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Genetic Variability and Diversity Pattern for Agromorphological Traits in Indian Mustard Germplasm

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Genetic diversity studies were carried out on 302 indigenous accessions of Indian mustard [*Brassica juncea* (L.) Czern & Coss] for variability assessment and identification of trait-specific germplasm. The Indian mustard germplasm was evaluated for eight important morpho-agronomic traits. Geographic information system (GIS), principal component and cluster analysis were carried out to analyse major clusters. Four principal components were identified explaining more than 74% of total variation. Three promising germplasm accessions (IC342781, IC570320 and IC426354) identified with maximum number of seeds per siliqua (>18.0 seeds) were collected from districts Patna (Bihar) and Adilabad (Andhra Pradesh). Similarly, three promising accessions (IC426398, IC521376 and IC395557) were identified with high oil content (>40%) from districts Nizamabad (Andhra Pradesh), Godda (Jharkhand) and Gorakhpur (Uttar Pradesh) respectively. The cluster analysis grouped mainly in two major clusters I and II and further sub-divided into a and b sub-groups. In cluster I sub-group b which indicates a close relationship between traits - the days to mean flowering and days to mean maturity while the plant height was grouped individually. In cluster II, number of primary branches and number of seeds/siliqua showed close relationship with oil content as compared to other traits. GIS based grid maps using Shannon-Weaver diversity index (0-4.0) were generated for showing high variability areas (light red/dark red grids) in different agro-ecological regions of India. The results indicated that Indian mustard germplasm collected by NBPGR from different parts of India has broad genetic base. Thus, promising genotypes identified for various economically important morpho-agronomic traits can be utilized to develop improved varieties of Indian mustard.

Key Words: Genetic diversity, GIS tools, Indian mustard, Trait-specific germplasm, Variability assessment

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss] commonly known as raya, rai or laha, is the second most important oilseed crop of India. It is cultivated over seven million hectares, primarily in the north-western states of India, either as a sole or as inter-crop under irrigated or rain-fed conditions (Mahto and Haider, 2012). In India, a great diversity exists in *B. juncea* for plant type, seed size, siliqua length, oil content and maturity period (Rana and Singh, 1992; Misra, 2012; Semwal *et al*., 2013). The crop is moderately tolerant to acidic soils, thrives well under cold and drought conditions (Singh, 1997; Duhoon and Koppar, 1998; Singh and Sharma, 2007). Indian mustard is a potential oilseed crop to meet the challenges that may arise due to climate change and can play an important role to enhance the production and productivity (Kumar *et al*., 2004; Singh and Sharma, 2007). The low productivity can considerably be increased through the use of diverse donor genotypes for various qualitative and quantitative traits.

So far studies pertaining to geo-referencing and diversity distribution pattern have been conducted in only a few crops namely jatropha (Sunil *et al*., 2009), black gram (Abraham *et al*., 2010) and rapeseed-mustard (Semwal *et al*., 2013). Attempt has been made to analyse variability in different germplasm accessions of *B. juncea* collected from diverse agro-ecological regions (western Himalaya, north-western plains, gangetic and eastern plains, central India, north-eastern hill region and peninsular region) of India. Promising/trait-specific germplasm have been identified and relationship among yield related traits has been studied. Geo-referenced maps as well as grid based diversity indices maps using GIS tools have been developed to represent areas of high variability.

Materials and Methods

A total of 302 accessions of Indian mustard germplasm were collected from over 261 collection sites in 83 districts of 19 states of India. Geo-coordinates of the

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collection sites were used for spatial distribution pattern of Indian mustard in the present study (Fig. 1). These accessions were grown at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi along with five check varieties *viz*. Laxmi, Pusa Jai Kisan, Rajat, RH-30 and Varuna during two crop seasons (2009-10 and 2010-11) in a plot of two rows of 3 m row length in Augmented Block Design (ABD), maintaining 30 and 10 to 15 cm row to row and plant to plant spacing respectively to record observations. Five random plants of each accession were selected at appropriate growth stages and observations were recorded on eight important morpho-agronomic traits (plant height, siliqua length, number of seeds per siliqua, number of siliquae on main fruiting branch, days to mean maturity, days to mean flowering and oil content). Near infra-red (NIR) method was used to analyse the oil content (%).

Mean and coefficient of variation (CV) were computed using standard statistical methods (Gomez and Gomez, 1984). The principal component analysis (PCA) was done on the correlation matrix of transformed data (Rao, 1964). Studies on cluster analysis were done on the basis of correlation coefficient and similarity matrices following Ward's methods (Ward, 1963; Kaufman and Rousseeuw, 1990). In order to know the spatial distribution and diversity assessment, DIVA-GIS tool was used for point to grid analysis (Hijmans *et al*., 2000). DIVA-GIS was run for each trait separately to assess the geographical distribution of diversity in different states of the country. Diversity indices values were mapped using Shannon-Weaver method (Shannon and Weaver, 1963).

Results and Discussion

Characterization and Evaluation of Indian Mustard

302 accessions of Indian mustard showed wide genetic variability in collected germplasm. Maximum number of germplasm accessions of Indian mustard used for evaluation were from Uttar Pradesh (97) followed by Andhra Pradesh (62), Himachal Pradesh (38), Jharkhand (42) and Bihar (31).

Quantitative characters of Indian mustard germplasm showed wide variation for majority of the morpho-agronomic traits (Table 1). Data indicated maximum variation for number of primary branches followed by number of seeds per siliqua and oil content (%). Three accessions (IC342781, IC570320 and IC426354) were found to have more than 19 seeds/siliqua. There was a good variation for oil content and yield related characters such as number of seeds per siliqua, siliqua length and days to mean maturity. Five promising accessions (IC426398, IC521376, IC395557, IC342772 and IC312500) had more than 40% oil content. High variation for number of siliquae on main fruiting branch indicated the potential of the germplasm accessions for the development of high yielding varieties to fulfil the demand of oil in the country.

Promising Donor Genotypes Identified

Based on characterization and evaluation of Indian mustard, promising accessions for various agro-morphological traits have been identified. The details of important traits and promising accessions have been presented in Table 2. Maximum promising accessions

Table 1. Statistical values of important quantitative traits in Indian mustard (*B. juncea*) germplasm

Traits	Min.	Max.	Mean	CV (%) Phenotypic	Mean values of check varieties				
					Pusa Jai Kisan (1)	Rajat (2)	RH-30 (3)	Varuna (4)	Laxmi (5)
Plant height (cm)	116.7	275.4	202.1	13.7	204.3	212.1	185.7	212.6	218.4
No. of primary branches	4.4	16.8	7.9	24.1	7.8	7.2	6.9	7.87	8.1
No. of siliquae on main fruiting branch	14.7	71.2	48.4	20.6	49.3	48.9	49.2	45.7	53.5
Siliqua length (cm)	1.5	5.3	3.8	15.6	4.1	3.8	3.9	3.7	3.7
No. of seeds per siliqua	6.0	25.1	13.5	15.0	13.5	13.1	13.2	12.8	12.4
Days to mean flowering	35.0	110.0	59.0	23.2	53.0	50.0	50.0	48.0	50.0
Days to mean maturity	139.0	168.0	155.0	3.1	155.0	154.0	152.0	154.0	155.0
Oil content (%)	24.1	41.0	33.2	11.8	36.8	34.2	35.8	35.7	35.6

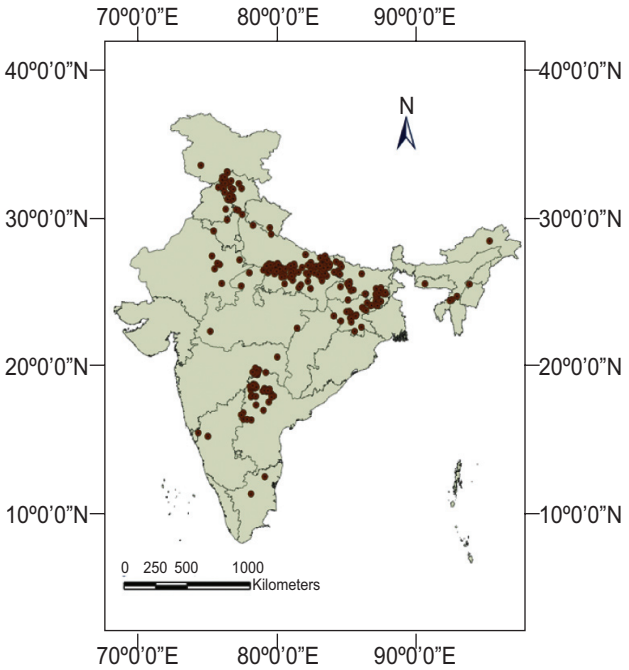

Fig. 1. Geographic distribution of collection sites of Indian mustard (*B. juncea*) germplasm

related to eight important morpho-agronomic traits of Indian mustard germplasm were identified from Uttar Pradesh, Jharkhand, Bihar and Himachal Pradesh. Trait like plant height (dwarf nature) is desirable because plants scape lodge at maturity. Promising accessions for dwarf types were identified from Andhra Pradesh and Uttar Pradesh. It is concluded that three regions viz. western Himalaya, gangetic plains and eastern India are complimentary sites for collection of promising germplasm of Indian mustard. More number of primary branches (> 15) per plant, higher number of siliquae on main fruiting branch (> 50), long siliqua length (> 5.0cm) and high number of seeds per siliqua (> 18.0) are important yield contributing traits. Promising/trait-specific germplasm identified for various economically useful traits, could be used as donor genotypes in the Indian mustard improvement programme.

Principal Component and Cluster Analysis

The identification of a principal component was based on the correlation coefficient between different agronomic characters, their Eigen values of the principal components. Interrelationships among traits have been presented in Figure 2 and Table 3. Principal component analysis revealed that four principal components explained more than 74% of total morphological variation (Fig. 2). Out of the four indigenous collections shown in Fig. 2, only IC310757 was observed as promising accession collected from Morena (Madhya Pradesh). Correlation coefficients between oil content, siliqua length, number of seeds per siliqua and other morphological traits are useful in selection of desirable plant type in designing crop improvement programme. The plant height was positively and significantly correlated (r = 0.51) with days to mean maturity while days to mean flowering was also positively and significantly correlated (r = 0.70) with days to mean maturity.

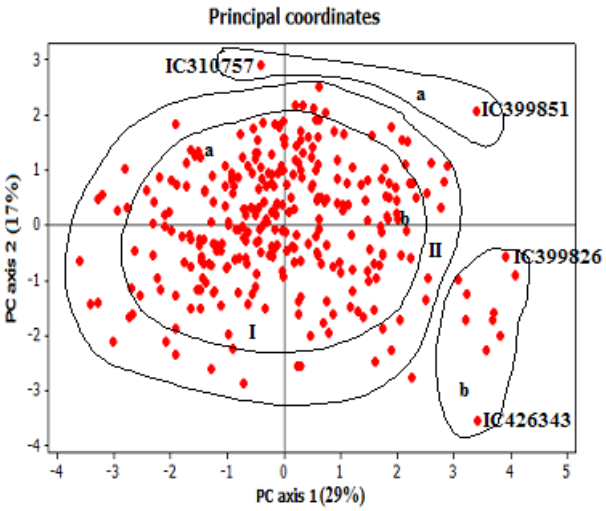

Fig. 2. Principal coordinates highlighting grouping of 302 accessions of Indian mustard

Based on correlation coefficient and similarity matrices, dendrograms, Principal Coordinates were depicted in Figure 2. These values indicated a very good fit of the data to the clustering pattern. The cluster analysis grouped mainly in two major clusters I and II and further sub-divided into a and b sub-groups. In cluster II sub-group b which indicates a close relationship between traits - days to mean flowering and days to mean maturity while the plant height was grouped individually. In cluster I, number of primary branches and number of seeds/siliqua showed close relationship with oil content as compared to other traits.

The germplasm evaluated showed a large amount of divergence for characters considering the absolute range. Diversity analysis among accessions of *B. juncea* provided information on distinctness, similarities and overlap based on different morpho-agronomic traits, which corresponds firmly to their genetic status and contribution to the phenotype and environment.

Table 2. Promising donor genotypes identified for different traits in Indian mustard (*B. juncea*) germplasm

S.No.	Characters/Traits	Promising accessions (values)	State (Source of collection)
1	Dwarf plant height (cm) (< 134 cm)	IC426400 (116.7)	Andhra Pradesh
		IC385680 (121.0)	Uttar Pradesh
		IC395583 (130.4)	Uttar Pradesh
		IC426381 (131.0)	Andhra Pradesh
		IC570310 (133.4)	Andhra Pradesh
2	Number of primary branches (> 15)	IC520756 (16.8)	Jharkhand
		IC426343 (16.7)	Andhra Pradesh
		IC520752 (15.7)	Jharkhand
		IC447547 (15.2)	Himachal Pradesh
3	Number of siliquae on main fruiting branch (> 65)	IC248997 (71.2)	Bihar
		IC397901 (70.2)	Himachal Pradesh
		IC426299 (69.8)	Andhra Pradesh
		IC312514 (68.2)	Uttar Pradesh
		IC520754 (67.0)	Jharkhand
4	Long siliqua length (cm) (> 5.0cm)	IC310757 (5.4)	Madhya Pradesh
		IC355371 (5.3)	Uttar Pradesh
		IC520769 (5.2)	Jharkhand
		IC538744 (5.2)	Himachal Pradesh
		IC264133 (5.1)	Rajasthan
5	High number of seeds per siliqua (> 18.0)	IC342781 (25.1)	Bihar
		IC570320 (19.6)	Andhra Pradesh
		IC426354 (19.4)	Andhra Pradesh
		IC385700 (18.4)	Uttar Pradesh
		IC426319 (18.0)	Andhra Pradesh
6	Early mean flowering (< 40 days)	IC331819 (35)	Chhattisgarh
		IC385782 (37)	Jharkhand
		IC398759 (38)	Bihar
		IC398763 (39)	Bihar
		IC426383 (39)	Andhra Pradesh
7	Early mean maturity (< 142 days)	IC406349 (139)	Jharkhand
		IC426376 (139)	Andhra Pradesh
		IC426354 (140)	Andhra Pradesh
		IC426322 (141)	Andhra Pradesh
		IC426372 (141)	Andhra Pradesh
8	High oil content (%) (> 40%)	IC426398 (41.0)	Andhra Pradesh
		IC521376 (40.7)	Jharkhand
		IC395557 (40.5)	Uttar Pradesh
		IC342772 (40.3)	Jharkhand
		IC312500 (40.0)	Uttar Pradesh

Table 3. Analysis of phenotypic correlation coefficient in different morpho-agronomic traits in Indian mustard (*B. juncea*)

PLH	NPB	SFB	SLL		NSS	DMF	DMM	OIC
PLH	1.000							
NPB	0.290	1.000						
SFB	0.149	-0.040	1.000					
SLL	0.186	-0.158	0.110	1.000				
NSS	-0.061	0.112	-0.089	0.190	1.000			
DMF	0.412	0.281	-0.144	0.002	-0.138	1.000		
DMM	0.516*	0.129	-0.056	0.230	-0.211	0.702*	1.000	
OIC	0.071	-0.024	-0.171	-0.038	0.034	0.087	0.134	1.000

PLH= plant height (cm), **NPB**=number of primary branches, **OIC**=oil content (%), **NSFB**=number of siliquae on main fruiting branch, **SLL**=siliqua length (cm), **NSS**=number of seeds/siliqua, **DMF**=days to mean flowering, **DMM**=days to mean maturity, * significant values.

Diversity Analysis Studies of Indian Mustard using GIS Tools

GIS based grid maps were generated using Shannon-Weaver diversity index for plant height (cm), number of primary branches, oil content (%) and number of seeds per siliqua under different agro-ecological regions of the India. In the map, red/dark red colour of the grid indicated high variability observed in *B. juncea* germplasm accessions for different morpho-agronomic traits (Fig. 3). Geo-referenced grid maps were used to identify oil content and the diversity pattern (0.5 - 3.0), in different states of India (Fig. 3).

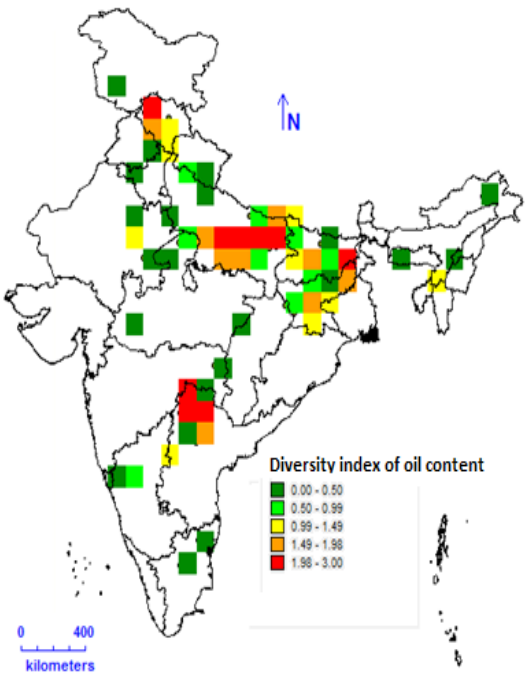

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Fig. 3. High diversity areas (red grids) for important morpho-agronomic traits of Indian mustard *(B. juncea)*

Variability studies play a very important role in crop improvement programme. In view of climate change resulting in the loss of biodiversity, there is a need to analyse the existing collections, identifying promising accessions and collect as much variability as possible before it is eroded (Upadhyaya *et al*., 2012). National Bureau of Plant Genetic Resources in collaboration with crop-based institutes of Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) has collected *B. juncea* germplasm (302 accessions) mainly from northern, north-western and peninsular states of India and evaluated during crop seasons of 2009-10 and 2010-11. Of these, 40 accessions were identified as promising genotypes for different economic traits.

The present study indicated wide range of variability for plant height, number of primary branches per plant, oil content (%) and number of seeds per siliqua. There was a good variation for oil content and yield contributing traits such as number of seeds per siliqua and siliqua length. Jindal and Labana (1985) presented information on the genetic components of variance of oil content and protein and they found high heritability (narrow sense) for oil content (58.15%) in mustard. Highest genotypic and phenotypic coefficient of variation for seed yield followed by number of siliqua per plant was observed by (Chowdhary and Goswami 1991). Similar observations reported by Ghosh *et al*. (2001); Kumar *et al.* (1988); Singh *et al*. (2003); Misra *et al*. (2007, 2012); Singh *et al.* (2014) and Verma *et al.* (2001) that all four yield components *viz.,* primary branches per plant, secondary branches per plant, siliquae per plant and seeds per siliqua exhibited significant positive association with seed yield. Genetic variability for plant height, siliqua length, 1000-seed weight, oil content and seed yield

per plant were observed by Pant and Singh (2001). Variability, heritability and genetic advance for forty Indian mustard cultivars and the varietal differences were highly significant for plant height, days to mean flowering, siliquae per plant, seeds per siliqua, days to maturity, 1000 - seed weight and seed yield per plot (Poonam and Singh, 2004).

Conclusions

Indian mustard is the second most important oilseed crop of India. There is a limited genetic variability available with the plant breeder for mustard improvement programme. Efforts were made to strengthen mustard germplasm from different agro-ecological regions of the country. Germplasm was evaluated for important agro-morphological traits for utilization in mustard improvement programme. Some of the promising accessions were identified as useful donors for early flowering (< 40 days) from districts Sarguja (Chhattisgarh) and Godda (Jharkhand) and high number of seeds per siliqua (>18 seeds)) from districts Patna (Bihar) and Adilabad (Andhra Pradesh) as compared to best checks. However, IC426398, IC521376 and IC395557 have been identified as donor for high oil content (> 40%) mainly from districts Nizamabad (Andhra Pradesh), Godda (Jharkhand) and Gorakhpur (Uttar Pradesh) respectively. The results concluded that Indian mustard (*B. juncea*) has wide-ranging genetic base in India. The Shannon-Weaver diversity index based on analysis of geographical distribution of morpho-agronomic traits, revealed four high diversity regions viz., Western Himalaya (Himachal Pradesh), gangetic plains (Uttar Pradesh) and eastern India (Bihar and Jharkhand). These promising genotype dwarf, early maturing, high yielding and high oil content can be used to enhance productivity of Indian mustard.

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