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Highlighting Agro-ecological Zones to Upscale the Production of Immunity-booster Plants in Punjab

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ABSTRACT

The work has been conducted in the Department of Pharmaceutical Sciences & Technology, Maharaja Ranjit Singh Punjab Technical University, Bathinda, in the year 2019-2020. Witnessing an increase in the demand for immunity-booster plants especially in the aftermath of COVID-19, it becomes imperative to highlight suitable growing areas for *Withania somnifera* (L.) Dunal (Ashwagandha), and *Ocimum sanctum* L. (Tulsi) in Punjab. The scope of this work is to suggest market-driven immunity-booster plants that can act as a substitute for high water, pesticides, and fertilizers-dependent rice crop to promote sustainable agriculture. The agro-ecological zoning model was devised by highlighting agro-climatic aptitude requirements of the plants and mapping their requirements with the agro-ecological conditions of Punjab with special emphasis on temperature, rainfall, soil texture, and pH to highlight optimally suitable, suitable, and lesser suitable zones for the plants. The suitability maps were prepared using Geographic Information System. Ashwagandha was optimally suitable for zones-II, III; suitable for zones-I IV; and lesser suitable for zone-V. Similarly, Tulsi was optimally suitable for zones-I, II, III and suitable for zones-IV and V. With no policy to regulate the right medicinal plants in the right area, this agro-ecological study is essential to upscale the production of immunity-booster plants.

Key words: Agro-ecological zoning, Ashwagandha, Immunity-booster, Medicinal plants, Tulsi

The Indian state of Punjab lies between latitudinal extent from 29º 33' to 32º 34' N and longitudinal extent from 73º 53' to 76º 56' E [1-2]. The Green Revolution has managed to transform India from “a begging bowl to a breadbasket”. Punjab is known as the ‘Bread Basket of India’ that produces twenty and nice per cent of India’s wheat and rice respectively [3-4]. It is also referred to as one of the most successful celebrated stories of the Green Revolution bearing good results at the time. This impression, however, is no longer in existence. With time, the momentum of the green revolution started to sustain, and wheat-paddy dominance has led to a decline in agricultural employment, slowing of productivity growth, overexploitation of groundwater resources, pesticide resistance, declining soil fertility, and increasing vulnerability to human diseases [5-6]. This trend has attracted the attention of the agricultural experts and scientists that are suggesting crop diversification as a measure for sustainable agriculture in Punjab [7-8].

According to the World Health Organization (WHO), 60-80% of the world population depends upon medicinal plants and related formulations for managing various diseases, and its estimate highlights that the global herbal industry is projected to be worth US$ 5 trillion by the year 2050 globally [9]. Recently, the Ministry of AYUSH through the National Medicinal Plants Board (NMPB) has allocated special funds for promoting the cultivation of medicinal plants as an alternative farming option for the farmers of India (https://pib.gov.in/PressReleseDetailm.aspx?PRID=1624153).

In the aftermath of COVID-19, immunity-booster medicinal plants have witnessed a sharp rise in their demand worldwide due to their preventive and prophylactic role in the management of this pandemic (https://www.business-standard.com/article/companies/dabur-himalaya-witness-spike-in-sales-of-ayurvedic-products-amid-COVID-19-1200429010421.html). Immunity-booster plants such as Ashwagandha and Tulsi are recommended by the Ministry of AYUSH, Government of India for managing COVID-19 [10]. Ashwagandha is known as a wonder herb due to its roots, seeds, and leaves possessing multiple pharmacological properties. Apart from strengthening immunity, it is widely used for anxiety, depression, and treating senile dysfunctions. It is a branched, undershrub to herb having 30-120 cm height [11-12]. The estimated annual trade of Ashwagandha is 2000-

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5000 MT and its estimated consumption by herbal industries is 4198.0 (Dry weight MT) which indicates its trade importance [13]. *Ocimum sanctum* also popularly known as Tulsi in India is 30-60 cm high and widely distributed in India. The plant exhibits a wide range of pharmacological properties. The plant is known for strengthening immunity, anti-bacterial, anti-fungal, anti-viral, anti-malarial, anti-protozoal, anthelmintic properties. It also has hepatoprotective, anti-diarrheal, mosquito repellent, anti-inflammatory, cardio-protective, anti-asthmatic, anti-stress properties [14]. Its oil comprising of Eugenol is used in the perfumery, cosmetics, herbal, and nutraceutical industries [15]. The estimated annual trade of Tulsi is 2000-5000 MT and its estimated consumption by herbal industries is 1362.81 dry weight MT [13].

Punjab falls in the agro-climatic zone-VI, which is called the Trans-Gangetic Plains Region [16]. Most of Punjab lies in the fertile plain; toward the southeast, one finds semi-arid and desert landscape; a belt of undulating hills extends along the northeast at the foot of the Himalayas [6,17]. It is divided into five agro-climatic zones with specific growing periods: Western Himalayas sub-humid; Northern plain dry-sub-humid; Northern plain semi-arid; Western plain; Western plain aried [18]. At present, there is no policy to regulate the right medicinal plant species in the right location, hence it is imperative to highlight potential growing areas for Ashwagandha and Tulsi considering the economic potential and need for crop diversification in the state. In the present study, an agro-ecological model highlighted optimally suitable, suitable, and lesser suitable zones for plants by identifying their bio-climatic needs and analyzing climatic (temperature, rainfall) and edaphic data (soil pH, texture) of Punjab.

MATERIALS AND METHODS

Collection and analyzing the agro-climatological data

The meteorological data pertaining to the PAU (Punjab Agricultural University) research stations were obtained for the analysis. Meteorological data corresponding to 08 PAU research stations distributed in different climatic zones of Punjab was analyzed [19]. The period for the meteorological record was selected based on the availability of meteorological data in the stations. The thermal regime was defined by the average annual temperature and similarly, the moisture regime was plotted based on annual rainfall data. For edaphic data, an agro-eco-subregion-based benchmark soils network was used for highlighting soils in different agro-ecological zones. In the agro-eco-subregion model, soils in the same family generally required the same management practices and maximum production result acquired from a soil family can be utilized as production targets of other soils belonging to the same family [20-21].

Preparation of maps

The maps were digitalized online and digital information layers were created using GIS Arc.GIS 10.3 software. A manual digitization method was used, through which X and Y coordinate values were assigned to describe the locations of points. The first layer comprised of basic geophysical structures viz. major roads, built-up and district boundaries [18,22]. The integration of geophysical characteristics; roads, built-up and district boundaries was done in the digitalized map**.** Maps were marked considering the five agro-climatic zones of Punjab. The ranges for temperature, rainfall, and soil were integrated with agro-ecological zones map of Punjab delineated by ENVIS center, Punjab (http://punenvis.nic.in/index1.aspx?lid=5617&mid=1 &langid=1&linkid=1257).

Agro-ecological zoning

Agro-ecological zoning model was devised in such a way to highlight optimally suitable zone (having all the climatic and edaphic parameters common with the bio-meteorological requirements of selected immunity-booster plants), suitable zone (having only two parameters common with the bio-meteorological needs of selected immunity-booster plants), and lesser suitable zone (having only one parameter common with the bio-meteorological need of the plant).

RESULTS AND DISCUSSION

Meteorological and soil data

The meteorological data was obtained and was analysed to highlight mean annual temperature and rainfall. The climatic data of a research station present in an agro-ecological zone represented data for the entire agro-ecological zone considering common climatic and edaphic conditions. Due to proximity, Ballowal saunkri research station represented agro-climatic zone-I and II and Amritsar, Jalandhar, Ludhiana, Patiala represented zone II and III and Bathinda, Faridkot represented zone IV while Abohar represented zone V as represented in (Table 1).

Table 1 Research stations with temperature ranges in Punjab

Research stations	Location co-ordinates of research stations	Period of collected data	Representing agro-climatic zone	Average minimum and maximum temperatures ranges (°C)	Average temperature range (°C) of the stations
Ballowal Saunkri	31.0993°N, 76.3870° E	1984-2015	Zone I and II	16.2-30.0	23.1
Amritsar	31.6340°N, 74.8723° E	1970-2018	Zone II and III	15.5-30.3	22.9
Jalandhar	31.3260°N, 75.5762° E	1971-2015	Zone II and III	16.4-29.3	22.85
Ludhiana	30.9010°N, 75.8573° E	1970-2018	Zone II and III	16.7-29.8	23.25
Patiala	30.3398°N, 76.3869° E	1970-2018	Zone II and III	17.6-30.2	23.9
Bathinda	30.2110°N, 74.9455° E	1977-2015	Zone IV	16.9-31.3	24.1
Faridkot	30.6769°N, 74.7583° E	2000-2015	Zone IV	20.3-29.9	25.1
Abohar	30.1469°N, 74.2008° E	2004-2015	Zone V	17.6-30.2	23.9

The minimum average temperature i.e., 15.5°C was observed in the Amritsar research station while the maximum temperature i.e., 31.3 was observed in Bathinda research station. The agriculture in Punjab is divided into *Kharif* and *Rabi* season representing the sowing of rice and wheat at the beginning and the end of the rainy season respectively. The average maximum and minimum temperature in *Kharif* season were 36.7°C observed in

Bathinda station and 22.4°C at Ballowal saunkri station. Similarly, 25.8°C and 8.4°C were the mean average maximum and minimum temperature for *Rabi* season observed at Bathinda and Amritsar respectively. However, the average annual temperature ranged between 22.8°C to 25.1°C in Punjab. Long-term historical meteorological analysis indicated that the prevalence of occurrence frost was limited to five days in January, two days in December, and one day in February [19]. The bibliographic data corresponding to the agro-ecological requirements of the selected plants suggested their tolerance to these extreme conditions.

As supported by several studies, the Indian climate is characterized by monsoon rainfall having high variability in space and time. The rainfall is received during the southwest monsoon coming from June to September [23]. The monthly variability ranges between 35 to 230 percent and the annual variability of rainfall is 25 to 30 percent in Punjab. The maximum rainfall was observed in the Ballowal Saunkri station representing zone I and the lowest was observed in the Abohar research station (Table 2).

As per the PRECIS (Providing Regional Climates for Impact Studies) model under A1B (describing the future world of rapid economic growth), A2 (describing heterogeneous world), and B2 (describing world emphasizing on local solutions to social, economic, and environmental sustainability) scenarios, rainfall trends which may vary with the period, therefore estimated rainfall ranges were denoted for each agro-climatic zone as mentioned in (Table 2).

Table 2 Research stations with rainfall (mm) ranges in Punjab

<table>
<tr><th>Stations</th><th>Location co-ordinates of research stations</th><th>Period of collected data</th><th>Total rainfall (mm)</th><th>Representing agro-climatic zone</th><th>Total estimated rainfall range (mm)</th></tr>
<tr><td>Ballowal Saunkri</td><td>31.0993°N, 76.3870° E</td><td>1984-2015</td><td>1049</td><td>Zone I and II</td><td>1000-1500</td></tr>
<tr><td>Amritsar</td><td>31.6340°N, 74.8723° E</td><td>1970-2018</td><td>722</td><td rowspan="4">Zone II and III</td><td rowspan="4">550-1000</td></tr>
<tr><td>Jalandhar</td><td>31.3260°N, 75.5762° E</td><td>1971-2015</td><td>990</td></tr>
<tr><td>Ludhiana</td><td>30.9010°N, 75.8573° E</td><td>1970-2018</td><td>759</td></tr>
<tr><td>Patiala</td><td>30.3398°N, 76.3869° E</td><td>1970-2018</td><td>774</td></tr>
<tr><td>Bathinda</td><td>30.2110°N, 74.9455° E</td><td>1977-2015</td><td>517</td><td rowspan="2">Zone IV</td><td rowspan="2">350-550</td></tr>
<tr><td>Faridkot</td><td>30.6769°N, 74.7583° E</td><td>2000-2015</td><td>468</td></tr>
<tr><td>Abohar</td><td>30.1469°N, 74.2008° E</td><td>2004-2015</td><td>323</td><td>Zone V</td><td><350</td></tr>
</table>

A benchmark soil has a large extent and represents a major land use, one that holds a key position in soil classification, one for which there is a large amount of data, or one that has special significance to farming, forestry, etc. [20-21, 24]. The agro-eco-subregion-based benchmark soils highlighted that zone-I was dominated with sandy skeletal, loamy sand to sandy loam. Similarly, sandy loamy to clay was dominated in zone II and sandy loam to silt calcareous dominated zone-III, and sand to loamy sand to calcareous dominated zone IV and V. The soil pH in Punjab encompassed a range from 6.8 to 9.3. The undulating mountainous zone-I represented the range from 7.5 to 8.2, while, zone II, III, IV, and V represented pH ranges of 6.8-8.3; 7.5-9.3; 8.1-8.5 respectively.

Agro-ecological zoning

Ashwagandha is annual, perennial and it can also be cultivated as a *Kharif* crop (starting from June and ending October) between 600-1200 m altitudes in India. Annual temperature ranging between 20-35°C is suitable for its cultivation. It is a late *Kharif* crop and the best sowing time is after the arrival of the monsoon. The early sowing of the plant may cause mortality due to heavy rainfalls [11, 25]. The mean maximum and minimum temperature during *the Kharif* season ranged from 35°C to 24.5°C which can be correlated to its suitable cultivation during *Kharif* season in Punjab. It requires rainfall ranging from 600-750 mm annually [11]. As most of the rainfall is received during the monsoon period starting from June, the *Kharif* season rainfall varied from 262 mm corresponding to Abohar research station to 888 mm corresponding to Ballowal saunkri. These *Kharif* rainfall ranges further supported that zone II and zone III was most suited for the plant across Punjab. Ashwagandha required sandy loamy soil with a pH ranging from 7.5-8 for optimum cultivation. Ashwagandha was: Optimally suitable (15.5-30.3°C; rainfall 550-1000mm; sandy skeleton, loam to clayey loam to silt clay and calcareous with pH range 6.8-9.3) corresponding to agro-climatic zones II, III. The zone-I and IV were considered only suitable due to more rainfall in zone I and the unsuitable soil pH of zone IV corresponding to the requirements of the plant. Whereas, zone-V had only temperature regimes suitable for its cultivation so it was considered lesser suitable zone as represented in (Fig 1).

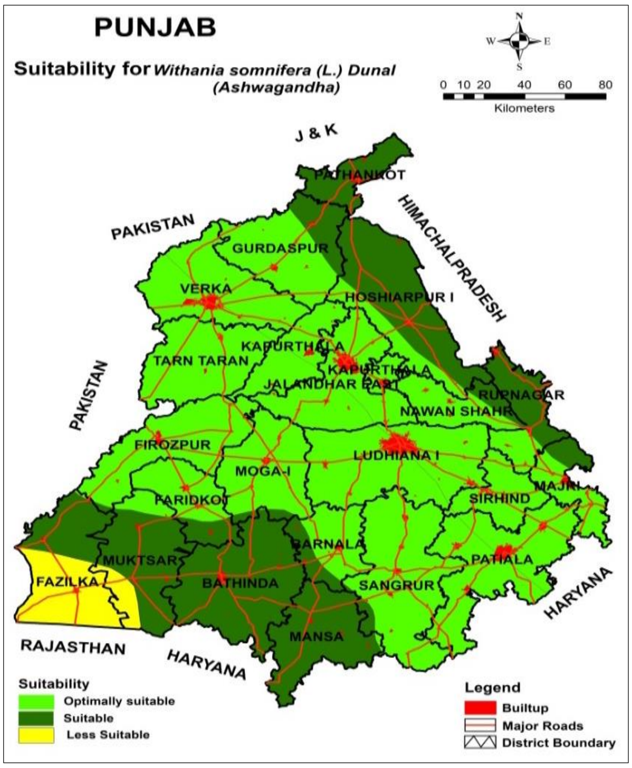

Fig 1 Potential growing areas of *Withania somnifera* in Punjab

The bio-climatic requirements for Tulsi were also identified after exploring available bibliographic data. Tulsi is an annual, perennial plant but it is also cultivated as a *Kharif* crop. It can be grown at an altitude ranging up to 900 m. It thrives on a diverse range of soils and requires high rainfall and humid conditions. However, for optimum growth, it requires 15-35°C annual temperature, 700-7600 mm rainfall, sandy loamy soils with pH ranging from 5 to 8.5 [26]. According to the present agro-ecological study, it was found optimally suitable for zones I, II, and III due to favorable temperature (15-35°C), rainfall (700-7600 mm), and soil parameters considering it both annual and Kharif crop. Whereas, it was found suitable for zones IV and V due to lesser rainfall ranges and have no less suitable zone as represented in (Fig 2). However, zones IV and V can be made optimum by increasing the frequency of irrigation in the areas.

Fig 2 Potential growing areas of *Ocimum sanctum* in Punjab

The IITM, Pune prepared PRECIS model having simulated baseline (1961-1990) and simulated mid to end century (2021-2100) climatic data for different agro-climatic zones that was downscaled to check the projected climatic variability in Punjab. The model analyzed the changes in temperature and rainfall by mid (2021-2050) and (2071-2100) under different scenarios classified as A1B, A2, B2. This method revealed that there was no significant variability in the temperature and rainfall in the coming years. Hence, this agro-climatic zoning model could be valid for up to at least 50 years for domesticating selected medicinal plants [19].

Many studies were conducted to highlight potential growing areas for castor bean, *Acrocomia aculeate, Cyamopsis tetragonoloba*, *Jatropha curcas, Lesquerella fendleri* (a multipurpose oilseed crop), *Camelina sativa, Salicornia bigelovii, Panicum virgatum* and *Argania spinosa* (L.) Skeels in different zones of Argentina [27-33]. These agro-climatic studies were limited only to the meteorological data such as temperature, rainfall, etc., however, the incorporation of significant land pattern data like soil texture and pH could have added more strength to the work. Since benchmark soil network had played a pivotal role in determining the land potential in the present study, consideration of both meteorological as well as land pattern data was the major advantage of the present study. Besides following this agro-ecological model, the authors recommend adopting, standard agro-practices, Good Agricultural Practices (GAP) guidelines for medicinal plants to achieve best results.

With no policy to regulate right crop in the right agro-ecological area, rational and sustainable use of land has become the key issue for government, scientists, policymakers, and land users for conserving the resources for future generations [34]. In view of this, adoption of immunity-booster plants in Punjab can be achieved through agro-ecological zoning studies. Moreover, if proper marketing is assured, the selected immunity-booster plants can become a substitute of water galloping rice crop eventually conserving the underground water table. As compared to rice (which is not an indigenous crop of Punjab), the selected immunity-booster plants are lesser prone to diseases and pest attacks; hence their adoption may lead to prevent excessive use of chemical fertilizers and pesticides [35-36].

Apart from their ecological role, Tulsi is known to possess anti-viral properties against Enterovirus 71 and Coxsackievirus by inhibiting the post-infection replication. The Ministry of AYUSH has also recommended *Ayush Kwath* comprising of Tulsi, ginger, cinnamon, black pepper for boosting immunity to prevent COVID-19 [37]. Similarly, Ashwagandha, a rasayan plant is a leading candidate against COVID-19 by resorting immune homeostasis and its formulation has achieved equal efficacy to Hydroxychloroquine (a potential candidate against COVID-19 management) in randomized clinical trials in treating rheumatoid arthritis [38]. Hence up scaling the production of immunity-booster plants can be a boon to the farmers of Punjab.

CONCLUSION

The agro-ecological model successfully highlighted potential growing areas considering the bio-climatic requirements of the selected immunity-booster plants and mapping the requirements with the climatological and edaphic patterns of the agro-ecological zones. The optimally suitable, suitable, and lesser suitable zones were highlighted using the digitalized maps developed using GIS software. Ashwagandha was optimally suitable for zone II and III corresponding to Gurdaspur, Kapurthala, Jalandhar, Ludhiana, Patiala, Tarn taran, Patiala, Sirhind, Moga districts of Punjab. It was suitable zone I and IV corresponding to the upper regions of Hoshiarpur, Pathankot, Roopnagar, and Bathinda, Mansa, Muktsar districts respectively. Ashwagandha was lesser suitable to zone V corresponding to the Fazilka district of Punjab. Similarly, Tulsi was optimally suitable to zone I, II, and III ranging from upper regions of Pathankot to Sangrur districts and suitable to zone IV and V corresponding to Bathinda and Fazilka districts of Punjab. The adoption of selected immunity-booster plants in the state can have a positive ecological role as they can be a possible substitute to the rice crop which is known to depend on huge underground water, fertilizers, and pesticides. Apart from their ecological role, the plants are recommended by the Ministry of AYUSH to manage COVID-19 and therefore can reap more benefits to the farmers considering their huge demand and industrial consumption worldwide. The present agro-ecological zoning model can be applied to any part of the world to highlight same plants in the different agro-ecological regions or different plants in same agro-ecological region.

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