Diversity Distribution Pattern in Collected Germplasm of Rapeseed-Mustard using GIS in India

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A total of 6,923 accessions of rapeseed-mustard germplasm were collected during 1976-2011 through crop-specific and multi-crop explorations in collaboration with Indian Council of Agricultural Research (ICAR) crop-based institutes and State Agricultural Universities (SAUs) from different diversity rich areas of the country. Out of 6,923 accessions, 5,358 were examined for the status of diversity distribution pattern, which showed representation of maximum accessions from Gangetic, north-western plains and western Himalayan regions of the country. The geo-referenced map of collected diversity also indicated that parts of north-western plains (mainly western Uttar Pradesh), Himachal Pradesh and Uttarakhand have been extensively surveyed for collections of *Brassica* germplasm. In addition, grid mapping technique (GIS based) was also used to know the diversity rich areas and occurrence of trait-specific germplasm of rapeseed-mustard in different parts of the country. The priority areas and diversity distributed in different agro-ecological regions identified for further collections have been discussed in the present communication.

Key Words: Diversity distribution, GIS, Grid map, Rapeseed-mustard, Trait-specific germplasm

Introduction

The genus *Brassica* L. (Brassicaceae) possess different annual or biennial species, is considered to be the potential source of edible oils, vegetables, condiments and pharmaceuticals. In this genus about 37 species are distributed across the globe (Warwick *et al*., 2000; Kumar *et al*., 2004). *Brassica* is a prospective, economically important genus contributing to meet the challenges related to climate change, enhanced production and productivity as well as consumer's need (Singh and Sharma, 2007). Two important cultivated brassicas in India viz., *Brassica juncea* (L.) Czern. and *B. rapa* L. exhibit rich variability mainly in parts of northern, North-western, central and North-eastern regions (Singh and Sharma, 2007; Kumar *et al*., 2004).

In India, rapeseed-mustard includes six important annual oilseed brassicas namely Indian mustard (*B. juncea)* commonly known as rai, raya or laha, three ecotypes of Indian rapeseed (*B. rapa* syn *B. campestris*) *viz*., toria, brown sarson (lotni and tora types) and yellow sarson, Swede rape or gobhi sarson (*B. napus* L.), Ethiopian mustard or karan rai (*B. carinata* Braun.) and black mustard [*B. nigra* (L.) Koch]. The other minor oilseed brassicas grown in dry areas of Rajasthan and Haryana are taramira or tara (*Eruca sativa* Mill.) and wild turnip (*Brassica tournefortii* Gouan) (Chopra and Prakash, 1991; Minnich and Sanders, 2000; Hanelt, 2001). In Indian sub-continent, *B. juncea* is the dominant species grown along with *B. rapa* that constitute the major sources of edible oil, while *B. oleracea* L. is used as vegetable in most parts of the country. Rapeseed-mustard has the ability to grow under varied agro-climatic conditions relatively under low temperature as well as in the extremes of temperate regions (Downey, 1983; Hanelt, 2001). Since long history of their cultivation and acclimatization in India, remarkable variability has been generated in rapeseed-mustard (Rana and Singh, 1992; Duhoon and Koppar 1998). The Himalayan region is considered to be the secondary centre of diversity for *B. rapa* (Zeven and de Wet, 1982). Two exotic species namely gobhi sarson (*B. napus*) and karan rai (*B. carinata*) have become popular among the farmers in those areas where winter spell is longer.

In India, so far limited studies have been conducted on the diversity distribution pattern of genus *Brassica*. Keeping this in view, DIVA-Geographic Information System (GIS) was used to analyse the passport data of collected rapeseed-mustard germplasm to identify the diversity rich pockets in the country. Similar studies have been conducted by various workers on wild potatoes

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(Hijmans *et al.,* 2000), *Jatropha curcas* L. (Sunil *et al.,* 2009), *Vigna mungo* (L.) Hepper (Abraham *et al.,* 2010), etc. in different parts of world. Recently, application of GIS has earned recognition as a useful tool for effective management of plant genetic resources (Jarvis *et al.,* 2002; Dutta, 2008).

Materials and Methods

The germplasm collected from different agro-ecological regions belonging to more than 3,000 collection sites was examined using information recorded in plant exploration database, plant collection reporter, annual reports and other published literature (Plant Germplasm Reporter 2008-09; Annual Reports NBPGR 1976-2011; Annual Report Directorate of Rapeseed Mustard Research, 2011). To shortlist the accessions with required passport information, a rigorous screening of 6,923 accessions of rapeseed-mustard was done and a total of 5,358 accessions were short-listed with details on state, district, village, collector number, Latitude (N) and Longitude (E). Mainly six *Brassica* species *viz*., *B. juncea, B. napus, B. nigra*, *B. oleracea*, *B. rapa* and *B. tournefortii* were used for present analysis. Geo-referenced maps were prepared using WGS84 datum and Everest projection systems. In order to know the spatial distribution and assessment of richness, DIVA-GIS version 7.3 was used for point to grid analysis using simple-circular neighborhood method (Hijmans *et al*., 2001; Saran *et al.,* 2010). The tool for conversion of the point data into grids which represents the germplasm collection sites was used. A grid of 1^0 x 1^0 cells (111 x 111 kms) to assign point to grid cells to map collected germplasm diversity was used for the country level data analysis (Hijmans *et al.,* 2000).

Results and Discussion

Germplasm Collection

The collected diversity includes *B. juncea* (2,078 accessions), *B. napus* (157 accessions), *B. nigra* (53 accessions), *B. oleracea* (485 accessions), *B. rapa* (2,573 accessions) and *B. tournefortii* (12 accessions) mainly from northern and north-western states of the country. The collection of rapeseed-mustard gained momentum under mission mode sub-project on Sustainable Management of Plant Diversity of the World Bank-funded National Agricultural Technology Project (NATP) during 1999-2005 in collaboration with crop-based institutes of ICAR and State Agricultural Universities. Considering the representation of aforesaid diversity from all surveyed states in India, Uttar Pradesh (838), Uttarakhand (673), Himachal Pradesh (499) and Bihar (328) were most explored states in terms of availability of germplasm accessions.

In oleiferous brassicas, *B. rapa* germplasm was assembled from Assam plains, parts of Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, West Bengal, Himachal Pradesh, Rajasthan, Uttar Pradesh and Uttarakhand; *B. juncea* from parts of Andhra Pradesh, Madhya Pradesh, Uttar Pradesh and Uttarakhand. *B. nigra* from Punjab, Haryana, Andhra Pradesh, Himachal Pradesh and Rajasthan; *B. tournefortii* from sandy tracts of Rajasthan and Haryana. The collected accessions were also pooled according to phyto-geographical/agro-ecological regions in order to know the region that represents maximum collections (Arora, 1991). It was observed that the highest collections were made from Gangetic, north-western plains and western Himalayan regions as compared to other regions of the country (Fig. 1).

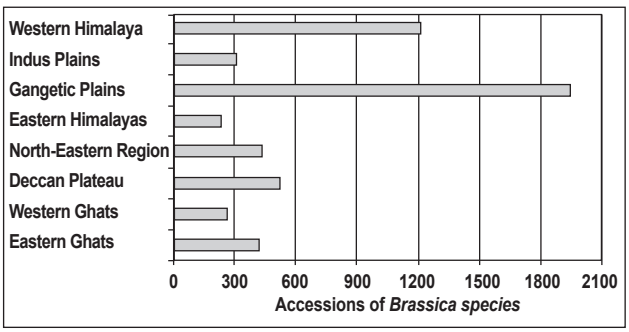

Fig. 1. Rapeseed-mustard germplasm collected from different phyto-geographical/agro-ecological regions of India

Some of the unique collections made during the period include yellow-seeded *toria*, dwarf mustard, dwarf and early *toria*, white flowered yellow *sarson* etc. (Singh and Sharma, 2007). The details of species-wise accessions collected from different agro-ecological regions are given in Table 1.

Mapping of Collected Diversity and Areas Surveyed

To know the eco-geographic diversity distribution of rapeseed-mustard through mapping the sites, passport data of collected germplasm were short listed in order to find out the gaps in exploration and germplasm collection (Fig. 2a). Mapping of diversity collected indicates that some of the diversity rich areas *viz*. parts of north-western plains (foothill regions of Himachal Pradesh, Uttarakhand and Western Uttar Pradesh); eastern and north-eastern parts (Bihar, Jharkhand, Assam and West Bengal) were extensively surveyed for germplasm collection.

Table 1. Species-wise germplasm diversity in rapeseed - mustard collected (Total number of accessions given in parenthesis for each species separately) from different states in India

Species (acc.)	Status of areas explored		
	Extensively explored	Moderately explored	Less explored
B. juncea (2,078)	Andhra Pradesh (170), Bihar (104), Haryana (103), Himachal Pradesh (92), Madhya Pradesh (156), Punjab (81), Uttar Pradesh (439) and Uttarakhand (265)	Assam (56), Chhattisgarh (53), Gujarat (38), Jharkhand (57), Karnataka (84), Maharashtra (41), Mizoram (69), Rajasthan (80) and West Bengal (76)	Arunachal Pradesh (33), Meghalaya (30), Nagaland (26) and Sikkim (22)
B. napus (157)	Himachal Pradesh (72) and Punjab (27)	Jammu & Kashmir (21) Uttar Pradesh (24)	Jharkhand (5) and Uttarakhand (8)
B. nigra (53)	Andhra Pradesh (10) Himachal Pradesh (16) and Rajasthan (8)	Haryana (7) and Tamil Nadu (7)	Jammu & Kashmir (5)
B. oleracea (485)	Jammu & Kashmir (154), Uttar Pradesh (104), Himachal Pradesh (63),	Arunachal Pradesh (37), Assam (19), Chhattisgarh (11), Maharashtra (30), Odisha (11), Punjab (18), Rajasthan (28), and Uttarakhand (22)	Meghalaya (12), West Bengal (6)
B. rapa (2,573)	Assam (135), Bihar (224), Chhattisgarh (188), Haryana (98), Himachal Pradesh (256), Jharkhand (168), Madhya Pradesh (116), Uttar Pradesh (271) Uttarakhand (348) and West Bengal (94)	Arunachal Pradesh (75), Gujarat (15), Mizoram (28), Maharashtra (26), Odisha (61) Punjab (33), Rajasthan (58), and Sikkim (68)	Kerala (4) Manipur (15), Meghalaya (13), and Tripura (4)
B. tournefortii (12)	–	Haryana (7)	Rajasthan (5)

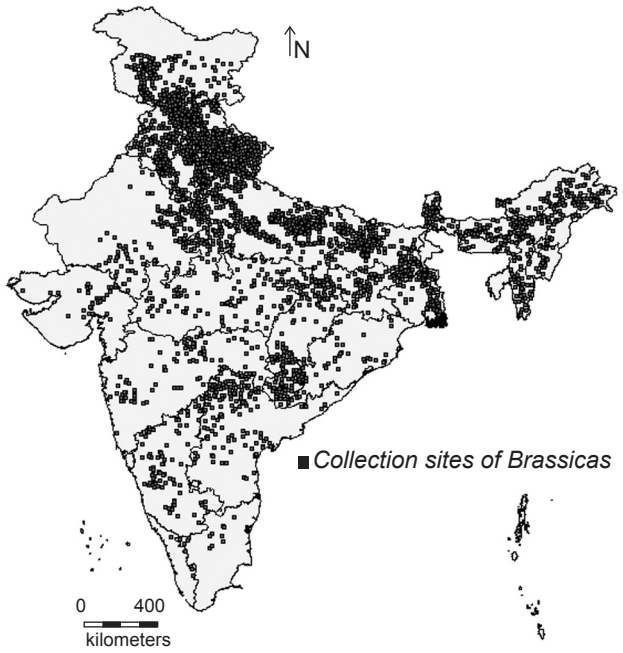

Fig. 2a. Geo-referencing of germplasm collection sites of rapeseed - mustard in India

The grid map shows that the highest numbers of accessions in rapeseed-mustard were collected from Uttar Pradesh (Table 1) covering 51 districts whereas remaining 24 districts may be considered under explored, depending on the availability and richness of crop diversity. Grid maps were generated for identifying the species richness areas or niches where rapeseed-mustard is predominantly grown. In the map, grid nos. 3-3 and 4-5 shows that the maximum number of *Brassica* species are distributed in this area as compared to other regions (Fig. 2b). Grid map also clearly shows that Gangetic plains, Western Himalaya and parts of North-eastern hill region would be target areas for future collections of rapeseed-mustard germplasm.

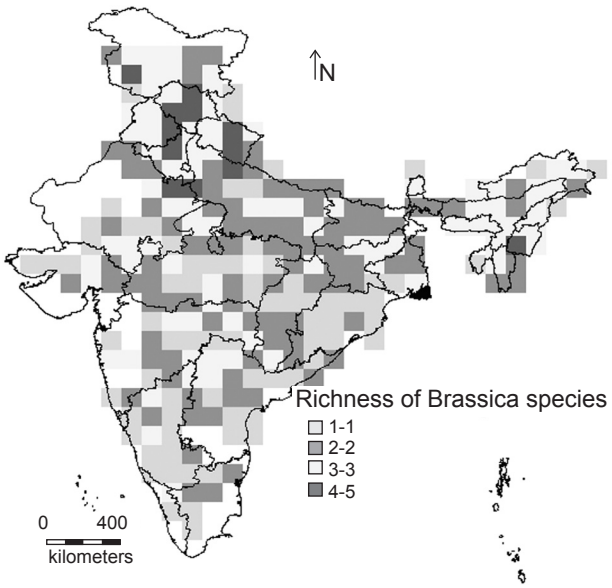

Fig. 2b. Grid map showing species richness in rapeseed-mustard germplasm collected from different regions of India

Table 2. Areas identified for trait-specific germplasm of rapeseed-mustard

Traits	Species	Accessions	State(s)
Dwarf habit	*B. juncea*	IC212077	Uttarakhand
	B. rapa	IC212022, IC267713, IC268307, IC374358, IC395569	Bihar (2), Chhattisgarh, Jharkhand, Uttar Pradesh
Early maturity	*B. rapa*	IC214824, IC267713, IC268307, IC76659, IC261641, IC261646, IC395569, IC212077, IC212022, IC212032	Andhra Pradesh, Bihar, Chhattisgarh, Haryana, Uttar Pradesh (3), Uttarakhand, West Bengal (2)
	B.nigra	IC426329, IC426354	Andhra Pradesh
High oil content	*B. juncea*	IC342780, IC203215	Bihar, Jharkhand
	B. rapa	IC248980, IC248990, IC426303, IC23003, IC23084, IC76659, IC35198, IC19955, IC343121, IC385678	Bihar (2), Chhattisgarh (2), Haryana, Himachal Pradesh, Jharkhand (2), Uttar Pradesh (2)
	B. nigra	IC426303	Andhra Pradesh
Long siliqua	*B. juncea*	IC385781	Jharkhand
	B. rapa	IC268327, IC343122, IC385663, IC385664	Madhya Pradesh, Uttar Pradesh (3)
Multi-locular pods	*B. rapa*	IC267710	Bihar

(Source: NBPGR Annual Reports, 1976 – 2011)

Variability Observed and Trait-specific Germplasm Collected

During germplasm collection, rich variability in different agro-morphological traits of indigenous rapeseed-mustard germplasm was observed in various forms *viz*., plant height, crop duration, branching pattern (basal, medium and top), appressed, semi-appressed, siliqua length, number of seeds/siliqua, seeds size (small and bold), seed colour (brown, dark brown, reddish brown and yellow), etc. Dwarf and early types were collected from north-eastern hill region of India, whereas late, tall and small seeded types from north-western Himalayas. In yellow sarson, germplasm with compact and tall habit, deep green, dissected leaves and waxiness texture at flowering and maturity stages was mainly from eastern Uttar Pradesh, Bihar and West Bengal (Table 2). The collected germplasm was characterized using minimal descriptors and the variability for superior traits in rapeseed-mustard germplasm was observed for plant height, maturity period, high oil content, multilocular pendants and long siliqua (Singh and Sharma, 2007).

On the basis of areas identified (Table 2) for collection of trait-specific germplasm in rapeseed-mustard, area nos. 4-4 and 5-5 in grid map represent regions with high diversity/ more number of promising traits (Fig. 3) while green areas represent regions with low diversity or occurrence of minimum promising traits. Grid map also depicts diversity pattern for collection of early types in few pockets from Chhattisgarh, Haryana, Uttar Pradesh, Uttarakhand and West Bengal; tribal dominated areas in Bihar, Jharkhand and Chhattisgarh for high oil content, and for leafy types from Uttarakhand and Himachal Pradesh. The collected germplasm exhibits good diversity for plant types, seed size, siliqua length and maturity period in *B. juncea* mainly from northern parts of India. There was outsized variation reported in plant habit, flowering period, siliqua size, seed size and number, maturity period and oil content in yellow sarson. Moreover, variability in *B. juncea* and *B. nigra* was also collected from drier tracts of Andhra Pradesh, Haryana and Rajasthan showed variation in seed size and seed colour and siliqua size. *B. tournefortii* was collected with seed colour (brown, dull brown and yellow), compact type with upright branches, leaves and pods, bushy or spreading type with horizontal branches, siliqua and leaves, early to late maturity, dwarf and tall types from parts of Rajasthan and Haryana (Plant Germplasm Reporter 2008; NBPGR Annual Reports, 2008 - 2011).

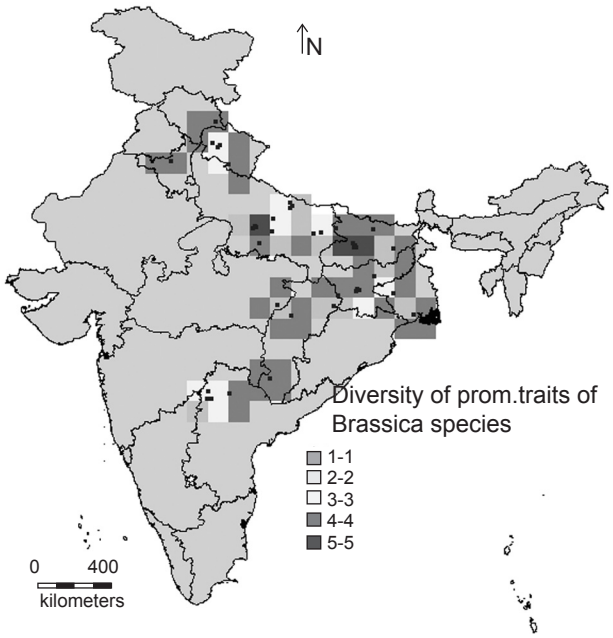

Fig. 3. Grid map showing trait-specific germplasm of rapeseed-mustard from different regions of India

Diminishing Areas under B. nigra Cultivation: Current Observations

The analysis of passport data of rapeseed-mustard indicated the reduction in areas of *Brassica nigra* mainly due to changing patterns of food habits, which was cultivated sporadically as a condiment in Kumaon region of Uttarakhand and peninsular region of Karnataka, Andhra Pradesh and Tamilnadu. At present, this species has completely been replaced by small seeded *B. juncea*. In North and southern districts of Karnataka and North-western districts of Andhra Pradesh, rapeseed-mustard is grown as mixed crop with other cereals, pulses and oilseed crops during *kharif*. Substantial reduction in areas under cultivation of rapeseed (*B. rapa*) and black mustard (*B. nigra*) was observed due to their susceptibility to diseases and pests and low productivity resulting in their replacement by brown mustard (*B. juncea*). In the states of Punjab, Haryana and Rajasthan, *B. tournefortii* was a common weed in drier parts up to 1960, but now it is rare in occurrence. It is distributed in dry tracts of Rajasthan, Haryana and Punjab with high concentration of diversity mainly on parched sand dunes. Disappearance of *B. tournefortii* from growing areas was recorded in last three decades as commercial hybrids have been adopted for large scale production.

Conclusions

Different agro-ecological regions of the country are rich in rapeseed-mustard germplasm diversity. Keeping in view the diversity assessment of rapeseed-mustard *vis-à-vis* germplasm collecting, the following areas have been suggested for future exploration and collection of *Brassica* spp. germplasm:

- Wild and weedy relatives/related species/taxa of rapeseed-mustard are very limited. There is an urgent need for strengthening the germplasm of wild and weedy relatives such as *Crambe, Sinapis* etc. from temperate, alpine region of Jammu & Kashmir, Himachal Pradesh and Uttarakhand.
- Trait- specific *Brassica* germplasm have been identified for future germplasm collection based on their presence in respective priority areas.

1. Yellow sarson (*B. rapa* var. yellow sarson) early types and dwarf types need to be collected from tribal dominated Bastar region of Chhattisgarh.
2. Black mustard (*B. nigra*) germplasm should be collected from Bageshwar and Pithoragarh districts of Uttarakhand.
3. Toria (*B. rapa* var. *toria*) need to be collected from Banka, Bhagalpur and Katihar districts of Bihar.
4. Leafy mustard (*B. juncea* var. *rugosa*) need to be collected from East Siang, West Siang and Kurung Kumey districts of Arunachal Pradesh; Almora and Pithoragarh districts of Uttarakhand.
5. Germplasm of *B. tournefortii* required to be collected from Fatehabad and Sirsa districts of Haryana; Churu, Barmer and Sikar districts of Rajasthan.

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