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Assessment of seed quality and oil content in different branches of Indian mustard (*Brassica juncea*) cultivars at different storage intervals

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India accounts for 12-15 % of global oilseeds area, 6-7 % of vegetable oils production and 9-10 % of the total edible oils consumption (FAO 2011). Among different oilseeds; soybean, groundnut and rapeseed-mustard account for about 80 % of area and 87 % of production in India. Rapeseed-mustard occupied 6.51 million ha area contributing to 7.67 million tonnes with average productivity of 1 179 kg/ha, next only to groundnut in our country (DAC 2011) of which more than 80% was the contribution of Indian mustard {*Brassica juncea* (L.) Czern}. Keigley and Mullen (1986) suggested that seed maturity is an important factor explaining seed position effects but little is known about the relations between the duration of pod growth, development, maturation and ageing and physiological seed quality attributes for individual seeds. No conclusive studies have been made till date in Indian mustard regarding the seed quality of the seeds harvested from different branches vis-à-vis their oil content as well as effect of storage on their quality and oil content. Changes occurring in seed during aging are significant as far as seed quality and longevity are concerned and are a consequence of the effects of different storage conditions. The seeds rich in lipids have limited longevity due to their specific chemical composition. The rate at which the seed aging takes place depends on the ability of seed to resist degradation by protection mechanisms which are specific for each plant species. Mustard being an oilseed crop and hygroscopic, it absorb moisture from surrounding storage environment and lose viability rapidly. Storage of seeds with high oil content demands special attention, otherwise processes may occur that lead to loss of germinability (Baleševiæ-Tubiæ *et al.* 2007a). It is necessary to use impervious containers to slow down the mustard seed viability deterioration under storage (Bhadauria *et al.* 2011). The ability of oilseeds to retain their viability over extended periods under ambient conditions has also not been widely investigated.

Since, grain retention for 1-2 years and use of the stored produce as a seed is a common practice among mustard growing farmers in India. So, we hypothesize that both the variation in duration of individual siliqua growth, development, maturation and ageing until harvest because of siliquae on branch position on the plant significantly contribute to the total variation in physical and physiological quality attributes of seeds harvested from mustard crop and oil content may also change in storage. Therefore, main aims planned for this study were (1) to examine the seeds for quality and oil content, (2) to study that to what extent the storage affects these parameters in seeds harvested from different branches of 20 cultivars of mustard, and (3) to establish the correlation, if any, among these attributes.

Different species of rapeseed-mustard are grown in different parts of India. A large number of cultivars have been released in the country for area and trait specific suitability. Twenty cultivars (Table 1) of Indian mustard were grown at the experimental farm of the Indian Agricultural Research Institute, New Delhi during *rabi* 2006-07.

The primary branches, secondary branches and main shoots of 50 plants were separately harvested at maturity, ie when the siliquae turns yellow and threshed. Cleaned seed of 20 cultivars from different branches was bulked separately and taken for different tests under the present study. The seeds were tested for various quality parameters, viz. test weight, germination percentage and oil content. The vigour indices were calculated, besides the seed coat proportion and hydration index were also estimated. The remaining seeds

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Table 1 Details of the cultivars used in the study

Cultivars	Year	Pedigree information	Developing institute
Pusa Jai Kisan (BIO 902)	1994	Somaclone of Varuna	IARI, New Delhi
CS 52	1998	Selection from DIRA 343	CSSRI, Karnal
CS 54	2006	B 380 × NDR 8603	CSSRI, Karnal
Durgamani	1974	Selection from Sriganganagar	Govt. of Rajasthan
Geeta (RB 24)	2003	Spontaneous mutant of cultivar RH 30	HAU, Regional Station, Bawal (Haryana)
Laxmi (RH 8812)	1997	PR-15 × RH 30A	CCS HAU, Hisar
Pusa Mustard 25 (NPJ 112)	2010	SEJ-8 × Pusa Jagannath	IARI, New Delhi
Pusa Mustard 26 (NPJ 113)	2010	VEJ Open × Pusa Agrani	IARI, New Delhi
Pusa Vijay (NPJ 93)	2008	Synthethtic B. Juncea x VSL-5	IARI, New Delhi
Pusa Agrani (SEJ 2)	1998	Early mutant of *Brassica juncea*/ Synthetic amphidiploid (*Brassica compestris* var. toria/ *Brassica nigra*)	IARI, New Delhi
Pusa Bold (DIR 50)	1984	Varuna × BIC 1780	IARI, New Delhi
Pusa Jagannath (VSL 5)	1999	Multicross between Varuna/ inter cross derivatives/ Synthetic *Brassica juncea*	IARI, New Delhi
RGN 48	2005	RSM-204 × B-75	ARS, RAU, Sriganganagar
RGN 73	2006	RGN-8 × Pusa Bold	ARS, RAU, Sriganganagar
RH 30	1985	Selection from P 26 / 3-1	CCS HAU, Hisar
RH 781	1991	(RL 18 × P 26 / 3-1) RL 18	CCS HAU, Hisar
Saurabh (RH 8113)	1987	Varuna × RC-781	CCS HAU, Hisar
Swarnjyoti (RH 9801)	2003	Selection from germplasm Line RC 1670	CCS HAU, Hisar
Varuna	1976	Selection from Varanasi Local	CSAU &T, Kanpur
Vasundhra (RH 9304)	2003	RH 839 × RH 30	CCS HAU, Hisar

were placed in a clean and dry room under ambient temperature conditions for four years. All the above said parameters were studied periodically after gap of two years. The methods used for recording the various observations on seed from each branch of 20 cultivars are explained below.

A random sample from pure and clean seed fraction was used for estimating 1 000-seed weight. Four replicates of 1 000-seeds were weighted. The mean value was expressed in grams.

Seeds from pure and clean seed fraction were used for estimation of first count and germination. The test for first count and germination was conducted following ISTA method (ISTA 2007). The seeds were categorized into normal seedling, abnormal seedling, hard and dead seeds. The percentage of normal seedling was used to calculate standard germination percentage.

Ten normal seedlings were taken at random from each replication. The root, shoot and total length of each seedling were measured in centimeter. The mean values from each replication were used for comparison of vigour.

Ten normal seedlings which were selected at random for observing seedling length were dried in a hot air oven at 70 ± 1^0C for 48 hr. Seedling dry weight was taken after cooling them and expressed as g/10 seedlings.

The vigour indices were computed adopting the method of Abdul Baki and Anderson (1973) by using following formula:

Vigour index I=Germination (%) × Seedling length

Vigour index II=Germination (%) × Seedling dry weight

Seeds were dried to 4–5% moisture level in oven at 103 °C for 16–18 hr. The oil content of the seed samples from each branch of 20 cultivars in four replications were determined by a non-destructive method (IUPAC 1989) using a Newport NMR analyzer (Model - 4000) after calibrating with pure mustard oil.

Fifteen random seeds from each branch of all cultivars were placed in petri dishes with damp absorbent paper and allowed to absorb distilled water at about 20°C for 6 hr in four replications. Non-imbibing seeds were discarded and 10 seeds from each replication were ensured for further processing. The seed coat of the softened seeds was removed manually, retaining the embryo with the cotyledons. The two fractions were dried at 70°C for 24 hr and weighed separately nearest to the four decimal places with an analytical balance immediately after removal from the oven. Mean seed weight was calculated from the 10-seed sample and the proportion of seed coat was expressed as a percentage relative to the weight of the whole seeds.

One thousand seeds from each branch of all cultivars in four replications were transferred to a measuring cylinder and weight/volume of water was added. The cylinders were covered with aluminium foil and left overnight at room temperature. Next day seeds were drained, superfluous water removed with filter paper and swollen seeds reweighed.

Hydration index was determined by using the following formula:

Hydration index= Hydration capacity/seed/Weight of 1000 dry seeds (g)

Where Hydration capacity was calculated using the formula:

Hydration capacity = Weight (soaked seeds) - Weight (seeds before soaking)

Pooled data only from initial (2007) and after two years of storage (2009) was used for analysis, as there was low germination in seeds from all the branches of 20 cultivars after four years (2011) of storage under ambient conditions. The per cent data of the seed vigour variables was transformed to arc sine values using the formula =+ASIN(SQRT((%Value)/100))*180/3.14 in Microsoft excel. The LSD, Duncan's test for homogenous sub sets and correlation coefficients were calculated using the SPSS package (version 10).

Germination (%)

The arc sine values of pooled germination (%) and decline in germination (%) after two years of storage has been given in Table 2 which shows that germination (%) of seeds harvested from the secondary branches (73.37) were at par with that of seeds harvested from main shoot (73.33), though the germination of seeds obtained from primary branches (70.05) was significantly less. The plants of Indian mustard are of indeterminate type and siliqua formation starts first on main shoot followed by primary and secondary branches. The mobilization of reserves continued till the harvest maturity and thus the variable influence of environment could be the reason for the differential results as explained by Donohue (2005). The per cent decline in germination (%) after two years of storage was significantly low in seeds from main shoot (2.77%) than the seeds from primary (3.61%) and secondary branches (3.59%). The cultivars tested differed significantly for germination and segregated in nine homogenous subsets while per cent decline in germination (%) after two years of storage formed 10 subsets. The highest decline was in CS 52 (4.35%), whereas the cultivar Varuna showed minimum deterioration (1.64%) after two years of storage. The differential response of cultivars in terms of decline in germination per cent of seeds harvested from different branches after two years of storage

Table 2 Pooled mean of per cent germination and per cent decline in germination after two years of storage in cultivars of Indian mustard

Cultivars	Germination (%) (Arc sine transformed values)				Per cent decline in germination (%) after two years of storage			
	Primary	Secondary	Main	Mean	Primary	Secondary	Main	Mean
BIO-902	78.45	81.18	80.29	79.97^{i}	2.59	1.84	2.27	2.23^{b}
CS 52	61.33	64.97	62.69	62.99^{ab}	4.22	4.86	3.96	4.35^{j}
CS 54	68.94	72.12	67.86	69.64^{def}	3.88	3.99	4.08	3.98^{hi}
Durga Mani	60.27	72.52	75.41	69.40^{cde}	5.22	4.05	2.10	3.79^{fgh}
Geeta	79.50	83.32	80.90	81.24^{i}	1.34	2.18	1.72	1.75^{a}
Laxmi	73.96	72.92	74.34	73.74^{gh}	3.50	2.87	2.87	3.08^{d}
Pusa Mustard 25	65.77	69.09	67.58	67.48^{c}	4.21	4.30	3.37	3.96^{hi}
Pusa Mustard 26	67.90	73.44	74.89	72.07^{efg}	4.08	3.88	2.48	3.48^{ef}
NPJ 93	65.81	64.47	67.04	65.77^{b}	4.30	4.94	3.43	4.22^{ij}
Pusa Agarni	77.69	80.76	80.29	79.58^{i}	2.88	2.69	2.27	2.61^{c}
Pusa Bold	76.37	74.14	76.48	75.66^{h}	3.34	2.46	2.41	2.74^{c}
Pusa Jagannath	72.25	71.52	73.66	72.47^{fgh}	2.92	4.05	2.90	3.29^{de}
RGN 48	65.81	76.48	70.39	70.89^{defg}	4.30	3.66	3.13	3.70^{fgh}
RGN 73	71.30	72.79	71.65	71.91^{efg}	3.69	3.94	3.03	3.55^{efg}
RH 30	76.61	83.49	76.43	78.84^{i}	2.63	2.37	2.41	2.47^{bc}
RH 781	66.82	71.52	67.58	68.64^{cd}	4.16	4.05	3.37	3.86^{ghi}
Saurabh	66.29	70.88	69.80	68.99^{cde}	4.23	4.11	3.17	3.84^{fgh}
Swarn Jyoti	57.73	61.26	62.79	60.59^{a}	5.82	5.54	0.30	3.89^{ghi}
Varuna	82.46	80.99	79.57	81.01^{i}	0.52	1.76	2.64	1.64^{a}
Vasundhara	65.77	69.68	67.04	67.49^{c}	4.30	4.23	3.43	3.99^{hi}
Mean	70.05^{a}	73.37^{b}	72.33^{b}		3.61^{a}	3.59^{a}	2.77^{b}	
CD (P=0.05) Cultivars		3.36				0.33		
CD (P=0.05) Branches		1.27				0.13		
CD (P=0.05) Cultivar × Branch		5.77				0.57		

Means followed by the same letter within a column are not statistically different (P= 0.05) according to the LSD test.

varied significantly. The highest germination per cent (83.49) was recorded in secondary branches of RH 30 and lowest germination (57.73%) was seen in primary branches of Swarnjyoti, respectively. However, the lowest decline (0.30%) in germination after two years of storage was observed in seeds from primary branches and highest (5.82%) in main shoot of cultivar Swarnjyoti. These results indicated that there were not only the genotypic differences with respect to potential germination but also with respect to liability to deteriorate. The seeds from all branches of all cultivars, but CS 52, NPJ 93 and Swarnjyoti maintained the germination above the minimum standards, however, the per cent decline after two years of storage was lowest in the seeds from main shoot. The key cause for the same may be mechanical damage, stages at harvest, mineral deficiency, growing condition and chemical damage which varies from genotype to genotype. The hypothesis that germination is dependent on interaction of genotype and the environment during seed maturation, has also been supported by earlier studies on *Brassica juncea* (Gunasekera *et al.* 2005). Each cultivar may have unique features which may help it to adapt to a specific condition (Amin 1999).

The ability to abort siliqua selectively during periods of high abiotic stress and resume once the stress has diminished, would enable plants to become S-strategists. As a consequence, low numbers of seeds develop per siliqua to guarantee that all the seeds formed will meet a minimum threshold of resources required for viability (Bennett *et al.* 2012).

Oil content (%)

Decline in oil content (%) after two years of storage varied significantly between cultivars, branches and cultivar × branches interaction (Table 3). The results of mean oil content revealed that seeds from secondary branches yielded significantly higher oil (37.86%) followed by seeds from primary branches (37.41%) and main shoot (36.70%). The differential response amongst the branches in *Brassica rapa* and *B. napus* inflorescences was observed (Archetti *et al.* 2009) and reported that seed development is frequently terminated following development of the first-formed siliqua and resumes at the end of flowering, leading to regions of the inflorescence without mature siliquae. This could be mainly because of distribution of nutrients and assimilates in different

Table 3 Pooled mean of oil content per cent and per cent decline in oil content after two years of storage in cultivars of Indian mustard

Cultivars	Oil content (%)				Per cent decline in oil content (%) after two years of storage			
	Primary	Secondary	Main	Mean	Primary	Secondary	Main	Mean
BIO-902	39.44	40.48	38.38	39.43 [n]	4.45	3.50	6.16	4.70 [a]
CS 52	36.83	37.65	35.99	36.82 [e]	6.72	6.67	7.96	7.12 [f]
CS 54	37.13	38.72	36.65	37.50 [g]	5.82	4.41	6.41	5.54 [bc]
Durga Mani	33.97	32.42	34.86	33.75 [a]	7.11	7.35	6.01	6.82 [ef]
Geeta	37.00	38.43	36.16	37.20 [f]	7.71	5.01	8.32	7.01 [f]
Laxmi	37.61	38.81	36.61	37.68 [h]	5.43	4.37	7.16	5.65 [c]
Pusa Mustard 25	35.76	35.84	34.43	35.34 [b]	7.46	7.70	8.09	7.75 [g]
Pusa Mustard 26	36.84	37.83	37.15	37.27 [f]	6.72	5.81	6.60	6.37 [de]
NPJ 93	36.84	37.29	36.19	36.77 [e]	6.77	6.38	7.65	6.93 [ef]
Pusa Agarni	38.59	38.86	38.87	38.77 [m]	4.94	4.37	4.45	4.59 [a]
Pusa Bold	36.40	36.86	35.68	36.31 [c]	6.89	6.14	7.18	6.74 [ef]
Pusa Jagannath	38.36	38.21	38.03	38.20 [j]	4.61	4.72	5.05	4.79 [a]
RGN 48	37.92	39.13	36.63	37.89 [i]	4.59	4.45	6.00	5.01 [ab]
RGN 73	38.19	38.49	38.08	38.25 [jk]	4.88	4.66	4.64	4.73 [a]
RH 30	37.97	38.65	38.16	38.26 [jk]	4.73	3.98	4.87	4.53 [a]
RH 781	38.83	39.38	35.55	37.92 [i]	4.03	4.56	8.11	5.57 [c]
Saurabh	38.08	38.98	38.07	38.38 [l]	4.70	3.89	4.57	4.39 [a]
Swarn Jyoti	38.73	37.70	37.64	38.02 [i]	4.68	5.49	4.84	5.00 [ab]
Varuna	37.04	36.64	35.89	36.52 [d]	6.85	6.22	7.33	6.80 [ef]
Vasundhara	36.66	36.97	34.97	36.20 [c]	5.54	6.10	5.99	5.87 [cd]
Mean	37.41 [a]	37.86 [b]	36.70 [c]		5.73 [a]	5.29 [b]	6.37 [c]	
CD (P=0.05) Cultivars		0.157				0.56		
CD (P=0.05) Branches		0.062				0.22		
CD (P=0.05) Cultivar × Branch				0.272				0.97

Means followed by the same letter within a column are not statistically different (P= 0.05) according to the LSD test.

organs and tissues that are in a constant state of flux throughout the growth and development of a plant. This has been reported (Bennett *et al.* 2012) that at key stages during the life cycle profound changes occur and perhaps one of the most critical phases of these changes is during seed filling. The per cent decline in oil content after two years of storage was significantly high in seeds from main shoot (6.37%) than the seeds from primary (5.73%) and secondary (5.29%) branches. Significant differences for oil content were noticed amongst the cultivars and they clustered in 13 homogenous sub-sets, whereas, seven groups were formed by the Duncan's multiple range test based upon the per cent decline in oil content after two years of storage. Significant differences were observed between cultivar × branches interaction for oil content and decline in oil content after two years of storage. The oil content ranged from 32.42 to 40.48 % while per cent decline was found highest (8.32%) in seeds from main shoot of cultivar Geeta and it was lowest (3.50%) in seeds from secondary branches of cultivar BIO 902. The genotypic constitution of plants and production conditions determine the quantity and quality of oil produced. The environmental factors like mean daily temperature and mean daily incident solar radiation during the main period of seed filling has also been found positively correlated with oil content (Donohue *et al.* 2005). Abdallah *et al.* (2011) demonstrated that short- or long-term sulphur limitation delays senescence and allows the plant to remobilize much more sulphur and nitrogen out of its leaves. Hence, it is advocated that agronomic consideration should be given to treatments that would make plants increase the rate of resource remobilization from the source to the sink.

Pearson correlation matrix for the variables under study

The relationship of all variables studied has been presented as Pearson correlation matrix in Table 4, where the significant correlation values at 5% and 1% have been shown. A linear relationship was found to exist between dependent variables, viz. seedling vigour index- I and II on one hand and independent variables like germination percent, seedling dry weight and seedling lengths on the other hand. As the number of abnormal seedlings and dead seeds increased the per cent first count and germination decreased significantly. These results were in agreement with the earlier findings (Donohue *et al.* 2005 and Gunasekera *et al.* 2005). The oil content (%) was found to be significantly correlated with test weight (r^2 = 0.148), first count (r^2 = 0.170) and seedling vigour index –I, whereas the highest correlation (r^2 = 0.202) was observed with per cent germination. The number of dead seeds were negatively correlated with the per cent oil content (r^2 = –0.187). Seeds with higher test weight had higher vigour and lesser dead seeds (r^2 = –0.211). Correlation of test weight with vigour index –II was found highest (r^2 = 0.363). Positive correlation of seed size with germination has also been reported earlier (Amin 1999). It was also noticed that

Table 4 Pearson correlation matrix for the variables under study in Indian mustard

	TW	SCP	HI	OC	FC	GER	ABSL	DS	RL	SL	TSL	DW	VII	VIII
TW	1.000	0.042	-0.030	0.148*	0.225**	0.135	0.077	-0.211**	0.318**	0.148*	0.343**	0.326**	0.346**	0.363**
SCP		1.000	0.003	0.068	-0.056	-0.170*	0.143	0.154*	-0.147*	-0.093	-0.166*	-0.275**	-0.188*	-0.274**
HI			1.000	0.246**	0.126	0.228**	-0.142	-0.200**	-0.076	-0.068	-0.092	0.186*	-0.023	0.225**
OC				1.000	0.170*	0.202**	-0.069	-0.187*	0.136	0.038	0.139	0.087	0.174*	0.130
FC					1.000	0.553**	-0.293**	-0.535**	0.043	0.410**	0.168*	0.269**	0.295**	0.409**
GER						1.000	-0.652**	-0.823**	0.192**	0.289**	0.270**	0.221**	0.512**	0.462**
ABSL							1.000	0.168*	-0.068	-0.181*	-0.120	-0.254**	-0.278**	-0.380**
DS								1.000	-0.168*	-0.247**	-0.234**	-0.094	-0.439**	-0.316**
RL									1.000	0.053	0.950**	0.181*	0.906**	0.208**
SL										1.000	0.362**	0.330**	0.373**	0.375**
TSL											1.000	0.272**	0.962**	0.311**
DW												1.000	0.281**	0.961**
VII													1.000	0.387**
VIII														1.000

*Correlation is significant at the 0.05 level (2-tailed), **correlation is significant at the 0.01 level (2-tailed).

TW, Test weight, SCP, seed coat proportion, HI, Hydration Index, OC, Oil content; FC, first count; GER, germination; ABSL, Abnormal seedlings; DS, Dead seeds; RL, Root length; SL, Shoot length; TSL, Total seedling length; DW, Dry weight; VII, Vigour index-I and VIII- Vigour index-I

Table 5 Pooled mean of various other variables in cultivars tested

Cultivars	First Count	Root length (cm)	Shoot length (cm)	TSL (cm)	Vigour Index-I	Dry weight (g)	Vigour Index-II	Hydration Index	Seed coat proportion
BIO-902	63.35^{ef}	9.39^{g}	3.82^{abcde}	13.22^{f}	1266.9^{h}	0.0402^{hi}	3.85^{jk}	0.471^{f}	27.97^{cdef}
CS 52	53.64^{ab}	5.01^{b}	3.23^{a}	8.24^{ab}	636.8^{a}	0.0233^{bc}	1.80^{abc}	0.297^{bcd}	28.98^{defg}
CS 54	62.24^{def}	6.21^{cde}	4.19^{cdef}	10.39^{de}	896.3^{efg}	0.0246^{c}	2.12^{cd}	0.329^{cde}	27.52^{cdef}
Durga Mani	58.49^{cd}	5.61^{bcd}	4.34^{defg}	9.95^{cd}	842.2^{cde}	0.0382^{gh}	3.23^{hi}	0.183^{ab}	22.62^{abc}
Geeta	77.42^{i}	3.37^{a}	5.57^{h}	8.94^{bc}	864.2^{def}	0.0463^{j}	4.48^{l}	0.494^{f}	24.42^{abcd}
Laxmi	72.20^{h}	7.00^{ef}	4.02^{cdef}	11.02^{e}	996.2^{g}	0.0432^{ij}	3.91^{k}	0.532^{f}	18.66^{a}
Pusa Mustard 25	67.78^{g}	5.43^{bc}	3.83^{abcde}	9.27^{bc}	774.9^{bcd}	0.0245^{c}	2.05^{bcd}	0.253^{abc}	31.34^{efg}
Pusa Mustard 26	56.88^{bc}	5.15^{b}	3.37^{ab}	8.52^{ab}	755.8^{bc}	0.0265^{cd}	2.36^{def}	0.312^{bcd}	28.84^{defg}
NPJ 93	58.32^{cd}	5.29^{b}	3.74^{abcd}	9.02^{bc}	734.3^{ab}	0.0187^{a}	1.52^{a}	0.196^{abc}	32.86^{fg}
Pusa Agarni	64.43^{fg}	9.60^{g}	3.84^{abcdef}	13.44^{f}	1284.1^{h}	0.0254^{c}	2.43^{def}	0.287^{bc}	20.62^{ab}
Pusa Bold	65.51^{fg}	10.46^{h}	5.56^{h}	16.01^{g}	1474.2^{i}	0.0475^{j}	4.38^{l}	0.187^{ab}	23.65^{abcd}
Pusa Jagannath	65.77^{fg}	12.18^{i}	4.48^{fg}	16.66^{g}	1484.4^{i}	0.0394^{ghi}	3.51^{ij}	0.210^{abc}	25.30^{bcd}
RGN 48	59.79^{cde}	7.25^{f}	3.94^{bcdef}	11.19^{e}	973.2^{g}	0.0334^{ef}	2.91^{gh}	0.477^{f}	24.82^{bcd}
RGN 73	57.27^{bc}	4.94^{b}	3.63^{abc}	8.57^{ab}	759.4^{bc}	0.0299^{de}	2.65^{fg}	0.449^{ef}	24.93^{bcd}
RH 30	67.40^{g}	2.84^{a}	4.81^{g}	7.65^{a}	725.0^{ab}	0.0354^{fg}	3.36^{i}	0.256^{abc}	22.68^{abc}
RH 781	63.81^{efg}	7.15^{f}	4.15^{cdef}	11.30^{e}	958.3^{fg}	0.0315^{ef}	2.67^{fg}	0.218^{abc}	33.75^{g}
Saurabh	61.48^{def}	6.68^{ef}	4.42^{efg}	11.09^{e}	945.0^{efg}	0.0196^{ab}	1.67^{ab}	0.295^{bcd}	26.02^{bcde}
Swarn Jyoti	52.40^{a}	6.39^{def}	3.90^{bcdef}	10.29^{de}	754.3^{bc}	0.0455^{j}	3.34^{i}	0.332^{cde}	20.44^{ab}
Varuna	62.12^{def}	9.35^{g}	4.48^{fg}	13.84^{f}	1335.4^{h}	0.0265^{cd}	2.55^{efg}	0.419^{def}	21.99^{abc}
Vasundhara	55.75^{abc}	7.01^{ef}	3.97^{bcdef}	10.99^{de}	917.5^{efg}	0.0263^{cd}	2.19^{de}	0.145^{a}	26.37^{bcde}
Mean (Cultivars)	62.30	6.82	4.16	10.98	968.9	0.0323	2.85	0.317	25.69
Range Among Cultivars over the branches	81.91-49.24	13.01-2.72	7.32-3.08	18.39-7.48	1691.2-616.4	0.0516-0.0165	4.82-1.39	0.821-0.121	41.14-17.41
CD (P=0.05) Cultivars	4.41	0.81	0.54	0.95	94.8	0.0028	0.37	0.115	5.00
CD (P=0.05) Branches	NS	NS	NS	NS	NS	NS	NS	NS	NS
CD (P=0.05) Cultivar × Branch	7.63	1.40	0.94	1.65	164.2	0.0056	0.64	0.199	8.67

higher the number of dead seed, higher was seed coat proportion (r^2 = 0.154) and lower was hydration index (r^2 = –0.200). The seed coat proportion was found inversely correlated with most of the vigour variables and it was highest with dry weight (r^2 = –0.275) and followed by vigour index-II. The seed coat has been reported intimately associated with temporal and spatial dispersion of seed germination in a large number of plant species (Taylor *et al*. 2010). In soybean, the relative weight proportion represented by the seed coat decreases as seed weight increases (Calero *et al.* 1981). The positive correlation often found between seed size and testa permeability has led several authors to conclude that the soybean lineages best adapted to tropical conditions are the small-seeded ones (Mugnisjah *et al.* 1987). The data depicted in supplementary Table 5 portrays that there were significant differences only amongst the cultivars and not between the branches for all other variables tested.

SUMMARY

It was found out that seeds from secondary branches retained more oil and seeds from main shoot deteriorated less in germination over the period. Reuse of seeds is common practice among farmers of India in almost all crops. Hence, present findings related to higher germination (%) in the seeds from main shoot may be of much practical use to the farmers who use their own saved seed. However, it is always good that the stored seed being used for sowing for next season should be assessed for its viability before sowing. The present finding may also be of practical use to the farmers who store mustard for a period of 2-3 years for want of good procurement price. Since, the procurement is based on the oil content basis now, but the reduction in oil content over the longer storage per se may result in net loss as compared to sale of freshly harvested grains. Hence, it is concluded from this study that pure seeds from main shoot of better cultivars could be reused as seed and produce from secondary branches could be put to better use by extracting oil from them. The siliquae on the lower section of the main shoot are the first formed and contain the heaviest seeds, whereas the later formed siliquae on lateral branches contain lighter and significantly fewer seeds. Seeds from siliquae on lateral branches have high viability, but further detailed experiments are necessary to establish if there is a fitness cost in case these smaller seeds are selected over multiple generations.

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