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RESEARCH ARTICLE

Predicting the potential distribution of *Echinochloa colona* (L.) Link. and *Cyperus rotundus* L. under future climatic scenarios in India

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ABSTRACT

Weed's geographical and temporal expansion severely affects the global biodiversity, agricultural ecosystems and economy of the country like India. Therefore, in order to help and better prioritize the management tactics, MaxEnt model was used to predict the current and future distribution of *Echinochloa colona* and *Cyperus rotundus*, two economically important weeds of agricultural ecosystems. With the help of 552 and 343 occurrence points of *E. colona* and *C. rotundus*, respectively, along with 8 bioclimatic parameters, elevation, and soil layers; modelling was performed and predictions were made for probable hotspots of the species in future changing climate scenario. The area under the receiver operating characteristics (ROC) curve (AUC) was used to test the model's accuracy, and Jackknife test was used to observe the variable importance for both the species. The model predicts that under Representative Concentration Pathway (RCP) 4.5 for both 2050 and 2070, climatic conditions were generally highly suitable for *E. colona*, except for certain areas in southern, western, and northern India. Whereas, under RCP 8.5 for the same years, a notable reduction in suitable areas is predicted for the species, particularly in Central India. On the other hand, *C. rotundus* is projected to contract the suitable areas in future climates under both the scenarios depicting the reduced suitability under future climate. Findings of this study would contribute to a better understanding of the nature of the niche shift of both the species and the potential for invasion under future climate scenarios. This will help in understanding the impact of the species and in making informed decisions on matters related to biodiversity, public health, agriculture, and the economy.

Keywords: *Cyperus rotundus*, Climate change, *Echinochloa colona*, MaxEnt model, Potential distribution, Weed species distribution modelling

INTRODUCTION

Biotic and abiotic factors contribute in crop yield and economic losses. Among the major biotic constraints, weeds are the significant pest affecting agricultural production, agrobiodiversity and natural water bodies (Gharde *et al*. 2018). They can negatively impact the crop by competing for resources such as water, sunlight and space; sheltering crop pests; interfering with water management; reducing the yield and quality and subsequently increasing the cost of the production (Chauhan 2020, Rao 2022). The alien invasive weeds (AIW) are those, which are introduced into places outside their natural range, adversely affecting native biodiversity, ecosystem or human well-being. These species are introduced intentionally or accidentally outside their natural habitat, where they exhibit the ability to establish themselves, invade, out-compete native weeds and take over the new environment within short span of time. One of the major disadvantages of their introduction is extinction of native species, which has been well documented (Blackburn 2019). For instance, a tree species Saint Helena olive (*Nesiota elliptica*) endemic to Saint Helena that became extinct due to habitat destruction and competition with invasive alien plants introduced to the island during human settlement and agriculture (Cronk 2016). Further, uncontrolled expansion of weeds in agriculture ecosystem may cause huge crop yield losses (Rai and Singh 2020).

Climate change, mostly known by the term "*Global Warming*", is now a well-accepted phenomenon which may be due to both natural and human intervention. According to Inter-governmental Panel on Climate Change (IPCC), "Climate change refers to any change in the state of climate identified by fluctuations in the mean and/or the variability of its properties due to natural event or human activities, and that persists for a longer period like decades or

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more" (IPCC 2007, Anwar *et al.* 2021). Recent IPCC report states that the Earth has already warmed about 1.1–1.2 °C since pre-industrial times, will likely reach 1.5 °C between 2030–2040, and could warm up to ~5 °C by 2100 under high emissions (IPCC 2023). Climate change is also expected to affect the distribution and occurrence of the weeds in future (Gharde *et al.* 2024). It will have a profound effect on crop protection, including the effects on pests, diseases and weeds (IPCC 2022). Furthermore, the physiology and biological cycle of the weeds and their competitive relationship with crops will also be affected significantly (Ziska and Dukes 2011). Climate change may also affect the geographic distribution of a native species or invasion of crops by a new weed species (López-Tirado and Gonzalez-Andújar 2023). To minimize the effect of weed success favoured by climate change, there is need to predict the potential geographical distribution of species accurately. This will help in understanding the impact of the species and in making informed decisions on the matter related to biodiversity, public health, agriculture and the economy. Apart from this, it will also help in early detection of the hot spots of the species enabling prompt actions in order to reduce management cost after its introduction in new places (Dorji *et al.* 2022, Singh *et al.* 2024).

Predictive models used for the species distribution modelling are powerful tools that can assist in making the decision on the management of these invasive species under different climate scenarios. Some commonly used models are CLIMEX, BIOCLIM, MaxEnt and CLIMATCH known for their simplicity and the data accessibility (Srivastava *et al.* 2019, Gharde *et al.* 2023a). This modelling approach is a well-established approach to model and project the habitat suitability of a species based on their current distribution relative to climatic factors (Elith *et al.* 2006, Gharde *et al.* 2023b). This technique has gained importance in ecology, biogeography, biodiversity conservation and management of natural resources (Adhikari *et al.* 2019). Numerous studies have been conducted in the past to assess the impact of climate change on the potential distribution of the species and found the difference in the results (Merow *et al.* 2017). In India, widespread obnoxious invasive alien weeds such as *Parthenium hysterophorus, Lantana camara*, *Chromolaena odorata* (Patil and Janarthanam 2013), *Cassia tora* (Panda *et al.* 2018), *Tridax procumbens* (Panda and Behera 2019), *Ethulia gracilis* (Aravind *et al.* 2022), *Calyptocarpus vialis* (Lal *et al.* 2024), *Phalaris minor* (Gharde *et al.* 2023a) *etc*. have been studied for their probable geographical distribution in future climatic scenarios.

Holm (1969) listed 10 serious weed species that cause serious consequences to agriculture worldwide which also includes purple nutsedge (*Cyperus rotundus* (L.) and jungle rice (*Echinochloa colona* (L.) Link.). These species are capable of adapting different environmental conditions, and have spread all over the world (Holm 1969). *Echinochloa colona* ranked as the world's fourth worst weeds infesting numerous crops in several countries and causing significant reduction in the yield of crops (Holm *et al.* 1991). However, it tends to occur mostly in rainfed agriculture system. Due to its characteristics such as plasticity in morphology, phenology, fast growth, prolific seed production, seed dormancy, and adaptability to a wide range of environments, it contribute to the successful establishment of this species in agroecosystems (Rao 2021). Purple nutsedge (*Cyperus rotundus* L.), native to India, is considered as economically damaging weed, which has been widely adapted in the countries across Africa, America, South Asia, and southern/central Europe, significantly impacting the tropical and subtropical regions of the globe (Srivastava *et al.* 2013). This weed cause huge yield losses (20–90%) in various crops across the world (Peerzada 2017). Due to its distinctive characteristics such as high rate of reproduction, perennial nature, genetic diversity, ability to adapt to adverse environments, easy dispersion and strong competitive abilities help this weed to occur in a wide range of agro-climatic regions (Peerzada 2017). As a glabrous perennial sedge, it can grow under various soil conditions, preferably in moist soils, and is commonly found in wasteland, gardens, orchards, and cultivated areas (Khalid and Siddiqui 2014). In particular, it can be a threat to croplands, resulting in the loss of food and feed valuable to human beings (Holm 1969).

Keeping in view, the harmful effects caused by these two weeds in agriculture ecosystem, it is necessary to explore the expansion risk of these weeds in India. Therefore, the aim of this study was to model and project the habitat suitability of two important weed species of agricultural system, *viz. E. colona* and *C. rotundus* under current as well as future climatic scenarios.

MATERIALS AND METHODS

Collection of occurrence data of the species

Occurrence data of the two species, *viz. E. colona* and *C. rotundus* was obtained from the sources such as Flora of Peninsular India, Herbarium JCB, Centre for Ecological Sciences, Indian Institute of Science, Bangalore (http://flora-peninsula-indica.ces.iisc.ac.in/); Centre for Agriculture and

Biosciences International (CABI); Global Biodiversity Information Facility (GBIF) (https://doi.org/10.15468/dl.ja9yr2 and https://doi.org/10.15468/dl.m35m8j); iNaturalist; India Biodiversity Portal; and other published literature (**Table 1**). *E. colona* is native to tropical and subtropical Asia and is now widespread in the warm regions of Asia, Africa, and Australia (Holm *et al*. 1991, Lazarides 1980, Peerzada *et al*. 2016), therefore, occurrence data for both native and invaded range (India) was collected for this species. For *C. rotundus*, occurrence records collected from India were used for modelling, as India represents its native range. For those published literature where geo-coordinates of the study location was not provided, they were collected from google search engine to locate the site of the experiment. After the elimination of ambiguous and duplicate records, 552 and 343 occurrence points were retained for further analysis for *E. colona* and *C. rotundus*, respectively (**Figure 1**).

Climate data

Climatic data for 19 bioclimatic variables (bio1 to bio19; **Table 2**) with a spatial resolution of 30 arc-seconds (~1 km²) were downloaded from the WorldClim database (www.worldclim.org). Elevation data from the Shuttle Radar Topography Mission (SRTM) were also obtained from the same source. All the downloaded layers were converted into ASCII (American Standard Code for Information Interchange) format using QGIS version 3.36. Future climate data for Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 for the years 2050 and 2070, at the same 30 arc-seconds resolution, were downloaded in ASCII format from the Climate Change, Agriculture and Food Security (CCAFS) website (www.ccafs-climate.org) (Gharde *et al*. 2023a). According to the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC, 2014), four RCPs were described. Among them, RCP 4.5 represents a moderate greenhouse gas emission scenario (with a projected temperature rise of about 2-3°C), while RCP 8.5 represents a high emission scenario (with a projected temperature rise of around

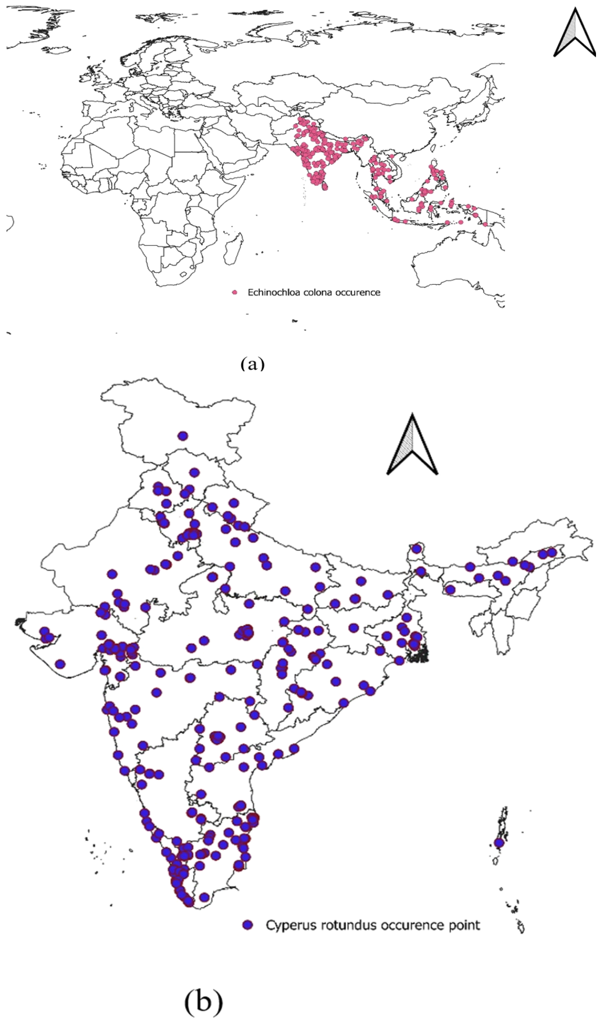


Figure 1. Maps depicting the occurrence points of (a) *Echinochloa colona* and (b) *Cyperus rotundus* in the study region

Table 1. List of published literature from where occurrence records were collected for *Echinochloa colona* and *Cyperus rotundus*

Species	Source of data
Echinochloa colona	Das *et al*. (1996), Rao and Rao (2006), Swain *et al*. (2008, 2012), Babu (2012), Maharaj and Prabhakaran (2014), Borkar *et al.* (2015), Kumar *et al.* (2016), Chopra *et al*. (2017), Praneetha *et al.* (2017), Aparna *et al.* (2018), Krishnaveni and Prasanna (2019), Borkar *et al.* (2021), Dhankar *et al*. (2022), Kaushal *et al.* (2023) **GBIF** (https://doi.org/10.15468/dl.p6sbf4; https://doi.org/10.15468/dl.zupkex; https://doi.org/10.15468/dl.jbjdjx; https://doi.org/10.15468/dl.uc9d6k; https://doi.org/10.15468/dl.kqdtgv; https://doi.org/10.15468/dl.tumy99; https://doi.org/10.15468/dl.s49hma; https://doi.org/10.15468/dl.c4wuz6; https://doi.org/10.15468/dl.k5ncnb; https://doi.org/10.15468/dl.bgdwxa; https://doi.org/10.15468/dl.cpwyzq; https://doi.org/10.15468/dl.gk2tm7; https://doi.org/10.15468/dl.d28bzv)
Cyperus rotundus	Satao *et al*. (1995), Babu and Kandasamy (1997), Gupta *et al*. (2002), Chopra and Chopra (2004), Ghorai *et al.* (2005), Kumar and Mishra (2005), Sharma and Gupta (2007), Pal (2009), Singh *et al.* (2010), Venkatasubramanian *et al*. (2010), Kumar *et al.* (2012), Samariya and Sarin (2013), Kumar *et al*. (2013), Singh *et al*. (2014), Nidugala *et al.* (2016), Desai *et al.* (2017), Dhyani (2017), Edwina and Leela (2020), Golla *et al*. (2022), Vadivel *et al*. (2022)

Table 2. List of climatic variables

Code	Variable name
bio1	Annual mean temperature
bio2	Mean diurnal range [mean of monthly (max temp - min temp)]
bio3	Isothermality (bio2/bio7) (* 100)
bio4	Temperature seasonality (standard deviation *100)
bio5	Max temperature of warmest month
bio6	Min temperature of coldest month
bio7	Temperature annual range (bio5- bio6)
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 (coefficient of variation)
bio16	Precipitation of wettest quarter
bio17	Precipitation of driest quarter
bio18	Precipitation of warmest quarter
bio19	Precipitation of coldest quarter

5°C). The future climate data used in this study were generated from the Canadian Earth System Model (CanESM2) developed by the Canadian Centre for Climate Modelling and Analysis. These datasets were statistically downscaled from a Global Circulation Model (GCM) using WorldClim version 1.4.

Data preprocessing and modelling approach

Before the modelling, data were pre-processed to make them ready for further analysis. Occurrence points for the species were prepared in csv file format with species name along with latitude and longitude data. For 19 bioclimatic variables downloaded from WorldClim database, correlation analysis was done and variables having Pearson correlation coefficient values $|r| \geq 0.8$ were excluded from the analysis to avoid multicollinearity effects from the data. After following this criterion, eight bioclimatic variables along with elevation (and soil in case of *C. rotundus*) were chosen for further analysis.

In case of *E. colona*, raster layers of environmental variables were kept for whole world, however, they were clipped to match the extent of the study region for *C. rotundus*. All the raster layers of environmental variables were converted to follow the uniform projection system (EPSG: 4326 WGS-84) and 30 arc seconds spatial resolution. The MaxEnt v3.4.4 software (downloaded from https://biodiversityinformatics.amnh.org/open_source/maxent/) was used to model the present and future distribution of both the species using occurrence data and environmental variables. The relative importance of the variables was established using the jackknife method (Liao *et al*. 2017). Before the model run, the output file format for the model was set to 'cloglog'. A ten-fold cross-validation approach was used to minimize the uncertainties in the response curves and prediction on occurrences. The final model output was thus obtained through averaging these layers. This technique randomly split the occurrence data into 10 number of equal-size "folds" and models are formed using nine folds leaving each fold in turn and then left-out folds are then used for model validation. Thus, this technique use all data for validation purpose. The algorithm in MaxEnt was set to 'auto features' and the procedure was set to run 500 iterations with 10,000 background points with a regularization multiplier of 1. The Area under the receiver operating characteristics (ROC) curve (AUC) was used to test the model's accuracy. AUC values greater than 0.7 are generally considered to indicate good model performance, whereas values exceeding 0.9 are regarded as outstanding. AUC value less than 0.7 is considered as 'fair'. All environmental layers were converted into ASCII format before running the model (Thapa *et al*. 2018, Singh *et al*. 2024). MaxEnt provides gradient surface for the suitability of areas with values between 0-1 based on suitability.

RESULTS AND DISCUSSION

Model performance

The mean omission and predicted area for the *E. colona* and *C. rotundus* are shown in **Figure 2**, which shows that the models performed better than the random one (AUC 0.5) when evaluated for omission. The MaxEnt model can generate the area under ROC curve and find the models' AUC value on its own, which can be utilized as model selection criteria. In this study, the average AUC values are 0.958 and 0.735 for *E. colona* and *C. rotundus*, respectively. This indicated that models performed much better than the random prediction (AUC 0.5) and suggesting that the outcomes of the prediction were more precise. AUC value suggested that in case of *E. colona*, the model-predicted distribution completely matched the species' actual distribution.

Importance of bioclimatic variables

In order to determine the importance of the bioclimatic variables in prediction, jackknife test was used available in MaxEnt. The MaxEnt generates the result of jackknife test for regularized training gain, test gain and AUC for both the species.

Jackknife test revealed that two bioclimatic variables Annual Mean Temperature and Mean Temperature of Warmest Quarter provided higher test gain in case of *E. colona*, however, Min Temperature

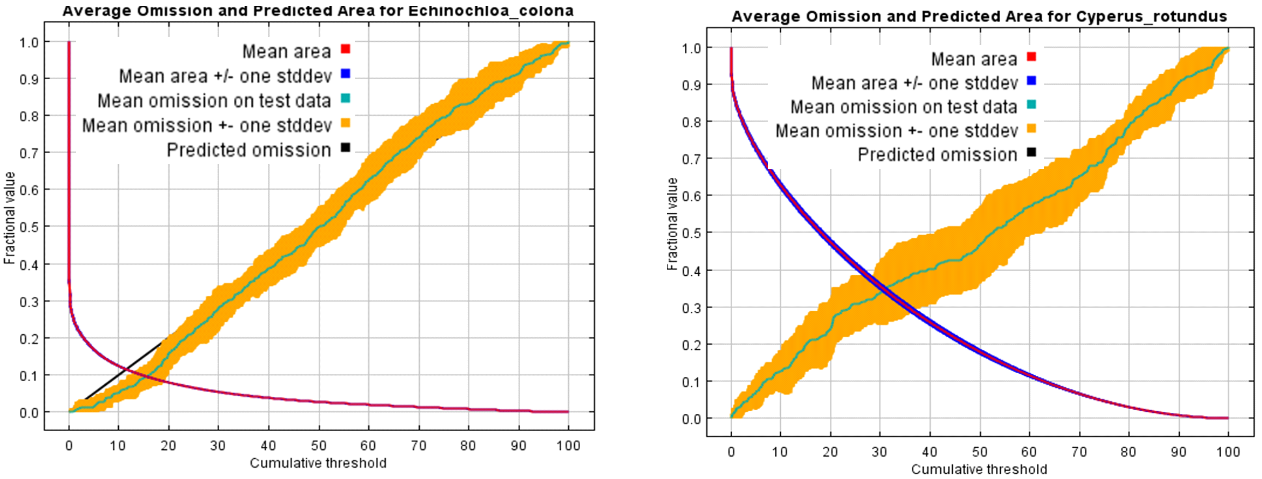


Figure 2. Plot showing the average omission rate and predicted area for *Echinochloa colona* and *Cyperus rotundus* as a result of the cumulative threshold being approximately over 10 duplicate runs

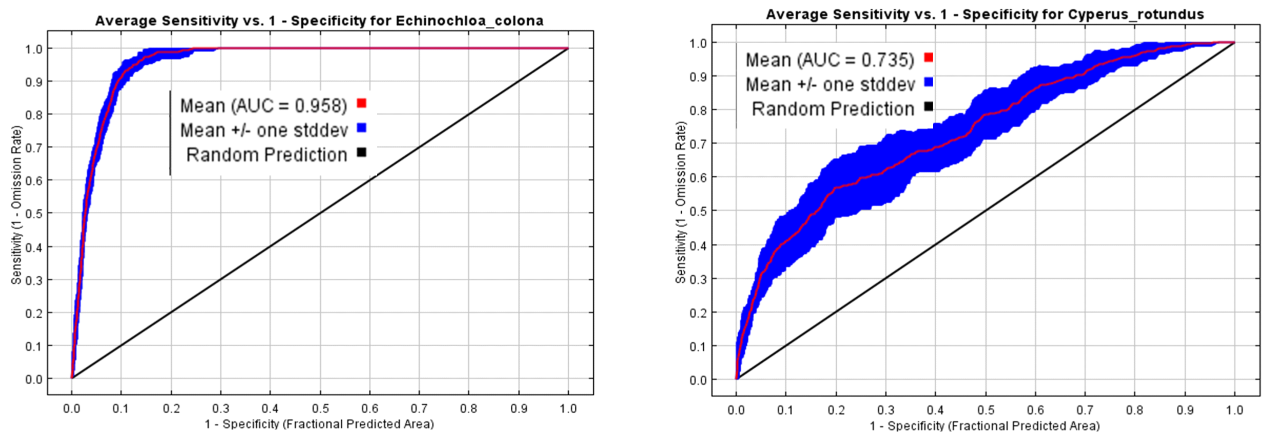
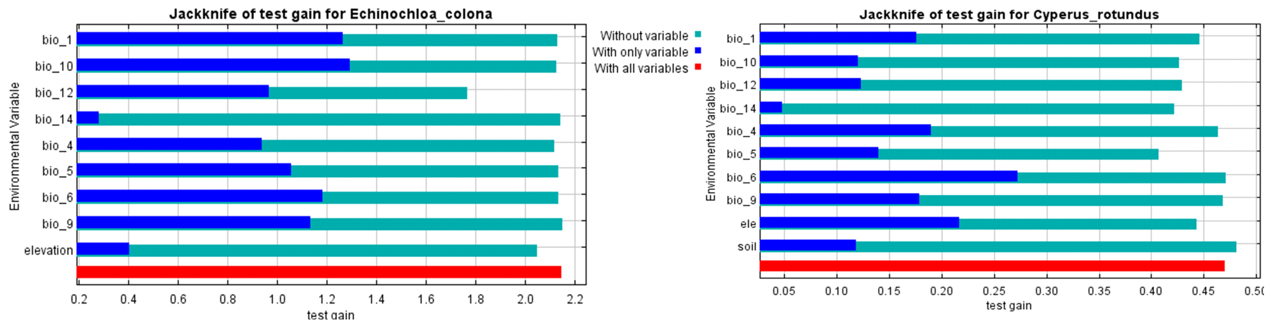


Figure 3. Plot showing the AUC values for *Echinochloa colona* and *Cyperus rotundus* as a result of the 10-fold cross-validation method



Note: bio_1 = Annual Mean Temperature; bio_4 = Temperature Seasonality; bio_5 = Max Temperature of Warmest Month; bio_6 = Min Temperature of Coldest Month; bio_9 = Mean Temperature of Driest Quarter; bio_10 = Mean Temperature of Warmest Quarter; bio_12 = Annual Precipitation; bio_14 = Precipitation of Driest Month; Elevation, above mean sea level

Figure 4. Significance of bioclimatic variables for the distribution of *Echinochloa colona* and *Cyperus rotundus* as a result of jackknife test

of Coldest Month and elevation are found to be affecting the distribution of *C. rotundus* significantly. However, it was observed that for *E. colona*, Annual Precipitation caused the greatest decrease in test gain when omitted from the analysis. This indicates that it contains more unique information than the other bioclimatic variables and has the strongest influence on model performance in its absence. These findings revealed that these variables made significant contribution in increasing the predictability in the modelling process. **Figure 5a** revealed that higher suitable conditions for *E. colona* are characterized by annual mean temperature at 23°C. Lin and Kuo (1996) also reported that non-dormant seeds of *E. colona* can germinate well when mean temperatures are 20-34°C. In the present study, test also revealed that Mean Temperature of Warmest Quarter at 32°C are ideal for the species and temperature beyond that

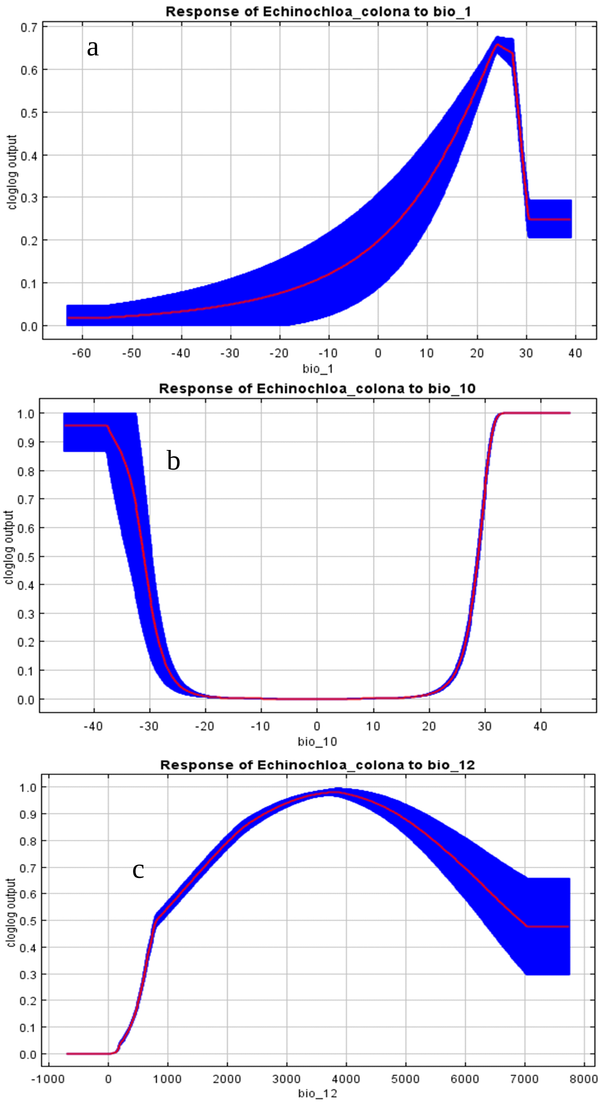


Figure 5. Response of the *Echinochloa colona* with respect to significant environmental variables

is giving the same favourability conditions for the species without any gain, however, it also shows that annual precipitation ranged between 3000-4000 mm are highly promising conditions for species development. This commemorates the findings of Civico and Moody (1979) where they found that *E. colona* is not affected by the flooding conditions to a depth of 5 cm, once established, and thus, can survive in both flooded and non-flooded rice fields. However, submerged conditions make it die. Further, it is observed that growth of *E. colona* was reduced when they were subjected to drought stress (Chun and Moody 1985). The plants produced shorter panicles and initiated later compared to those grown under well-watered conditions. These studies support that the species requires higher precipitation (not sub-merged) areas for the development. In case of *C. rotundus*, Minimum Temperature of Coldest Month >22°C is found to be suitable for the species which

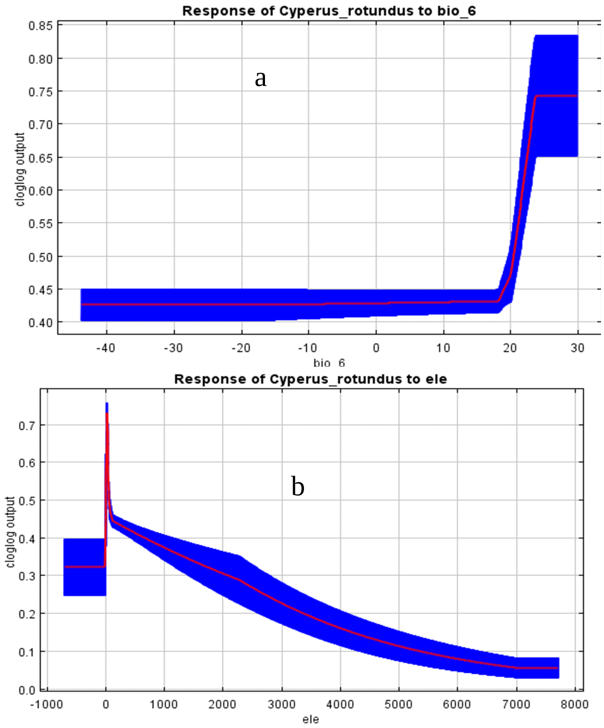


Figure 6. Response of the *Cyperus rotundus* with respect to significant environmental variables

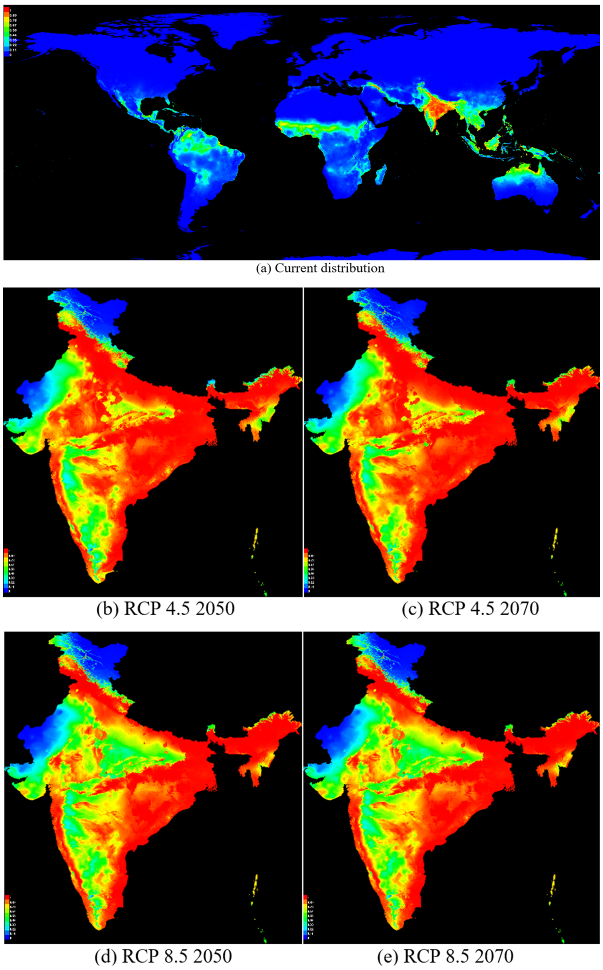
indicates its tendency to tolerate the high temperature (**Figure 6**), as also observed by Dor and Hershenhorn (2013). Santos *et al.* (1997) also reported that due to its rapid growth, perennial nature, and abundant tuber production, this weed is highly invasive and difficult to control in warmer regions. Our graph depicts that at lower temperature (<18°C) species favourability decreases. Elevation was also observed as significant factor affecting the distribution of the species. Analysis revealed that with increasing altitudes, species performance in a place is decreasing which revealed its non-adaptability to places with high altitudes limited by cold temperatures (Holm *et al.* 1977).

Distribution pattern of *Echinochloa colona* in current and future climatic scenarios

In current climatic conditions, central part of India including eastern states West Bengal and Odisha showing highly suitable areas for *E. colona*. Other parts of India including extreme north, west, north-east, Indo-Gangetic plains and southern India (excluding some parts of Kerala) are found to be moderately suitable for the species (**Figure 7a**). However, in future climatic scenarios most parts of the India are found to be highly suitable for the species (**Figure 7b-e**). Analysis revealed that under RCP 4.5 for both years 2050 and 2070 (**Figure 7b and c**), climatic conditions were found to be highly suitable for the species excluding some parts of the south, west and northern India, however, a significant decrease in areas of suitability especially in Central India is predicted under RCP 8.5 for both the years (**Figure 7d and e**). Instead, climatic suitability is shifted to the coastal parts of India along with eastern, North-eastern and Northern states.

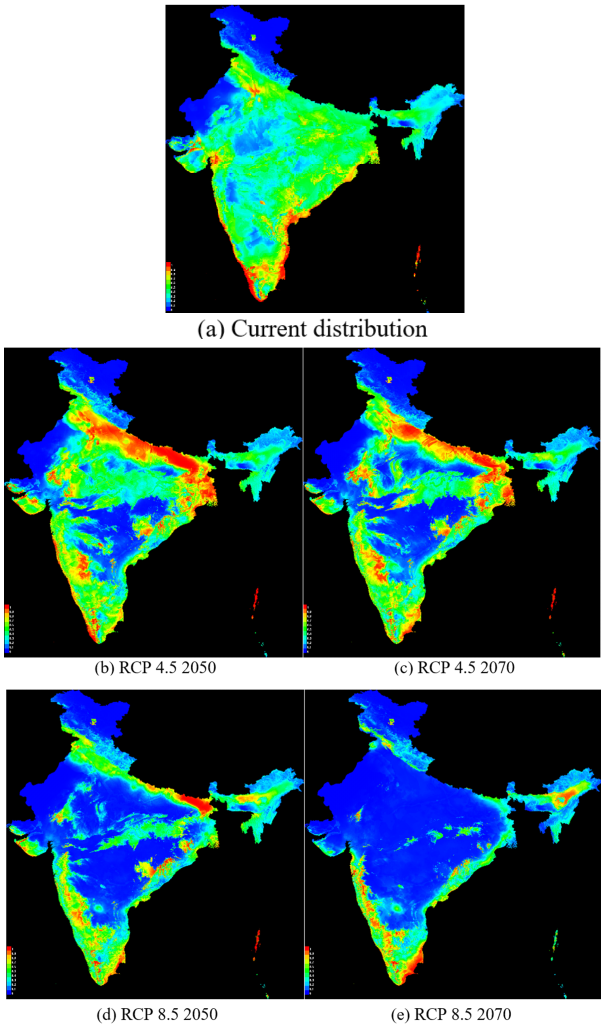
In case of *C. rotundus*, most of the parts of India (excluding western Himalaya region, parts of Rajasthan, few places of central plains and western and southern plateau and hills) were found to be moderately suitable (green colour) for *C. rotundus* (**Figure 8a**), however, a significant decrease in suitable areas were found under RCP 4.5 and 8.5 for both the years 2050 and 2070 due to increase in temperature. Very high and high suitable areas (red and yellow colour) found to be increased under RCP 4.5 for both the years with slight decrease in 2070 as compared to 2050 (**Figure 8b and c**). Indo-Gangetic plains were found to be highly suitable (red colour) for the species including very few parts of the country. This species is expected to find very few areas of the country as suitable areas. The species suitability conditions were found in southern states including few areas in west, east and north-eastern states (**Figure 8b and c**). The suitability was further decreased in RCP 8.5 2050 and 2070 for the species where very few areas of southern and north-eastern states were found to be suitable (very high, high and moderate) for the species (**Figure 8d and e**).

Thus, by identifying climatically and environmentally suitable areas, early detection and



In maps, red colour depicts very high suitable, yellow colour as high suitable, green colour as moderately suitable and blue colour as not suitable areas

Figure 7. Predicted distribution maps of *Echinochloa colona* under (a) current climate; and future climatic scenarios (b) RCP 4.5 for 2050 (c) RCP 4.5 for 2070 (d) RCP 8.5 for 2050 and (e) RCP 8.5 for 2070



In maps, red colour depicts very high suitable, yellow colour as high suitable, green colour as moderately suitable and blue colour as not suitable areas

Figure 8. Predicted distribution maps of *Cyperus rotundus* under (a) current climate; and future climatic scenarios (b) RCP 4.5 for 2050 (c) RCP 4.5 for 2070 (d) RCP 8.5 for 2050 and (e) RCP 8.5 for 2070

preventive management in regions are possible that are at high risk of invasion but not yet heavily infested. This supports a shift from reactive control measures to proactive planning. The models help prioritize surveillance efforts, optimize the allocation of limited resources such as labour, herbicides, and biological control agents, and reduce unnecessary expenditure in low-risk areas. Furthermore, the study identify key environmental drivers influencing weed distribution, which aids in developing habitat-specific and climate-informed management strategies for both the species. This study also forecast potential range expansion or contraction, allowing policymakers and land managers to design long-term adaptation and mitigation strategies. Overall, the study provides a scientific basis for risk assessment, policy formulation, and sustainable, cost-effective weed management planning.

Conclusion

In the present study the impact of global climate change on the distribution of *Echinochloa colona* and *Cyperus rotundus* was been projected. Our findings revealed that *E. colona* is expected to expand its areas in the country in future climatic scenarios irrespective of the RCPs for both the years 2050 and 2070 while *C. rotundus* is showing overall contraction in the invaded areas than the current geographical distribution. However, through modelling highly favourable areas are projected to increase for *C. rotundus* in future climate. Thus, both the species studied are responding differently to future climate. The findings of this study will not only help to make informed decisions on the matter related to agriculture, biodiversity, public health and the economy but it will also help in early detection of the species to enable speedy actions to reduce their management cost.

REFERENCES

Adhikari A, Mainali KP, Rangwala I and Hansen AJ. 2019. Various measures of potential evapotranspiration have species-specific impact on species distribution models. *Ecological Modelling* **414**: 108836.

Anwar, MP, Islam, AKMM, Yeasmin S, Rashid MH, Juraimi AS, Ahmed S, Shrestha A. 2021. Weeds and Their Responses to Management Efforts in A Changing Climate. *Agronomy* **11**(10): 1921.

Aparna KK, Menon MV, Joseph J and Prameela P. 2018. Diversity of *Echinochloa spp*. in Palakkad rice tracts of Kerala. *Indian Journal of Weed Science* **50**(2):124–128.

Aravind NA, Charles B and Ravikanth G. 2022. Will *Ethulia gracilis* Del become invasive in India? An Analysis Using Ecological Niche Modelling Approach. *International Journal of Ecology and Environmental Sciences* **48**: 295–301.

Babu MBBP. 2012. Impact of varying densities of jungle rice on rice productivity. *Indian Journal of Weed Science* **44**(1): 43–45.

Babu RC and Kandasamy OS. 1997. Allelopathic effect of *Eucalyptus globulus* Labill. on *Cyperus rotundus* L. and *Cynodon dactylon* L. *Pers. Journal Agronomy & Crop Science* **179**: 123–126.

Blackburn TM, Bellard C and Ricciardi A. 2019. Alien versus native species as drivers of recent extinctions. *Frontiers in Ecology and the Environment* **17**: 203–207.

Borkar VS, Kumaran KS and Kumar KLS. 2015. Evaluation of wound healing potency of *Echinochloa colona* using In vivo and In vitro methods. *International Journal of Pharma Sciences and Research*, Vol. **6**(8): 1140–1145.

Borkar VS, Sonwane G, Devhare P, Diwre R and Jain S. 2021. Evaluation of antidiabetic activity of *Echinochloa colona* plant extract. *International Journal of Pharmaceutical Sciences and Research* **12**(8): 4354–4364.

Chauhan BS. 2020. Grand challenges in weed management. Front. Agron. 1:3.

Chopra N and Chopra NK. 2004. Effect of glyphosate on purple nut sedge (*Cyperus rotundus*) in watermelon (*Citrullus vulgaris*) seed crop yield. *Indian Journal Weed Science* **36** (3&4): 293–294.

Chopra N, Tewari G, Tewar LM, Upreti B and Pandey N. 2017. Allelopathic effect of *Echinochloa colona* L. and *Cyperus iria* L. weed extracts on the seed germination and seedling growth of rice and soyabean. *Hindawi Advances in Agriculture*, **01–05**, Article ID 5748524.

Chun JC and Moody K. 1985. Some factors affecting germination and growth of *Echinochloa colona*. *Korean Journal of Weed Science* **5**: 103–108.

Civico RSA and Moody K. 1979. The effect of the time and depth of submergence on growth and development of some weed species. *Philippine Journal of Weed Science* **6**: 41–49.

Cronk QCB. 2016. *Plant extinctions and declines on Saint Helena*. Botanical Journal of the Linnean Society (Oxford Academic).

Das P, Samantaray S and Rout GR. 1996. Organogenesis and in vitro flowering of *Echinochloa colona* effect of growth regulators and explant types. *Biologia plantarum* **38**(3): 335–342.

Desai M, Patel GD, Patel NK, Bhatt ST and Patel M. 2017. Effect of different herbicides on *Cyperus rotundus* L. in turf. *Journal of Pharmacognosy and Phytochemistry* **6**(6): 643–647.

Dhankar R, Singh SK, Poonia T, Dhankar P, Parihar MD and Goya S. 2022. Effect of pre and post–emergence herbicides on *Echinochloa colona* infestation in groundnut (*Arachis hypogaea* L.). *The Journal of Rural and Agricultural Research* Vol. **22**(1): 84–86.

Dhyani S. 2017. Morphological & microscopical features of leaf and stem of *Cyperus rotundus* L. and *Cyperus procerus Rottb*: a comparative analysis. *International Journal of Research in Ayurveda Pharm* **8**(1): 46.

Dor E and Hershenhorn J. 2013. Effect of Low Temperature on *Purple Nutsedge (Cyperus rotundus*) Reproductive Biology. *Weed Science* **61**: 239–243.

Dorji S, Lakey L, Wangchen T and Adkins S. 2022. Predicting the distribution of *Parthenium weed (Parthenium hysterophorus l.*) under current and future climatic conditions in Bhutan. *Journal of Environmental and Occupational Health* **12**(4): 169–181.

Edwina K and Leela P. 2020. Phytotoxic effect of *Cynodon dactylon* (L.) *Pers*. and *Cyperus rotundus* L. on growth and biochemical changes of *Vigna radiata* (L.) R. Wilczek. *International Research Journal on Advanced Science Hub (IRJASH)* **02**(09): 90–96.

Elith J, Graham CH, Anderson RP, Dudík M, Ferrier S, Guisan A, Hijmans RJ, Huettmann F, Leathwick JR, Lehmann A. 2006. Novel methods improve prediction of species' distributions from occurrence data. *Ecography* **29**: 129–151.

Gharde Y, Dubey RP, Singh PK and Mishra JS. 2023a. Littleseed *canarygrass* (*Phalaris minor Retz.*) a major weed of rice-wheat system in India is predicted to experience range contraction under future climate. *International Journal of Pest Management* **71**(8): 1–12.

Gharde Y, Dubey RP, Singh PK, kumar S, Jamaludheen A, Mishra JS and Gupta PK. 2023b. Bibliographic analysis of modelling weed distribution and invasion with global perspective. *Indian Journal of Weed Science* **55**(1): 1–12.

Gharde Y, Singh PK, Dubey RP and Gupta PK. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection* **107**: 12–18.

Gharde Y, Singh PK, Mishra JS, Dubey RP, Jamaludheen A and Hota S. 2024. Prediction on distributional patterns of weeds under future climatic scenarios. *Indian Journal of Weed Science* **56**: 372–380.

Ghorai AK, De RK, Pandit NC, Mandai RK and Chakraborty AK. 2005. Biological control of *Cyperus rotundus* L. by *fusarium oxysporum. Indian Journal Weed Science* **37**(1&2): 142–143.

Golla S, Pasala PK, Sura S, Nainita K and Katabathina D. 2022. Anti urolithiatic activity of *Cyperus rotundus* tubers: In silico, In vitro and In vivo approaches. *Brazilian Journal of Pharmaceutical Sciences* **58**:181009:1–11.

Gupta VP, Kumar V, Mishra RK, Thiagarajan V and Datta RK. 2002. *Puccinia romagnoliana* Marie & Sacc. – A potential bioherbicide agent for biocontrol of purple nutsedge (*Cyperus rotundus* L.) in mulberry. *Journal Phytopathology* **150**: 263–270.

Holm L. 1969. Weed problems in developing countries. *Weed Science* **17**: 113–118.

Holm LG, Plucknett DL, Pancho JV and Herberger JP. 1977. The world's worst weeds. Distribution and Biology. Honolulu, Hawaii, USA: University Press of Hawaii.

Holm LG, Plucknett DL, Pancho JV and Herberger JP. 1991. The world's worst weeds. Distribution and Biology. Malabar, Florida. The University Press of Hawaii, p. 609–612.

IPCC 2001. Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Watson, R.T. and the Core Writing Team (eds.)]. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 398 pp.

IPCC 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

IPCC 2014. Climate Change 2014. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects; Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK, 2014.

IPCC 2022. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp.

IPCC. 2023. Climate Change 2023*:* Synthesis Report. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Kaushal I, Dubey V and Sinha MK. 2023. Floristic and phytosociological survey of weeds in direct seeded rice. *International Journal of Creative Research Thoughts* **11**(6): 632–640.

Khalid S and Siddiqui SU. 2014. Weeds of Pakistan: *Cyperaceae*. Pak *Journal Weed Science Research* **20**: 233–263.

Krishnaveni SA and Prasanna K. 2019. Intervention of *Echinochloa crusgalli* on growth morphology of rice. *International Journal of Current Microbiology and Applied Sciences* **8**(1): 3044–3049.

Kumar LD, Sankar SS, Venkatesh P and Kalarani HD. 2016. Green synthesis of silver nanoparticles using aerial parts extract of *Echinochloa colona* and their characterization. *European Journal of Pharmaceutical and Medical Research* **3**(4): 325–328.

Kumar M, Das TK and Yaduraju NT. 2012. An integrated approach for management of *Cyperus rotundus* (purple nutsedge) in soybean–wheat cropping system. *Crop Protection* **33**: 74–81.

Kumar N, Singh JP, Ranjan R, Devi SC and Srinivasan MV. 2013. Bioethanol production from weed plant (*Cyperus rotundus*) by enzymatic hydrolysis. *Advances in Applied Science Research* **4**(4): 299–302.

Kumar SVS and Mishra SH. 2005. Hepatoprotective activity of rhizomes of *Cyperus rotundus* L. against carbon tetrachloride –induced hepatotoxicity. *Indian Journal Science,* **67**(1): 84–87.

Lal R, Chauhan S, Kaur A, Jaryan V, Kohli RK, Singh R, Singh HP, Kaur S, Batish DR. Projected Impacts of Climate Change on the Range Expansion of the Invasive Straggler Daisy (*Calyptocarpus vialis*) in the Northwestern Indian Himalayan Region. *Plants*. 2024 **13**(1): 68.

Lazarides M. 1980. The Tropical grasses of South-east Asia. Strauss and Cramer, Vaduz, p. 225.

Liao, Y, Lei Y, Ren Z, Chen H and Li D. 2017. Predicting the potential risk area of illegal vaccine trade in China. *Scientific Reports* **7**: 3883.

Lin RJ and Kuo WHJ. 1996. Seasonal changes in the germinability of buried seeds of *Echinochloa colonum (*L.*)* Link. and *Alopecurus aequalis* Sobol. var. amurensis, *Komarov Memorial Series, College of Agriculture, National Taiwan University* **36**: 232–244.

López TJ and Gonzalez AJL. 2023. Spatial weed distribution models under climate change: a short review. *PeerJ* **11**: 15220.

Maharaj S and Prabhakaran J. 2014. Herbicidal efficacy of *Excoecaria agallocha* L., a mangrove plant on growth and development of barnyard grass (*Echinochloa colona* L.). *International Journal of Advanced Research.* Volume **2**(4): 926–932.

Nidugala H, Avadhani R, Prabhu A and Basavaiah R. 2016. In vitro cytotoxic activity of rhizome extracts of *Cyperus rotundus* (L.) against colon carcinoma and ehrlich ascites carcinoma. *Journal of Applied Pharmaceutical Science* **6**(11): 172–175.

Pal DK. 2009. Determination of brain biogenic amines In *Cynodon dactylon pers*. and *Cyperus rotundus L*. treated mice. *International Journal of Pharmacy and Pharmaceutical Science* **1**(1): 190–197.

Panda RM and Behera MD. 2019. Assessing harmony in distribution patterns of plant invasions: a case study of two invasive alien species in India. Biodiversity and Conservation **28**: 2245–2258.

Panda RM, Behera MD and Roy PS. 2018. Assessing distributions of two invasive species of contrasting habits in future climate. *Journal of Environmental Management*. 213.

Patil BB and Janarthanam MK. 2013. Distribution of some obnoxious weeds in north-western Ghats of India. *Indian Journal of Weed Science* 45(4): 267–272.

Peerzada AM, Bajwa AA, Ali HH and Chauhan BS. 2016. Biology impact and management of *Echinochloa colona* (L.) Link. *Crop Protection* **83**:56–66.

Peerzada AM. 2017. Biology agricultural impact, and management of *Cyperus rotundus* L the world's most tenacious weed. *Acta Physiologiae Plantarum* **39**(12): 270.

Praneetha P, Durgaiah G, Reddy NY and Kumar RB. 2017. In vitro hepatoprotective effect of *Echinochloa colona* on ethanol–induced oxidative damage in hepg2 cells. *Asian Journal Pharmaceutical Clinical Research*, **10**(9): 259–261.

Rai Kumar P, Singh JS. Invasive alien plant species: Their impact on environment, ecosystem services and human health. *Ecological Indicators, Ecological Indicators* **111**: 106020.

Rao AN. 2021. *Echinochloa colona and Echinochloa crus-galli In* biology and management of problematic crop weed species (Eds. Bhagirath Singh Chauhan BS), Academic Press. Pages (pp.197-239), ISBN 9780128229170)

Rao AN. 2022. Weed management role in meeting the global food and nutrition security challenge. *Indian Journal of Weed Science* **54**(4): 345–356.

Rao AS and Rao RSN. 2006. Effect of stage and dose of cyhalofop–butyl on *Echinochloa colona* control in blackgram grown as paira crop. *Indian Journal Weed Science* **38** (1&2): 148–149.

Samariya K and Sarin R. 2013. Isolation and identification of flavonoids from *Cyperus rotundus* L. in vivo and in vitro. *Journal of Drug Delivery & Therapeutics* **3**(2): 109–113.

Santos BM, Morales-Payan JP, Stall WM, Bewick TA and Shilling DG. 1997. Effect of shading on the growth of *nutsedges (Cyperus spp.). Weed Science* **45**: 670–673.

Satao RN, Tayde AS and Murarkar SR. 1995. Control of *Cyperus rotundus* L. *Crop Research*, **10**(1); 99–102.

Sharma R and Gupta R. 2007. *Cyperus rotundus* extract inhibits acetylcholinesterase activity from animal and plants as well as inhibits germination and seedling growth in wheat and tomato. *Life Sciences* **80**: 2389–2392.

Singh A, Gharde Y and Singh PK. 2024. Explaining distributional patterns of *Trianthema portulacastrum* and *Ageratum conyzoides* in India under future climatic scenarios using Ensemble modelling approach. *Indian Journal of Weed Science* **56**(1): 63–72.

Singh R, Pratap T, Pal R, Singh VP, Rekha and Singh J. 2014. Management of nutsedge in sugarcane by ethoxysulfuron. *Indian Journal of Weed Science* **46**(4): 342–345.

Singh S, Walia US, Kaur R and Shergill LS. 2010. Chemical control of *Cyperus rotundus* in maize. *Indian Journal of Weed Science* **42** (3 & 4): 189–192.

Srivastava RK, Singh A and Shukla SV. 2013. Chemical investigation and pharmaceutical action of *Cyperus rotundus*-a review. *Journal of Biologically Active Products from Nature* **31**: 66–172.

Srivastava V, Lafond V and Griess VC. 2019. Species Distribution Models (SDM) applications benefits and challenges in invasive species Management. *CABI Reviews* **20**: 1–13.

Swain D, Singh M, Paroha S and Subudhi HN. 2008. Evaluation of allelopathic potential of *Echinochloa colona* (L.) Link on germination and development of rice plant. *Oryza* Vol. **45**(4): 284–289.

Swain D, Singh M, Paroha S and Subudhi HN. 2012. Evaluations of allelopathic effect of *Echinochloa colona* weed on rice (*Oryza sativa* L. 'Vandana'). *Journal of Environmental Biology* **33**: 881–889.

Thapa S, Chitale V, Rijal SJ, Bisht N and Shrestha BB. 2018. Understanding the dynamics in distribution of invasive alien plant species under predicted climate change in Western Himalaya. *PLoS ONE* **13**(4): e0195752.

Vadivel SA, Thrisha M, kumar MP, Jagadeesan S, Agash E, Jeeva S and Kumar PD. 2022. In–vitro Study of anti–bacterial activity and phytochemical investigation of *Cyperus rotundus*. *Journal of Pharmaceutical Science & Research* **14**(1): 684–685.

Venkatasubramanian P, Kumar SK and Nair VSN. 2010. *Cyperus rotundus*, a substitute for *Aconitum heterophyllum*: Studies on the Ayurvedic concept of Abhava Pratinidhi Dravya (drug substitution). *Journal of Ayurveda & Integrative Medicine* **1**(1): 33–39.

Ziska LH and Dukes JS (Eds.). 2011. *Weed Biology and Climate Change.* Wiley-Blackwell.