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AGRO-MORPHOLOGICAL STUDIES REVEALED BROAD GENETIC STRUCTURE OF SPATIALLY DISTRIBUTED *BRASSICA RAPA* POPULATIONS

SOHAIL AHMAD JAN[1, 3*], ZABTA KHAN SHINWARI[1, 2*], MALIK ASHIQ RABBANI[3], HARIS KHURSHID[1, 5] AND NAZIR AHMAD[4]

[1]*Department of Biotechnology, Quaid-i- Azam University, Islamabad, Pakistan*
[2]*Qarshi University, Lahore, Pakistan*
[3]*Plant Genetic Resources Institute (PGRI), National Agricultural Research Centre (NARC), Islamabad, Pakistan*
[4]*PARC Institute of Advanced studies in Agriculture (PIASA), NARC, Islamabad, Pakistan*
[5]*Oilseeds Research Program, NARC, Islamabad, Pakistan*
[*]*Corresponding author's email: sjan.parc@gmail.com; shinwari2008@gmail.com*

Abstract

Brassica rapa sub-species presents rich diversity all over the world. The three different *B. rapa* sub-species (brown sarson, yellow sarson and toria) have distinct qualitative and quantitative characters. In present study we have described some major characteristics of three important sub-species of *B. rapa* (brown sarson, yellow sarson and toria). The brown sarson, yellow sarson and toria sub-species have rich diversity in leaf shapes (vegetable and non-vegetable types), early flowering, number of pods, pod shattering, yield per plant, etc. The brown sarson showed excellent yield and other morphological performances as compared to other two sub-species. The development of early flowering in brown sarson/toria and high yielding brown/yellow sarson offers unique opportunities for the improvement of the species.

Key words: Brown sarson, Genetic variability, Toria, Vegetable type, Yellow sarson.

Introduction

Brassica rapa is one of the most important vegetable oil, bioenergy and fodder crop (Tahir *et al.,* 2012). The haploid genome of *B. rapa* containing 10 haploid number of chromosome but with passage of time increased variation within species and sub-species was observed (Qian *et al.,* 2006; Zhao *et al.,* 2009). The three new ecotypes namely Chinese turnip rape (ssp. *rapa*), Pak choi (ssp. *chinensis*) and Chinese cabbage (ssp. *pekinensis*) are commonly grown in China for multiple purposes (Zhao *et al.,* 2009). The Sarson sub-species *trilocularis* and *oleifera* were advanced in India and Europe respectively (Snowdon, 2007; Zhao *et al.,* 2009).

The three important sub-species of *B. rapa* (brown sarson, yellow sarson and toria) are commonly grown in India especially in winter season. Theses sub-species are grown in different environmental conditions in both dry and irrigated soils as a single crop or intercrop system (Chauhan *et al.,* 2011). The other important type of brown sarson namely lotni gives better response in Kashmir and Himachal Pradesh regions. Among these three subspecies the two toria populations (PT-141, PT-145) gives very early maturation response (<60 days). These toria genotypes provide a best opportunity to achieve maximum yield in short time (Bhajan *et al.,* 2013). Some new dark types and self incompatibility group has been characterized from Pakistan that grow in winter season. This group is totally different from the Asian and European types (Zhao *et al.,* 2005). Some leafy vegetable sub-species of *B. rapa* are also grown in China and Japan. The most common among these is Chinese Pak choi (ssp. *chinensis*) having green-white midrib is an early ancient form Chinese cabbage (ssp. *pekinensis*) having broad leaves and found in different head structure, is native to China (Li, 1981). The yellow seeded canola has more fatty acid, protein and fiber quantity than other types. Naturally the yellow seeds are present in *B. rapa*, *B. juncea* and *B. carinata* species but absent in *B. napus* naturally. Several new breeding methods have been used to develop new yellow seeded *B. napus* (Rahman & McVetty, 2011).

Morpho-molecular based evaluation of crop species helps in production of new crop cultivars/varieties. These methods classify accessions into different groups on the basis of specific characters they possess (Hartings *et al.,* 2008; Zhang *et al.,* 2008). *B. rapa* have three different sub-species those show considerable variations from each other for both qualitative and quantitative characters. In order to screen best genotypes among these, it is important to screen unique genotypes for crop improvement and possibly to develop new high yielding varieties. However, there is insufficient data available to differentiate these three sub-species for both qualitative and quantitative agro-morphological characters. Therefore in present study we have described some of the important features of these three important sub-species (brown sarson, yellow sarson and toria) of *B. rapa.*

Materials and Methods

Agro-morphological study of three important *B. rapa* sub-species brown sarson, yellow sarson and toria: Two years experiment was conducted in Plant Genetic Resources Institute (PGRI), National Agricultural Research Centre (NARC), Islamabad, Pakistan. Sowing was done in mid of October, 2014-16 by using augmented design. The row to row distance of 60 cm and path distance of 30 cm was maintained. The plot size was 2 rows of 5 m length for each genotype. Ten genotypes from all three sub-species of *B. rapa* were selected (Table 1). Data from five random selected plants was taken and its various agro-morphological parameters were studied such as days to flower initiation (DFI), days to 50% flower initiation (50% DFI), days to flower completion (DFC), leaf length (LL), leaf width (LW), pod shattering (after 28 days of pod maturity), plant height (PH), main raceme length (MRL), pods per main raceme (P/MR), stem thickness (ST), pod length (PL), Pod width (PW), seeds per pod (S/P), seed yield per plant (SY/P) and thousand seeds weight (1000-SW).

Table 1. List of brown sarson, yellow sarson and toria *B. rapa* genotypes.

Assessions	*B. rapa* sub-species	Origin	Source
Br-502	Brown sarson	Pakistan	NARC, Islamabad, Pakistan
Br-505	Brown sarson	Pakistan	NARC, Islamabad, Pakistan
Br-522	Brown sarson	Pakistan	NARC, Islamabad, Pakistan
Br-529	Yellow sarson	Netherlands	NARC, Islamabad, Pakistan
Br-531	Yellow sarson	Netherlands	NARC, Islamabad, Pakistan
Br-563	Yellow sarson	Germany	NARC, Islamabad, Pakistan
Br-537	Toria	Netherlands	NARC, Islamabad, Pakistan
Br-516	Toria	Pakistan	NARC, Islamabad, Pakistan
Br-517	Toria	Pakistan	NARC, Islamabad, Pakistan

Table 2. Characteristic features of three sub-species of *Brassica rapa*.

Trait	Yellow Sarson	Brown Sarson	Toria
Growth	Yellow sarson has both extensive and lateral spread. The height of plant varies from 100 to 160cm or more. The growth vigour is highly dependent on seasonal variations.	Brown sarson has long root, with a limited lateral spread, enabling its successful cultivation under drier conditions. The height of plant varies from 100-210cm. The growth vigour is highly dependent on seasonal variations.	Toria is more or less a surface-feeder. The height of plant varies from 150cm (in some genotypes of toria). The growth vigour is highly dependent on seasonal variations.
Leaf lamina	Lamina prominent upto the very base of the leaf, particularly in lower leaves.	Mostly Lamina absent or partially absent in basal half of leaves.	Lamina absent in basal half of leaves
Leaf color	Majority of genotypes shows Dark green color leaves.	Both light and dark green leaves are common.	Toria genotypes shows green to dark green color leaves.
Branching	Branches erect, ascending, straggling plants absent.	Branches are erect to spreading, straggling plants occasionally present.	In toria, the branches are erect most of the time somewhat dichotomous.
Corolla (Inflorescence is coroymbose raceme)	Four petals are widespread/ spaced apart from each other. Petals narrow with spaces between adjacent ones. Combined lengths of claw and blade is 10 mm approx.	Having broad petals generally over-lapping or may be placed apart, depending upon the variety. Average length of claw plus blade is ~11mm.	Like brown sarson, in case of 'toria' the four petals may be overlapping or spaced apart depending upon the variety. The petals generally shed on the third or fourth day of flowering.
Anthers	All the six anthers are introrse both in the bud and open flower.	In some forms anthers are introrse while in the bud but those of four median stamens become extrorse once the flower opens.	Anthers introrse at bud stage but extrorse at opening of flower.
Ovary (Hypogynous syncarpous)	In yellow sarson, the ovary has three or four carpel.	In brown sarson, the ovary having two carpels.	In toria, the ovary having two carpels.
Pollination	Generally the flowers exhibit self compatibility and are self fertile. Highly self pollinated.	Flowers are mostly self-incompatible and self infertile. Hence cross pollination is widespread.	Highly self-incompatible and self sterile flowers. Therefore highly cross pollinated.
Pods	Very broad and short. Yellow sarson has pointing down pods.	Unlike yellow sarson its pods are long but narrow, sometimes torulose. Mostly brown sarson possess pointing down pods.	Thin, long and smaller pods than brown and yellow sarson. Toria possess appressed to pointing down pods.
Seeds	Seeds non-mucilagnous; light yellow, dark yellow and yellow brown. Oval to round in shape, larger than sarson.	Seeds mucilaginous; Dark-brown seeds dominate; light brown, light-reddish, brown red, brown or reddish-brown. Bold, small-large-sized.	Seeds non-mucilaginous; Light-brown seeds dominate. Small sizes is prevalent however slightly larger than *B. juncea*.
Maturity	Normally 1-2 weeks or more later in flowering and maturity than brown-sarson. The maturity response varies with genotype.	At least 1-2 weeks earlier in flowering/maturity as compared to yellow sarson. Flowers and matures at least a fortnight later than toria if sown at same time. Also depend seasonal variations, field condition and type of genotype used.	Flowers and matures at least a fortnight earlier than brown sarson when sown at the same time. Matures within 120-150 days. Also depend on type of genotype and seasonal variations.
Growing period	Sown in Oct/Nov; harvested in March/April as Rabi crop. Also depend on geographic weather condition.	Sown in Oct/Nov. and harvested in April/May as Rabi crop. Also depend on geographic weather condition.	Late Kharif season crop, sown in September/October; harvested in April/May. Also depend on geographic weather condition.
Cultivation & its uses	Grown alone and mainly grown for oil purpose. The plants are not suitable for vegetable purposes.	May be grown mixed mostly as rain-fed. It is used as oil seed, fodder, medicinal, salad, vegetable oil and for cooking purposes.	Grown alone and irrigated for oil purpose; plants are not good for vegetable purpose; oil is used for cooking purpose.

Fig. 1. Distinctive structure of *B. rapa* sub-species (brown sarson, yellow sarson and toria) (a) Typical leaves of *B. rapa* (b) Brown sarson broad leaves vegetable type (c, d) Bunchy types, Chinese vegetable cabbage brown sarson (e) Typical yellow sarson leaves (f) Typical toria leaves (g) Variable pod structure among three types of sarson; The left side, yellow sarson have broad but small sized pods as compared to other types (h) Typical seed color of brown and yellow sarson (i) Light brown seed color of toria

Table 3. Morphological study of three sub-species of *B. rapa*.

Assessions	DFI (days)	DF50% (days)	DFC (days)	LL (cm)	LW (cm)	Pod shattering (%)	PH (cm)	MRL (cm)	P/MR (No.)	ST (mm)	PL (cm)	PW (mm)	S/P (No.)	SY/P (g)	1000SW (g)
Br-502	78	82	89	31.6	13.4	3.12	173	39.2	29.8	17.3	5.5	3.4	10.7	36.8	2.8
Br-505	37	44	47	17.8	8.4	11.35	146	35	21.2	17.4	5	4	17.5	19.7	3.3
Br-522	38	58	61	25	9	0	201.6	61.2	40	25	4.6	43	9.3	24	3.3
Br-529	58	64	73	12.2	7.8	5	139	47.6	18	18.2	5.9	5.3	8.6	26.4	3.9
Br-531	73	87	89	19	8.2	0	161.4	49.6	23	28.7	6.7	8.5	14.2	20.3	3.5
Br-563	111	113	116	29.6	12.5	0	170	40	30.8	15	4.3	3.3	13.1	25.5	3.8
Br-537	37	50	52	14.4	8.4	0	171.2	48.6	26	13.7	4.8	3.5	15	16	3.9
Br-516	37	45	47	21.6	11.5	11	187.4	59.6	17.8	19.2	5.2	4.4	18.6	18	3.9
Br-517	47	52	58	23.4	12.3	11.25	169.2	48.8	20	18.9	4.6	3.9	11.9	10.7	3.9

Results and Discussion

In present study the Intra-specific morphological based differences were noted among three important sub-species of *B. rapa*. All the genotypes showed maximum variations from each other (Fig. 1 and Table 2). The brown sarson (Br-505) Br-537 (toria) and toria (Br-516) genotypes showed very early flowering (37 days). These genotypes also showed very early days to 50% flowering and days to flower completion. While the yellow genotypes shows very late flowering as compared to other two types (Table 3). The maximum leaf length and leaf width (31.6 and 13.4 cm) were observed in brown sarson genotype (Br-502) followed by yellow sarson genotype (Br-563). The brown and toria genotypes showed maximum pod shattering as compared to yellow sarson. The maximum pod shattering of 11.35, 11 and 11.25% was observed in genotypes Br-505, Br-516 and Br-517 respectively (Table 3). The maximum plant height (201.5cm), main raceme length (61.2cm) and number of pods per main raceme (40) were noted in genotype Br-522. The brown sarson showed maximum plant height, main raceme length, pods per main raceme than other two sub-species. Similarly the yellow sarson genotype Br-531 had very thick stem (28.7mm), pod length (6.7cm) and pod width (8.5mm) than brown sarson and toria. The highest number of seeds per pod (18.6) was observed in toria genotype (Br-516) followed by 17.5 in brown accession (Br-505). The maximum seed yield per plant 36.8 and 26.4 g was recorded from brown and yellow sarson genotypes (Br-502 and Br-529). In present experiment the brown and yellow sarson gave better yield as compared to toria type instead of its maximum 1000 seed weight (3.9 gm) (Table 3). Padilla *et al.* (2005) found morphological based variation in *B. rapa* ssp. *rapa* L.

includes turnip greens and turnip tops. 134 different landraces from northwestern Spain were evaluated for different agro-morphological traits. All the genotypes were classified in five major groups. Considerable variations for both qualitative and quantitative characters were observed. Bhajan *et al.* (2013) reported that the two toria genotypes PT-141 and PT-145 have very early maturity period (<60 days) than other types. The early maturity of these crop species is associated with increased photoperiod intensity (Singh & Sharma, 1996). Sinhamahapatra *et al.* (2010) noted that plant with increased number of siliquae/plant gives maximum yield. Genetic diversity study is useful to study agro-morphological, biochemical and molecular processes of important crop species/sub-species (Jan *et al* ., 2017[a,b]; Jan *et al.*, 2016[a,b,c] ; Hussain *et al.*, 2016; Rehman *et al.*, 2015; Shinwari *et al.*, 2014; Iqbal *et al.*, 2014; Shinwari *et al.*, 2013).

Conclusion

Agro-morphological variation in *B. rapa* at sub-species level is mainly the result of widespread evolution encompassing diverse eco-geography. In the present study we observed significant phenotypic variations of quantitative agronomic traits at sub-species level taxon. This genetic divergence viz a viz economically important characters e.g. days to flowering, number of seed per pods, pod length/width, seed yield/plant, 1000-seed weight and pod shattering resistance etc. can be utilized in breeding programs for further crop improvement. However, we suggest further applications of more advanced investigative tools like biochemical assays and molecular markers to elucidate the molecular basis of genetic divergence within these sub-species of *B. rapa*.

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