (MaxEnt) modelling approach for predicting potential climate suitable locations of popular banana varieties in India: I. Poovan (AAB). *International Journal of Applied & Pure Science and Agriculture*, 2 (2): 270-276.

Sivaraj N, Rameash K, SarathBabu B, 2016b. Mapping the climate suitability using Maximum Entropy modelling approach for red banana cultivation in India. *International Journal of Applied & Pure Science and Agriculture*, 2 (2): 277-283.

Sivaraj N, Rameash K, Sarath Babu B, 2016c. Assessing potential pockets on climate suitability for sustainable Hill Banana (Virupakashi –AAB variety) cultivation in India. *Advances in Applied Research*, 8(1):1-7.

Sivaraj N, Elangovan M, Kamala V *et al.*, 2016. Maximum Entropy (Maxent) Approach to Sorghum Landraces Distribution Modelling. *Indian*

Journal of Plant Genetic Resources, 29(1):1 6-21.

Tittensor D P, Baco A R, Brewin P E, *et al.*, 2009. Predicting global habitat suitability for stony corals on seamounts. *Journal of Biogeography*, 36: 1111–1128.

Verbruggen H, Tyberghein L, Pauly K, *et al.*, 2009. Macroecology meets macroevolution: evolutionary niche dynamics in the seaweed Halimeda. *Global Ecology and Biogeography*, 18: 393–405.

Watson D.J. (1947). Comparative physiological studies in the growth of field crops. I. Variation in net assimilation rate and leaf area between species and varieties, and within and between years. Annals of Botany, 11: 41–76.

Williams J N, Seo C W, Thorne J, *et al.*,2009. Using species distribution models to predict new occurrences for rare plants. *Diversity and Distributions*,15: 565–576.

Wollan AK, Bakkestuen V, Kauserud H, *et al.*, 2008. Modelling and predicting fungal distribution patterns using herbarium data. *Journal of Biogeography*, 35: 2298–2310.

How to cite this article:

Nilamani Dikshit, Natarajan Sivaraj, Sunanda Dikshit, Venkateswaran Kamala, Dinesh Chand and Sunil Gomashe. 2019. *In-situ* Assessment of Morpho-physiological Traits and Ecological Niche Modelling Studies on *Sesamum mulayanum* Nair. *Int.J.Curr.Microbiol.App.Sci.* 8(04): 1179-1189. doi: https://doi.org/10.20546/ijcmas.2019.804.135