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**Research Article**

# Genetic diversity and distribution of cucumber (*Cucumis sativus* L.) landraces in India: A study using DIVA-GIS approach

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**Abstract**
DIVA-GIS, a Geographical Information System is designed to assist the plant genetic resources and biodiversity communities to map the range of distribution of species in which they are interested. The regions where diverse accessions occur could be found by analysing the geographical diversity distribution. In the present study, 50 landraces of cucumber procured from ICAR-NBPGR, New Delhi was evaluated for six yield contributing traits in Augmented Block Design. To study the diversity and distribution of germplasm, geo-referenced points of the collection sites of the genotypes and the agro-morphological data recorded were supplemented to shape files and map geo-referenced points using DIVA-GIS software. A wide range of variability was observed for the quantitative traits studied, as evidenced by the wide range of SDI for days to first harvest (0- 0.350 to 1.356 - 2.000) to fruit length (0 - 0.450 to 1.840 - 3.000). Highest yield per plant was observed in IC613477 (2205.29 g), a collection from West Bengal and lowest in IC331627 (94.53 g), from Uttarakhand, with an overall mean of 1189.03 g. High SDI of 1.73 to 3.00 was recorded for accessions collected from Andaman and Nicobar Islands, Tripura and Uttarakhand for yield per plant. Collections from West Bengal, Tripura and Mizoram possessed diversity for days to first harvest, fruit weight, fruit diameter and yield per plant, as indicated by the appearance of red grids in these states for these characters. Hence, future germplasm collections can be targeted from these diversity rich states and adjoining areas.

**Key words**
Cucumber, *Cucumis sativus*, diversity analysis, DIVA-GIS

## Introduction

Availability of genetic diversity is a pre-requisite for any crop improvement programme. An insight into the magnitude of genetic variability present in a population is of paramount importance to utilize the germplasm in a judicious manner (Abraham, 2012). DIVA-GIS is a recently updated technology that supports the analysis of exploration, genebank and herbarium databases to elucidate genetic, ecological and geographic patterns in the distribution of crops and wild species. It enables us to understand and comprehend the distribution of diversity on the geographical scale, helps in identifying gaps in collection and also planning future explorations for collecting plant genetic resources (PGR). However, it was less used for plant genetic resources (PGR) management in India during the past. Recently, GIS and remote sensing are widely used for biodiversity assessment and mapping of various phyto-geographic zones of India. The present study would be the first of its kind in India by integrating DIVA-GIS for the study of diversity analysis in salad cucumber (*Cucumis sativus*). Moreover, for a successful breeding programme, identification of potential donor(s) for yield combined with desirable agronomic and quality traits is a prerequisite.

Hijmans and Spooner (2001) utilized the DIVA-GIS tool for the first time to analyse geographic distribution in wild potato germplasm. They analysed 6073 geo-referenced points spread over 16 countries and found that majority of the species are narrow endemics and the grid cells were used to map species richness. Further Hijmans *et al*. (2003) assessed the predictability of frost tolerance in wild potato species with geographic factors using DIVA-GIS. They observed that there was significant geographic clustering of areas with wild potatoes with similar levels of frost tolerance. Jarvis *et al*. (2003) assessed the conservation status of the genus *Arachis* spp. using 2175 geo-referenced points and prioritized the biological and geographical future conservation actions. The species richness of the genus excluding *Arachis hypogoea*, were assessed by predicting the distribution using 36 climatic variables and synthesizing it with the land data to map potential distribution of each species.

Similarly, this tool has been successfully used for *in-situ* assessment of phenotypic diversity in *Jatropha* (Sunil *et al*. 2008), assessing diversity and identifying diversity rich pockets in *Phaseolus* bean (Jones *et al*., 1997), black gram (Abraham *et al*. 2010), Sesame (Spandana *et al*., 2012), eggplant (Kumar *et al*., 2013) and *Cajanus scarabaeoides* (Dikshit *et al*. (2015).

**Materials and Methods**

A study on the distribution of diversity in a species at the ecosystem level (geographical distribution) is an important aspect as it gives an insight into the environmental conditions conducive for propagating the diversity (Abraham, 2012). To study the diversity and distribution of the study material using DIVA-GIS (available at www.diva-gis.org), geo-referenced points of the collection sites of the genotypes and observations recorded on six yield contributing traits on 50 cucumber landraces from 12 states of India representing different agro-ecological zones were exploited. The passport data indicating the geographical coordinates of the collection sites and accession identity used for DIVA-GIS analysis are provided in Table 1. The field experiment was carried out at ICAR-NBPGR Regional Station, Vellanikkara, Thrissur. The accessions for study comprised collections representing various states of India *viz.*, Kerala (1), Karnataka (1), Maharashtra (2), West Bengal (12), Himachal Pradesh (1), Andaman and Nicobar Islands (3), Uttarakhand (2), Odisha (1) and North Eastern states namely Tripura (8), Mizoram (14), Nagaland (1) and Arunachal Pradesh (4). The accessions were raised in augmented block design with eight blocks and three check varieties during June-August, 2015. Recommended agronomic practices as per package of practices of Kerala Agricultural University (2011) were followed to raise a good crop.

The mean values recorded for the traits for individual accession were supplemented to shape files and map geo-referenced points using DIVA-GIS software version 7.1.6. India shape file was used for plotting the geo-referenced points using the layer menu on the software. Point-to-grid option using circular neighbourhood method on the "Analysis Menu" was used to get grids over the points of collection. The output variables *diversity* and *statistics* were selected for getting output files. Under *Diversity*, Shannon Diversity Index (SDI) was picked. Under *Statistics*, coefficient of variation was selected. From these output maps, the distribution pattern, diversity and coefficient of variation were generated. The colour of the grid varied from green, light green, yellow, orange and red in the order of their magnitude of variability. Colours of grids are indicative of the extent of diversity in the germplasm lines, where green coloured grids indicated the less diverse regions whereas red coloured grid, the most diverse region.

Shannon Diversity Index accounts for both abundance and evenness of the trait in the states (Negassa, 1985). The proportion of descriptors states relative to the total number of states (*pi*) is calculated, and then multiplied by the natural logarithm of this proportion (ln *pi*). The resulting product is summed across the states and multiplied by -1:

$$H = - \sum pi \ln pi$$

where, '*pi'* is the proportion of individuals found in species 'i'.

**Results and Discussion**

In the present study, DIVA-GIS grid maps were generated for the descriptors namely days to first harvest, fruit length (cm), fruit diameter (cm), single fruit weight (g), number of fruits per plant and yield (g/plant). A wide range of variability was observed for the quantitative traits, among the 53 accessions as evidenced by the wide range of SDI for days to first harvest (0 – 0.350 to 1.356 – 2.000) to fruit length (0 - 0.450 to 1.840 – 3.000) (Table 2) (Fig. 1 and 2). The accessions also exhibited diversity in qualitative traits like fruit shape, fruit skin colour and fruit skin texture (Plate 1). The mean value for days to first harvest was 50.34 days among the accessions. However, first harvest started by 37.21 days after sowing in IC595505, a collection from Kolazib, Mizoram and was delayed up to 64.54 days in IC331445. Earliness in yielding is a preferred character for commercial cultivation. Significant differences among genotypes for days to first harvest were reported earlier by Gaikwad *et al*., (2011). Rich diversity was observed for days to first harvest in states namely West Bengal and Mizoram as depicted by red grids in the map. The value of Shannon Diversity Index (SDI) for days to first harvest ranged from 0 - 0.350 for accessions from Kerala, Karnataka, Maharashtra, Orissa, Tripura and Uttarakhand. Fruit length, diameter and fruit weight are generally considered as the most important yield contributing characters. Long thin fruits are preferred in slicing cucumbers. The mean value for fruit length across accessions was 15.01 cm, ranging from 5.14 cm in IC331627 to 20.85 cm in IC613472, respectively (Plate 2). Fruit diameter ranged from 3.85 cm in IC595517 to 6.31 cm in IC595515 (Plate 3) and accessions from West Bengal, Tripura and Mizoram recorded SDI of 1.76 – 3.00 (Fig. 3). The overall mean was 4.99 cm. Accessions from Kerala, Karnataka, Maharashtra, Orissa, Tripura, Himachal Pradesh and Nagaland recorded low SDI of 0.00 to 0.43 indicating low diversity, whereas accessions from West Bengal, Tripura and Mizoram recorded SDI of 1.73 to 3.00

for fruit weight (Fig. 4), the mean values ranging from 32.97 g (IC331627) to 343.04 g (IC613472).

The more will be the number of fruits; greater will be the fruit yield as suggested by Resende (1999). IC277048 and IC612081 recorded highest and lowest values for number of fruits per plant (11.47 and 1.60 respectively). The mean value across accessions was 5.35 fruits per plant. Accessions from Tripura and Mizoram recorded high SDI of 1.63 to 3.00 for this trait (Fig. 5). Coefficient of variation (CV) was high (>20 %) for fruit length (21.42 %), fruit weight (27.27 %), number of fruits per plant (42.02 %) and yield per plant (42.80 %) (Table 3). Yield is the reflection of number of fruits per plant and the average weight of the fruit. Highest yield per plant was observed in IC613477 (2205.29 g), a collection from West Bengal and lowest in IC331627 (94.53 g), from Uttarakhand, with an overall mean of 1189.03 g. High SDI of 1.73 to 3.00 was recorded for accessions collected from Andaman and Nicobar Islands, Tripura and Uttarakhand for yield per plant (Fig. 6). The availability of variability was very low in Kerala state, as cucumber is a recently introduced vegetable in the state, mostly grown in poly-houses/ protected structures on commercial basis. Similar study on distribution and diversity in *C. sativus* var. *hardwickii*, (progenitor of cultivated cucumber) using DIVA-GIS revealed variability in fruit shape, colour, fruit weight, fruit length, fruit width and fruit perimeter (Chand *et al*., 2015).

The results of the study indicated that collections from West Bengal, Tripura and Mizoram possessed diversity for days to first harvest, fruit weight, fruit diameter and yield per plant, as indicated by the appearance of red grids in these states for these characters. However, high SDI for number of fruits per plant was observed in Mizoram and Tripura. Therefore, diverse accessions for all these traits can be sourced from Mizoram and Tripura. Accessions from West Bengal also exhibited variability in majority of characters. In addition, other North Eastern states like Arunachal Pradesh and Nagaland also harbours diversity for various characters, as indicated by the light green coloured grids. The Ecocrop model for assessing areas suitable for cucumber cultivation in India indicated that entire North Eastern India, Gangetic plains, Western Ghats and parts of Deccan Plateau are suitable for cucumber cultivation (Chand *et al*., 2015) which is in line with the diversity rich areas identified in the present study. The results from the study also assist in identification of trait specific germplasm collected from the diversity rich areas, conserved in gene banks, thus increasing probability of identifying the ideal genotypes and economizing the resources and time required in the evaluation of large number of germplasm accessions (Kumar *et al*., 2013). This facilitates faster utilization of germplasm in breeding programme. Hence, among the cucumber germplasm sourced from twelve Indian states, and based on DIVA-GIS analysis it can be concluded that Mizoram, Tripura, and West Bengal are diversity rich pockets for cucumber germplasm for various yield contributing traits. Future germplasm collections can be targeted from these states and adjoining states like Manipur, Meghalaya, Sikkim etc as the centre of origin of cucumber is thought to be foot hills of Himalayan Mountain and north eastern belt is contiguous to this region. GIS mapping may also be effectively used for plant genetic resources documentation and gap analysis.

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**Table 1. Passport data of the cucumber germplasm used in the study**

| S. No | Accession No. | State | Latitude | Longitude | S. No | Accession No. | State | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|---|
| 1 | IC541367 | A&N Islands | 12.229 | 92.809 | 26 | IC613460 | Mizoram | 24.185 | 92.422 |
| 2 | IC541391 | A&N Islands | 12.508 | 92.932 | 27 | IC613474 | Nagaland | 26.760 | 95.610 |
| 3 | IC539818 | A&N Islands | 12.654 | 92.899 | 28 | IC331445 | Odisha | 18.856 | 82.735 |
| 4 | IC613471 | Arunachal Pradesh | 27.158 | 95.569 | 29 | IC595508A | Tripura | 23.084 | 91.364 |
| 5 | IC613472 | Arunachal Pradesh | 27.299 | 96.148 | 30 | IC595510 | Tripura | 23.025 | 91.541 |
| 6 | IC613473 | Arunachal Pradesh | 27.086 | 95.442 | 31 | IC618083 | Tripura | 23.025 | 91.541 |
| 7 | IC618084A | Arunachal Pradesh | 27.176 | 96.078 | 32 | IC595512 | Tripura | 23.262 | 91.346 |
| 8 | IC331619 | Himachal Pradesh | 30.905 | 77.097 | 33 | IC595514 | Tripura | 24.012 | 91.381 |
| 9 | IC469517 | Karnataka | 12.763 | 76.060 | 34 | IC595515 | Tripura | 23.482 | 91.535 |
| 10 | IC595518 | Kerala | 9.684 | 76.337 | 35 | IC595517 | Tripura | 23.545 | 91.502 |
| 11 | IC277048 | Maharashtra | 17.248 | 73.371 | 36 | IC613470 | Tripura | 23.005 | 91.546 |
| 12 | IC277030 | Maharashtra | 18.516 | 73.182 | 37 | IC331627 | Uttarakhand | 30.317 | 78.032 |
| 13 | IC613457 | Mizoram | 23.545 | 92.442 | 38 | IC202058A | Uttarakhand | 30.317 | 78.032 |
| 14 | IC595504 | Mizoram | 24.150 | 92.384 | 39 | IC613470 | West Bengal | 22.370 | 88.090 |
| 15 | IC613458 | Mizoram | 24.150 | 92.384 | 40 | IC613475 | West Bengal | 22.900 | 88.300 |
| 16 | IC595505 | Mizoram | 24.102 | 92.342 | 41 | IC613476 | West Bengal | 22.900 | 88.300 |
| 17 | IC613459 | Mizoram | 24.145 | 92.405 | 42 | IC613477 | West Bengal | 22.900 | 88.300 |
| 18 | IC612081 | Mizoram | 24.185 | 92.422 | 43 | IC613478 | West Bengal | 22.900 | 88.300 |
| 19 | IC613461 | Mizoram | 24.236 | 92.431 | 44 | IC613479 | West Bengal | 22.940 | 88.230 |
| 20 | IC613462 | Mizoram | 24.224 | 92.431 | 45 | IC613480 | West Bengal | 22.940 | 88.230 |
| 21 | IC612082 | Mizoram | 24.011 | 92.403 | 46 | IC613481 | West Bengal | 23.070 | 88.590 |
| 22 | IC613465 | Mizoram | 23.145 | 92.405 | 47 | IC613482 | West Bengal | 22.950 | 88.610 |
| 23 | IC613466 | Mizoram | 23.154 | 92.384 | 48 | IC613483 | West Bengal | 23.050 | 88.700 |
| 24 | IC613467 | Mizoram | 23.154 | 92.384 | 49 | IC613484 | West Bengal | 22.960 | 88.720 |
| 25 | IC613488 | Mizoram | 23.224 | 92.431 | 50 | IC613485 | West Bengal | 22.990 | 88.820 |

**Table 2. Shannon diversity index for different characters and the representation of diversity in states using grids**

| S. No. | Character | Shannon diversity index | States | Grid colour |
|---|---|---|---|---|
| 1 | Days to first harvest | 0.000 - 0.350 | Kerala, Karnataka, Maharashtra, Odisha, Tripura, Himachal Pradesh, Nagaland | Green |
| | | 0.350 - 0.699 | West Bengal, Uttarakhand, Andaman & Nicobar Islands | Light Green |
| | | 0.699-1.049 | - | Yellow |
| | | 1.049 - 1.398 | - | Orange |
| | | 1.398 - 2.000 | Tripura, Mizoram, West Bengal | Red |
| 2 | Fruit length (cm) | 0.000-0.450 | Kerala, Karnataka, Maharashtra, Odisha, Tripura, Nagaland | Green |
| | | 0.450-0.920 | West Bengal, Uttarakhand, Arunachal Pradesh, Himachal Pradesh | Light Green |
| | | 0.920-1.380 | Andaman & Nicobar Islands | Yellow |
| | | 1.380-1.840 | Mizoram | Orange |
| | | 1.840-3.000 | Tripura, Mizoram, West Bengal | Red |
| 3 | Fruit diameter (cm) | 0.000-0.440 | Kerala, Karnataka, Maharashtra, Odisha, Nagaland, Tripura, Himachal Pradesh | Green |
| | | 0.440-0.880 | West Bengal, Uttarakhand, Arunachal Pradesh | Light Green |
| | | 0.880-1.320 | Andaman & Nicobar Islands | Yellow |
| | | 1.320-1.760 | Mizoram | Orange |
| | | 1.760-3.000 | West Bengal, Tripura | Red |
| 4 | Number of fruits per plant | 0.000-0.410 | Kerala, Karnataka, Maharashtra, Odisha, Nagaland, Tripura, Himachal Pradesh | Green |
| | | 0.410-0.820 | West Bengal, Uttarakhand, Arunachal Pradesh | Light Green |
| | | 0.820-1.230 | Andaman & Nicobar Islands | Yellow |
| | | 1.230-1.630 | West Bengal, Mizoram | Orange |
| | | 1.630-3.000 | Tripura, Mizoram | Red |
| 5 | Fruit weight (g) | 0.000-0.430 | Kerala, Karnataka, Maharashtra, Odisha, Nagaland, Tripura, Himachal Pradesh | Green |
| | | 0.430-0.870 | West Bengal, Uttarakhand, Arunachal Pradesh | Light Green |
| | | 0.870-1.300 | Andaman & Nicobar Islands | Yellow |
| | | 1.300-1.730 | Mizoram | Orange |
| | | 1.730-3.000 | West Bengal, Tripura, Mizoram | Red |
| 6 | Yield per plant (g/plant) | 0.000-0.430 | Kerala, Karnataka, Maharashtra, Odisha, Nagaland, Tripura, Himachal Pradesh | Green |
| | | 0.430-0.870 | West Bengal, Uttarakhand, Arunachal Pradesh | Light Green |
| | | 0.870-1.300 | Andaman & Nicobar Islands | Yellow |
| | | 1.300-1.730 | Mizoram | Orange |
| | | 1.730-3.000 | West Bengal, Tripura, Mizoram | Red |

**Table 3. Variability parameters for the traits studied**

| Traits | Mean | Std. Dev. | Std. Error | C. V. % | Minimum | Maximum |
|---|---|---|---|---|---|---|
| **DFH** | 50.34 | 7.92 | 1.06 | 15.59 | 37.21 | 64.54 |
| **FL (cm)** | 15.01 | 3.22 | 0.44 | 21.42 | 5.14 | 20.85 |
| **FD (cm)** | 4.99 | 0.55 | 0.08 | 10.96 | 3.85 | 6.31 |
| **NFPP** | 5.35 | 2.25 | 0.31 | 42.02 | 1.60 | 11.47 |
| **FW (g)** | 227.45 | 62.03 | 8.52 | 27.27 | 32.97 | 343.04 |
| **YPP (g)** | 1189.03 | 508.85 | 69.90 | 42.80 | 94.53 | 2205.29 |

DFH- Days to first harvest; FL-Fruit length (cm); FD- Fruit diameter (cm); NFPP- Number of fruits per plant; FW-Fruit weight (g); YPP- Yield per plant (g)

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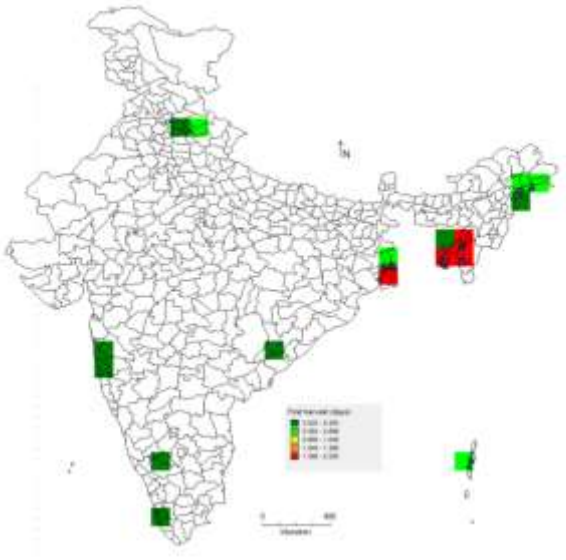

**Fig. 1. DIVA-GIS analysis of diversity in days to first harvest**

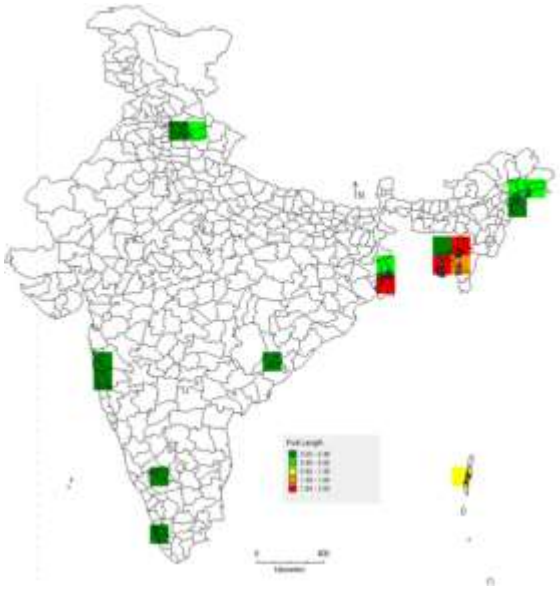

**Fig.2. DIVA-GIS analysis of diversity in fruit length**

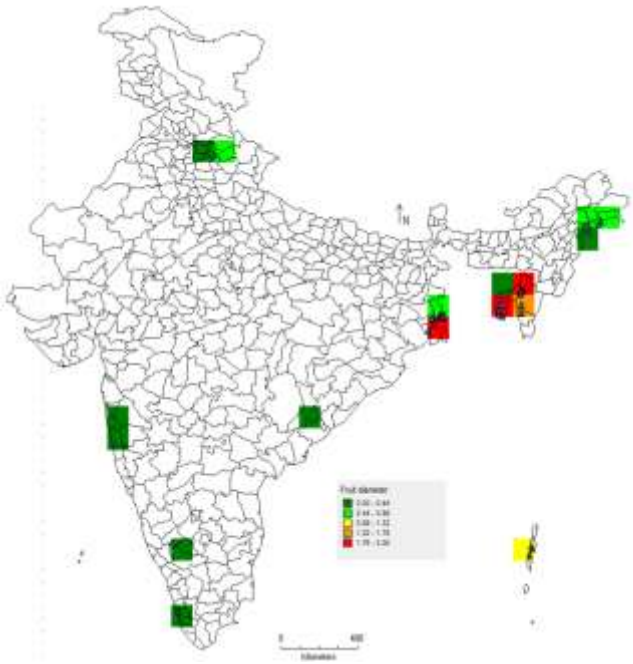

**Fig. 3. DIVA-GIS analysis of diversity for fruit diameter**

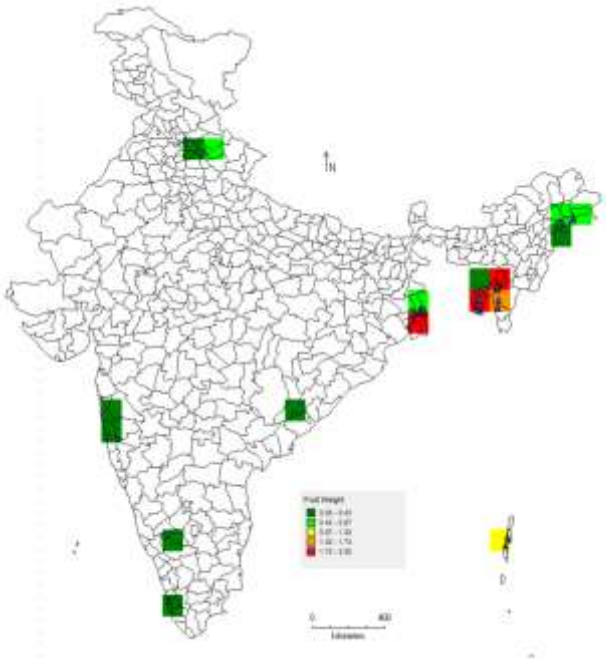

**Fig. 4. DIVA-GIS analysis of diversity in fruit weight**

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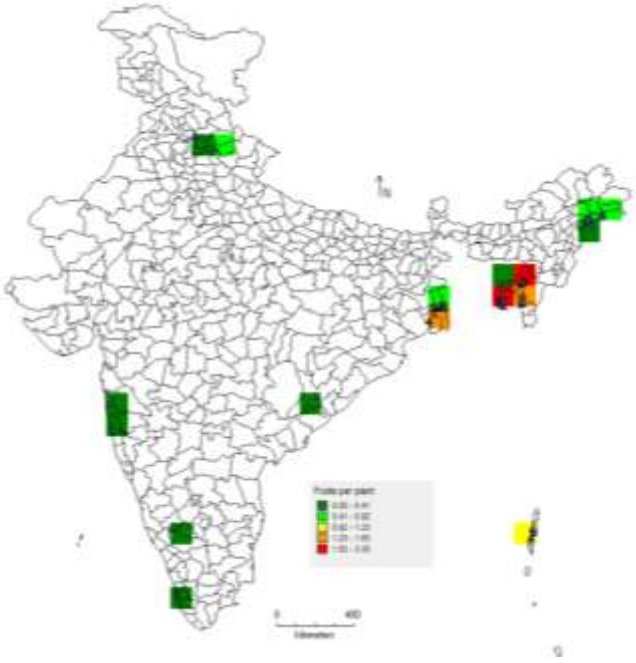

**Fig. 5. DIVA-GIS analysis of diversity in number of fruits per plant**

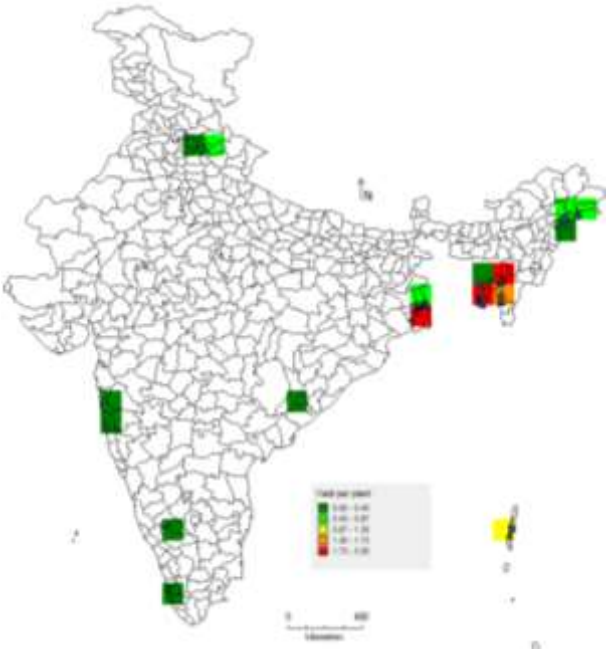

**Fig. 6. DIVA-GIS analysis of diversity in yield per plant**

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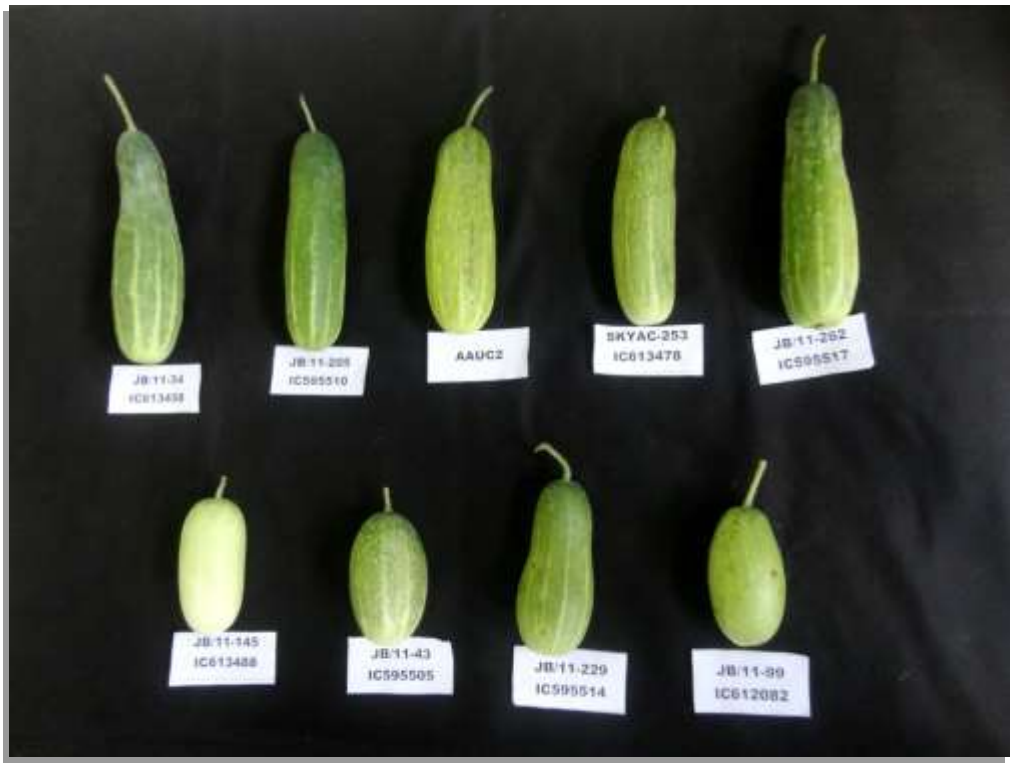


**Plate 1. Diversity in fruit shape, colour and skin texture in cucumber accessions**


**Plate 2. Accessions with minimum and maximum values for fruit length and weight**


**Plate 3. Accessions with maximum and minimum values for fruit diameter**


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