J. Indian Soc. Coastal Agric. Res. 36(2): 54-63 (2018)

Selection of Rapeseed-mustard Varieties in Coastal Region of West Bengal: A Way Forward to Rice-fallow Intensification

H. BANERJEE[1], S. SAMANTA[1], A. DUTTA[2], S. SARKAR[3]* and S. GARAI[3]

[1]Regional Research Station (CSZ), Bidhan Chandra Krishi Viswavidyalaya, Kakdwip
South 24-Parganas, West Bengal - 743 347

[2]Department of Seed Science and Technology, Bidhan Chandra Krishi Viswavidyalaya
Mohanpur, Nadia, West Bengal - 741 252

[3]Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya
Mohanpur, Nadia, West Bengal - 741 252

Received: 06.08.2018 Accepted:17.11.2018

To understand the variation in growth and yield-determining traits of promising rapeseed-mustard cultivars under late sown condition, field experiments were set up during winter of 2014-15 and 2015-16 at Research Farm of BCKV, Kakdwip, West Bengal. The field trial was arranged as a randomized complete block design with eight rapeseed-mustard cultivars, out of which four are BARC-released gamma-mutant genotypes of rapeseed-mustard (TM 106, TM 217, TM 143 and TM 204) and four popular high yielding cultivars (RB50, Pusa Bold, Kranti and B85) replicated thrice. Results revealed that TM 143 produced significantly ($p \leq 0.05$) higher number of siliquae than rest others. The maximum number of siliqua from the main fruiting axis was collected from the cv. TM 204; however, it was statistically at par with cv. TM 143 and cv. Pusa Bold. Similarly, the cv. TM 143 produced more number of seeds per siliqua than all other tested cultivars; however, it was statistically at par with cv. TM 204 and cv. TM 217. Cultivars exhibited significant variation in test weight and the highest value was recorded for the cv.TM 143; being at par with cv. TM 204. Finally, the cv. TM 143 proved its superiority over all other tested cultivars by producing significantly ($p \leq 0.05$) higher seed yield (1.80 $t ha^{-1}$) which was statistically at par with cv. TM 204. In addition, the cv. RB-50 produced significantly ($p \leq 0.05$) higher stover yield, which was closely followed by cv. TM 204 and cv. TM 217. Hence, adoption of mutant rapeseed-mustard cultivars, namely cv. TM 143, cv. TM 204 and cv. TM 217 particularly under late sown condition will be beneficial for rice-fallow system in coastal Bengal.

(***Key words:*** *Rapeseed-mustard, Coastal region, Growth, Yield*)

Rapeseed-mustard occupies a premier position in oilseed production scenario in India just after groundnut, producing 7.88 mt seeds from an area of 6.70 mha (Crop Production Statistics Information System, 2016). Globally, India accounts for 12-15% of oilseeds area and 7-8% of production (Jha *et al*., 2012). The projected demand for oilseed in India is around 30.2 mt by 2020, of which about 14 mt (41%) has to be met by rapeseed-mustard (Mittal, 2008). The contribution of West Bengal towards nation's production of rapeseed-mustard is deplorably low (6.07%) (Economic review, GoWB, 2015) due to lower productivity of 1194 kg ha^{-1} (Annual Report, GOI, 2016-17). The lower productivity could be attributed to cultivation of old varieties with poor yielding ability, sub-optimal and imbalanced use of fertilizers, inadequate or absence of irrigation, attack by insect pests, etc. (Dutta *et al*., 2017). However, during last five years, adaptation of promising varieties embedded with high genetic yield potentiality has been increasing the trend of rapeseed-mustard cultivation in this state.

The cropping pattern in coastal region of West Bengal is mainly dominated by mono-cropping of Kharif paddy. In this region, small and marginal farmers totally depend on low yielding-long duration-traditional rice varieties (145−150 days) during wet season, wherein most of the lands remains fallow during dry season due to lack of irrigation facilities (Banerjee *et al*., 2017). Rapeseed-mustard can be grown in this area, after withdrawal of monsoon, either as rainfed crop on residual soil moisture. It contributes significantly towards maintaining livelihood security in coastal region because of its potentiality to grow in resource-scarce condition. Hence, there is an urgent need for diversification and intensification of rice-

**Corresponding author:* E-mail: sukamalsarkarc@yahoo.com

based cropping system with rapeseed-mustard to enhance both productivity and profitability per unit area per unit time without affecting the soil health (Shah *et al*., 2015). Beside this, selection of suitable cultivars is a key factor influencing the growth and yield of the crop (Sheoran *et al*., 2014). It is therefore a challenge to identify a suitable cultivar of rapeseed mustard that could perform well under delayed sowing (beyond November after harvesting of Kharif rice) in coastal saline zone of West Bengal.

MATERIALS AND METHODS

Field experiments were conducted during winter of 2014-15 and 2015-16 at the Regional Research Station (Coastal Saline Zone) of Bidhan Chandra Krishi Viswavidyalaya situated at Kakdwip, South 24-Parganas, West Bengal (22°40′ N latitude, 88° 18′ E longitude and 7 m above mean sea level). The objective was to understand the variation in growth and yield-determining traits of the promising rapeseed-mustard cultivars under late sown condition in coastal ecosystem of West Bengal. The region belongs to the sub-humid and sub-tropical agro-ecological zone with an average annual rainfall of 1, 560 mm, 80% of which falls during the rainy season (June to September) due to south-west monsoon. Weather data, logged at Automated Weather Station (AWS) of the same Research Station, revealed that monthly maximum and minimum temperatures fluctuated between 26.4 to 33.1ºC, and 11.9 to 22.9ºC, respectively during the cropping season (December to April). Maximum and minimum relative humidity ranged from 72.5 to 91.8% and 66.9 to 86.4%, respectively. The total rainfall during the experimental period was 177.4 mm, however, there was no rain in January and March in either of the experimental years. The biennial average amount of evapo-transpiration (ET) during the cropping season was 408.2 mm. The ET was greater in the month of March and lower in the month of December. The soil was clay in texture and with the $EC_{1:2.5}$ following key properties at 0–30 cm layer: pH 5.91, organic carbon 0.64%, EC 1.53 dS m^{-1}, available N 156.0 kg ha^{-1}, available P_2O_5 100.5 kg ha^{-1} and available K_2O 321.3 kg ha^{-1}.

The field trial was arranged as a randomized complete block design with eight rapeseed- mustard cultivars replicated thrice, and the area of each plot was 20 m^2 (5 m × 4 m). In the present experiment, we have evaluated 4 BARC-released gamma-mutant genotypes of rapeseed-mustard (cv. TM 106, cv. TM 217, cv. TM 143 and cv. TM 204) along with four popular high yielding cultivars (cv. RB 50, cv. Pusa Bold, cv. Kranti and cv. B 85) (Table 1). Cultivars were evaluated in moist horizon where seeds were hand-placed under line sowing condition at a seed rate was 5 kg ha^{-1} with a spacing of 30 cm × 10 cm. To maintain optimum plant population per unit area, thinning was practiced at 20 days after sowing (DAS). Half nitrogen (N) as urea and full phosphorus (40 kg ha^{-1}) as single super phosphate and potassium (40 kg ha^{-1}) as muriate of potash were applied as basal (at final land preparation). Rest half N was given at 25 DAS (after completion of first weeding). Three irrigations were imposed coinciding with critical growth stages *viz*. active growth stage (at 20 DAS), siliqua development stage (at 40 DAS) and grain filling stage (60 DAS). Confidor (Imidacloprid) 17.8% SL was applied @4 ml per 10 liters of water at 40 DAS particularly against sucking insects like aphids, jassids, thrips, etc. Single spray of Actara (Thiamethoxam) 25 % WG @ 5 g per 15 liters of water was given at 50 DAS to protect the crop against a broad spectrum of sucking pests. Whitefly and leaf miner attack was checked by application of two sprays of Tarzan (Triazophos) 40% EC @1.5 ml per liter of water at 50 and 70 DAS.

For accessing growth parameters, 5 plants from each plot were randomly selected, uprooted and cleaned and observations were recorded to obtain mean value. For dry weight, uprooted plants were sun dried, then put into hot-air oven-dried at 70°C for 48 hours, and then weighed. At crop harvest stage, yield attributes were recorded for assessment of crop yield. However, seed and stover yield were determined from the net harvested data and converted to t ha^{-1} at 14% moisture content by using the following formula.

$$Y = \frac{Y_P}{S_P} \times 10{,}000 \times \frac{(100 - M)}{(100 - 14)}$$

Where, Y is seed/stover yield in t ha^{-1}, Y_P is plot yield in kg, S_P is plot size in m^2, M is moisture content in seed/stover (%) at the time of yield estimation.

The collected data were analyzed statistically by the analysis of variance (ANOVA) technique using the STAR Software version 2.0.1 (International Rice Research Institute, Philippines, 2013). The

Table 1. *Salient features of different rapeseed-mustard cultivars used for the study and their source of collection*

Cultivars	Category	Scientific name	Seed colour	Oil content (%)	Source
RB50	Rai / Indian mustard	*Brassica juncea*	Brown	38 – 40	PORS, Berhampore, West Bengal
Pusa Bold	Rai / Indian mustard	*Brassica juncea*	Brown	40	PORS, Berhampore, West Bengal
TM 106	Yellow Sarson	*Brassica napus* var. Glauca	Yellow	43	BARC, Trombay, Mumbai
Kranti	Rai / Indian mustard	*Brassica juncea*	Brown	40	PORS, Berhampore, West Bengal
TM 217	Yellow sarson	*Brassica napus* var. Glauca	Yellow	45	BARC, Trombay, Mumbai
TM 143	Yellow sarson	*Brassica napus* var. Glauca	Yellow	47	BARC, Trombay, Mumbai
TM 204	Yellow sarson	*Brassica napus* var. Glauca	Yellow	48	BARC, Mumbai
B 85	Rai / Indian mustard	*Brassica juncea*	Brown	38	PORS, Berhampore, West Bengal

PORS, Pulses and Oilseeds Research Station; BARC, Bhabha Atomic Research Centre

Pearson's correlation coefficients were calculated to describe the degree and pattern of associations of observed traits of cultivars. Direct and indirect path coefficients were calculated for quantitative traits using the software OPSTAT, as proposed by Sheoran *et al*. (1998). Agglomerative Hierarchical Clustering based on yield and yield attributing traits of rapeseed-mustard cultivars was done using Origin® Pro 2018.

RESULTS AND DISCUSSION

Growth parameters

Plant height of all rapeseed-mustard cultivars recorded an increasing trend upto maturity. Plant height recorded at different intervals was significantly ($p \leq 0.05$) influenced by the cultivars (Table 2). Except at early growth stage, mutant rapeseed-mustard cv. TM 204 produced significantly ($p \leq 0.05$) taller plant than other tested cultivars. While the shortest plants was recorded in cv. B 85. Dry matter accumulation increased steadily for all rapeseed-mustard cultivars up to 90 DAS, and finally decreased at harvest, showing significant difference between cultivars (Table 2). At 90 DAS, it was significantly ($p \leq 0.05$) higher for cultivar cv. TM 204 which was statistically at par with cv. RB 50 and cv. TM 106. Furthermore, tested cultivars did no exhibit any significant difference with respect to number of fertile plants m^{-2}. The cultivar TM 204 produced significantly the highest number of fertile plants m^{-2}, closely followed by cv. TM 217, cv. TM 143 and cv. Kranti. Cultivars showed significant ($p \leq 0.05$) variations on the flowering behaviour. The cv. B85 took less number of days to attain 50% and 100% flowering than other tested cultivars. While both cv. RB 50 and cv. TM 204 took maximum number of days to attain 50% and 100% flowering, respectively (Table 2).

Yield components and yield

The variation in mutant mustard genotypes was non-significant with respect to the number of secondary branches per plant (Table 3). However, the cv. TM 143 produced significantly ($p \leq 0.05$) higher number of tertiary branches per plant, and it was statistically at par with cv. TM 204. Number of siliqua per plant is considered as one of the most important yield-determining factors in rapeseed-mustard. Amongst the tested cultivars, cv. TM 143 produced significantly ($p \leq 0.05$) higher number of siliquae than rest while cv. B 85 recorded least number of siliquae per plant. The maximum number of siliquae from main fruiting axis was collected from the variety TM 204, however, it was statistically at par with cv. TM 143 and cv. Pusa Bold. The tested cultivars showed significant ($p \leq 0.05$) difference in length of main fruiting axis, and the cv. TM 204 achieved maximum length followed by cv. TM 143 and cv. TM 106. Significant ($p \leq 0.05$) variation was also observed for length of siliqua among the tested cultivars. The cultivar TM 143 produced the longest siliqua than other tested cultivars; however, it was statistically at par with cv. Kranti and cv. TM 204. Similarly, the cv. TM 143 produced more number of seeds per siliqua than other tested cultivars, however, it was statistically at par with cv. TM 204 and cv. TM 217. Cultivars exhibited significant variations in test weight and the highest value was recorded in cv. TM 143; being significantly at par with cv. TM 204. While early maturing cv. B 85 recorded the lowest test weight. Finally, the cultivar cv. TM 143 proved its superiority over all other tested cultivars by producing significantly ($p \leq 0.05$) higher seed yield (1.80 t ha^{-1}) which was statistically at par with cv. TM 204. Although the cv. RB-50 produced significantly ($p \leq 0.05$) higher stover yield, closely followed by cv. TM 204 and cv. TM 217 (Table 3). Cultivars under study also showed variations in harvest index and it was the maximum in the mutant genotype TM 143 followed by cv. B-85. A better harvest index is indicative of a shift in conversion of complex carbohydrate into simpler form and its mobilization towards increased sink capacity (Mishra *et al*., 2014).

Correlation study

Pearson correlation coefficients showing pair-wise associations between the assessed traits of the cultivars are presented in Table 4. Amongst the quantitative traits evaluated, significant and positive correlations were observed between PH and DTH ($r = 0.903$, $p \leq 0.01$), TBP ($r = 0.712$, $p \leq 0.05$), LSSPS ($r = 0.891$, $p \leq 0.01$), LS ($r = 0.818$, $p \leq 0.05$), SS ($r = 0.766$, $p \leq 0.05$), TW ($r = 0.820$, $p \leq 0.05$) and SEY ($r = 0.969$, $p \leq 0.01$). DM showed highly significant and positive correlation ($p \leq 0.01$) with DTFPF ($r = 0.878$), DTHPF ($r = 0.844$), and STY ($r = 0.868$). FP showed significant and positive correlation ($p \leq 0.05$) with TW ($r = 0.821$). Significant and positive correlations at $p \leq 0.01$ were also observed between DTFPF and DTHPF ($r = 0.979$) and STY ($r = 0.857$). But, DTHPF was significantly and positively correlated with only STY ($r = 0.753$, $p \leq 0.05$). Significant and positive correlations were observed between DTH and SBP ($r = 0.791$, $p \leq 0.05$), LSSPS ($r = 0.828$, $p \leq 0.05$), SP ($r = 0.748$, $p \leq 0.05$), LS ($r = 0.781$, $p \leq 0.05$), TW ($r = 0.854$, $p \leq 0.01$), SEY ($r = 0.834$, $p \leq 0.05$) and STY ($r = 0.727$, $p \leq 0.05$). Significant and positive correlations were detected between SBP and SP ($r = 0.733$, $p \leq 0.05$). Significant and positive correlations were also observed between TBP and SP ($r = 0.867$, $p \leq 0.01$), SS ($r = 0.926$, $p \leq 0.01$), SEY ($r = 0.735$, $p \leq 0.05$). LSSPS showed significant and positive correlation ($p \leq 0.01$) with LS ($r = 0.723$), TW ($r = 0.712$) and SEY ($r = 0.813$). On the other hand, SP was positively correlated with SS ($r = 0.796$, $p \leq 0.05$) and STY ($r = 0.838$, $p \leq 0.01$). Similarly, significant and positive correlations were also observed between LS and SS ($r = 0.756$, $p \leq 0.05$), TW ($r = 0.945$, $p \leq 0.01$) and SEY ($r = 0.850$, $p \leq 0.01$). Finally, SS showed significant and positive correlation with TW ($r = 0.724$, $p \leq 0.05$) and SEY ($r = 0.828$, $p \leq 0.05$), and TW with SEY ($r = 0.836$, $p \leq 0.01$).

The significant and positive association within the afore mentioned attributes is rational in plants with indeterminate growth habit (e.g.rapeseed-mustard) where it is challenging to confirm the date of maturity. The strong relationships among these characters in the present study indicated that these characters were governed by the same genetic system *i.e.* the characters were expected to be linked with each other and they should be given high priority during selection of high yielding genotypes of rapeseed-mustard. Singh *et al*. (2003) and Lodhi *et al*. (2014) also observed such positive association of seed yield (SEY) with siliqua on main branch (SMB) and PH (plant height). Generally, the positive associations among these three traits suggest the prospect of improving these important yield and growth-attributing characters concurrently.

Table 2. *Growth parameters and phenophases of rapeseed-mustard cultivars grown in coastal agro-ecosystem under late sown condition (pooled values of two years)*

Cultivar	Plant height (cm)				Dry matter accumulation (g m^{-2})				Fertile plants Nos. m^{-2} (at harvest)	Days to 50% flowering	Days to 100% flowering	Days to harvest
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest				
RB50	30.2	115.8	130.9	135.2	28.6	150.9	601.8	486.0	28.6	62	70	95
Pusa Bold	28.0	120.7	135.2	140.3	28.0	140.2	517.9	380.4	27.0	57	65	108
TM 106	29.6	130.5	150.0	152.6	30.7	206.6	600.4	490.7	29.0	60	69	108
Kranti	31.2	129.1	136.1	142.3	30.0	210.9	510.2	395.8	30.0	60	70	100
TM 217	28.0	130.5	155.0	159.0	26.7	186.4	521.7	422.9	31.6	56	65	108
TM 143	25.8	125.4	159.3	163.5	25.8	229.74	550.4	430.1	30.3	56	65	97
TM 204	30.9	140.2	162.3	165.2	18.0	200.4	610.3	485.4	32.3	62	70	108
B 85	20.1	90.5	120.5	129.0	22.3	140.3	325.0	295.6	27.0	45	58	80
$LSD_{0.05}$	NS	15.57	12.55	5.72	5.10	14.49	22.14	26.33	NS	4.15	4.61	6.57

DAS days after sowing; LSD, Least significant differences at $p \leq 0.05$

Path coefficient analysis of various traits in rapeseed-mustard

With the aim of analyzing the genetic correlations further and splitting the correlation coefficient into direct and indirect influences of different attributes, path coefficient technique was employed. It therefore, warrants an acute study of attributes those affect a certain correlation and can be advantageous in preparing a competent selection approach (Scheiner *et al.*, 2000). Results on the path coefficients with seed yield as the response variable are summarized in Table 5. Values of direct effects were <1, indicating that inflation due to multicollinearity was low. Among the growth and yield components, PH and DTH (0.477) exhibited highly positive direct effects on seed yield of rapeseed-mustard (Table 5). The direct selection for these two characters could be beneficial for yield improvement of rapeseed-mustard since these characters also showed positive correlation with seed yield. Other growth attributes and yield-determining traits exerted either negligible or low or negative direct effects on seed yield. Selection based on these characters will not improve yield of rapeseed-mustard.

Path-coefficient analysis is increasingly being used in plant breeding (Samonte *et al.*, 1998). Studies are scanty on agronomic traits in rapeseed-mustard to identify the pre-eminent selection standards linked to increased yield and the other attributes that influence it. Earlier, Pandey and Singh (2005), Verma *et al.* (2008), and Lodhi *et al.* (2014) reported maximum positive direct influence of PH and SMB on seed yield in case of Indian mustard. In our study, the observed two specific traits (PH and DTH) with superior genetic variability, heritability and higher

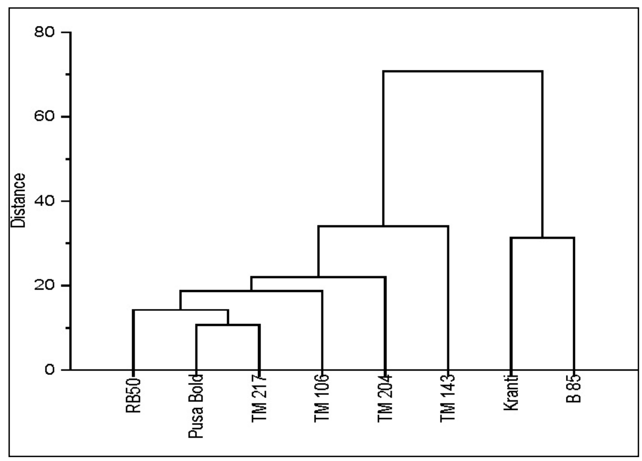

Fig.1. *Clustering of different rapeseed-mustard varieties grown in coastal agro-ecosystem (considering pooled value of 2 years) based on their yield components and yields by Agglomerative Hierarchical Clustering using Euclidean dissimilarity distance.*

Table 3. *Yield attributes and yields of rapeseed-mustard cultivars grown in coastal agro-ecosystem under late sown condition (pooled values of two years)*

Cultivars	Secondary branches plant^{-1} (nos.)	Tertiary branches plant^{-1} (nos.)	Siliqua plant^{-1} (nos.)	Siliqua main branch^{-1} (nos.)	Length of stem upto starting point of siliqua (cm)	Length of siliqua (cm)	Seeds siliqua^{-1} (nos.)	1000 seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
RB50	4.0	7.3	205.3	35.6	68.9	4.66	12.0	4.99	1.05	6.50	13.91
Pusa Bold	4.1	7.5	215.6	37.3	75.8	5.80	12.6	5.10	1.20	5.55	17.78
TM 106	4.0	6.9	195.6	35.6	80.2	5.69	11.0	5.60	1.30	5.60	18.84
Kranti	3.9	6.1	160.0	33.6	70.4	6.59	11.6	6.65	1.29	4.90	20.84
TM 217	4.5	7.5	215.0	30.6	79.2	6.01	12.6	6.00	1.45	5.85	19.86
TM 143	4.5	9.0	240.6	40.0	80.5	7.05	15.6	6.90	1.80	5.70	24.00
TM 204	4.5	8.1	210.3	40.6	95.4	6.80	14.4	6.71	1.75	5.90	22.88
B 85	3.7	6.4	130.6	30.3	60.8	4.42	10.3	3.70	0.95	3.10	23.46
$LSD_{0.05}$	NS	1.00	14.70	4.96	6.48	0.72	2.06	0.76	0.34	0.95	-

LSD, Least significant differences at $p \leq 0.05$

Table 4. *Pearson's correlation coefficients showing pair-wise association of different traits assessed amongst rapeseed-mustard cultivars (based on pooled values of two years)*

Traits	DM	FP	DTFPF	DTHPF	DTH	SBP	TBP	LSSPS	SP	SMB	LS	SS	TW	SEY	STY
PH	0.564^{NS}	0.612^{NS}	0.418^{NS}	0.353^{NS}	0.903**	0.694^{NS}	0.712*	0.891**	0.696^{NS}	0.317^{NS}	0.818*	0.766*	0.820*	0.969**	0.517^{NS}
DM		0.360^{NS}	0.878**	0.844**	0.745*	0.505^{NS}	0.401NS	0.662^{NS}	0.625^{NS}	0.363^{NS}	0.327^{NS}	0.377^{NS}	0.538^{NS}	0.421^{NS}	0.868**
FP			0.443^{NS}	0.498^{NS}	0.662^{NS}	0.355^{NS}	0.112NS	0.399^{NS}	0.221^{NS}	-0.192^{NS}	0.686^{NS}	0.360^{NS}	0.821*	0.670^{NS}	0.337^{NS}
DTFPF				0.979**	0.684^{NS}	0.290^{NS}	0.224NS	0.583^{NS}	0.538^{NS}	0.449^{NS}	0.441^{NS}	0.340^{NS}	0.629^{NS}	0.323^{NS}	0.857**
DTHPF					0.625^{NS}	0.198^{NS}	0.078NS	0.507^{NS}	0.378^{NS}	0.332^{NS}	0.413^{NS}	0.230^{NS}	0.620^{NS}	0.254^{NS}	0.753*
DTH						0.791*	0.554NS	0.828*	0.748*	0.375^{NS}	0.781*	0.618^{NS}	0.854**	0.834*	0.727*
SBP							0.545NS	0.472^{NS}	0.733*	0.258^{NS}	0.440^{NS}	0.418^{NS}	0.478^{NS}	0.627^{NS}	0.557^{NS}
TBP								0.637^{NS}	0.867**	0.643^{NS}	0.528^{NS}	0.926**	0.493^{NS}	0.735*	0.546^{NS}
LSSPS									0.660^{NS}	0.462^{NS}	0.723*	0.692^{NS}	0.712*	0.813*	0.588^{NS}
SP										0.679^{NS}	0.533^{NS}	0.796*	0.568^{NS}	0.681^{NS}	0.838**
SMB											0.464^{NS}	0.643^{NS}	0.380^{NS}	0.274^{NS}	0.500^{NS}
LS												0.756*	0.945**	0.850**	0.362^{NS}
SS													0.724*	0.828*	0.526^{NS}
TW														0.836**	0.541^{NS}
SEY															0.459^{NS}

Notes: PH = plant height at harvest in cm, DM = dry matter at harvest in g m^{-2}, FP = Fertile plants at harvest in nos., DTFPF = Days to 50% flowering, DTHPF = Days to 100% flowering, DTH = Days to harvest, SBP = Secondary branches $plant^{-1}$ in nos., TBP = Tertiary branches $plant^{-1}$ in nos., LSSPS = Length of stem upto starting point of siliqua in cm, SP = Siliqua $plant^{-1}$, SMB = Siliqua main $branch^{-1}$, LS = Length of siliqua in cm, SS = Seeds $siliqua^{-1}$, TW = Test weight in g, SEY = Seed yield in t ha^{-1}, STY = Stover yield in t ha^{-1}; * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$; NS = non-significant

Table 5. *Estimates of direct (bold faced main diagonals) and alternate/indirect path coefficient values of different traits in rapeseed−mustard cultivars grown in coastal agro-ecosystem (based on pooled values of two years)*

	PH	DM	FP	DTFPF	DTHPF	DTH	SBP	TBP	LSSPS	SP	SMB	LS	SS	TW	Total correlation with seed yield
PH	0.477	0.030	0.183	0.144	-0.245	0.431	-0.217	0.134	-0.042	0.039	-0.010	0.080	0.009	-0.043	0.969**
DM	0.269	0.054	0.108	0.303	-0.586	0.355	-0.158	0.076	-0.031	0.035	-0.012	0.032	0.005	-0.028	0.421^{NS}
FP	0.291	0.019	0.298	0.153	-0.346	0.316	-0.111	0.021	-0.019	0.012	0.006	0.067	0.004	-0.043	0.670^{NS}
DTFPF	0.199	0.047	0.132	0.345	-0.680	0.326	-0.091	0.042	-0.027	0.030	-0.015	0.043	0.004	-0.033	0.323^{NS}
DTHPF	0.168	0.045	0.149	0.338	-0.694	0.298	-0.062	0.015	-0.024	0.021	-0.011	0.040	0.003	-0.033	0.254^{NS}
DTH	0.430	0.040	0.198	0.236	-0.434	0.477	-0.247	0.105	-0.039	0.042	-0.012	0.076	0.007	-0.045	0.834*
SBP	0.331	0.027	0.106	0.100	-0.137	0.377	-0.313	0.103	-0.022	0.041	-0.009	0.043	0.005	-0.025	0.627^{NS}
TBP	0.339	0.021	0.033	0.077	-0.054	0.264	-0.170	0.189	-0.030	0.049	-0.021	0.051	0.011	-0.026	0.735*
LSSPS	0.425	0.035	0.119	0.201	-0.352	0.395	-0.148	0.120	-0.047	0.037	-0.015	0.070	0.008	-0.038	0.813*
SP	0.332	0.033	0.066	0.186	-0.262	0.357	-0.229	0.164	-0.031	0.056	-0.022	0.052	0.010	-0.030	0.681^{NS}
SMB	0.151	0.019	-0.057	0.155	-0.230	0.179	-0.081	0.121	-0.022	0.038	-0.033	0.045	0.008	-0.020	0.274^{NS}
LS	0.390	0.017	0.205	0.152	-0.287	0.372	-0.138	0.100	-0.034	0.030	-0.015	0.097	0.009	-0.050	0.850**
SS	0.365	0.020	0.108	0.117	-0.160	0.295	-0.131	0.175	-0.032	0.045	-0.021	0.074	0.012	-0.038	0.828*
TW	0.391	0.029	0.245	0.217	-0.431	0.407	-0.150	0.093	-0.033	0.032	-0.013	0.092	0.009	-0.053	0.836**

Notes: PH = plant height at harvest in cm, DM = dry matter at harvest in g m^{-2}, FP = Fertile plants at harvest in nos., DTFPF = Days to 50% flowering, DTHPF = Days to 100% flowering, DTH = Days to harvest, SBP = Secondary branches $plant^{-1}$ in nos., TBP = Tertiary branches $plant^{-1}$ in nos., LSSPS = Length of stem upto starting point of siliqua in cm, SP = Siliqua $plant^{-1}$, SMB = Siliqua main $branch^{-1}$, LS = Length of siliqua in cm, SS = Seeds $siliqua^{-1}$, TW = Test weight in g, * $p \leq 0.05$, **$p \leq 0.01$ and *** $p \leq 0.001$; NS = non-significant expected genetic gain under selection are considerably correlated with seed yield which can consistently be employed for enhancement of seed yield via ancillary selection.

Hierarchical clustering of tested rapeseed-mustard cultivars

Agglomerative Hierarchical Clustering (AHC) was performed for clustering the different homogeneous groups of rapeseed-mustard cultivars on the basis of their yield attributes and seed yields. Based on AHC analysis, a dendrogram is illustrated in Fig. 1 which reveals that eight different types of rapeseed-mustard cultivars (mutant and nationally popular high yielding cultivars) were grouped into three clusters based on the Euclidian distance score at 30. Cluster I included two HYV (RB 50 and Pusa Bold) and three gamma-mutant genotypes (TM 217, TM 106 and TM 204), Cluster II was comprised of one superior gamma-mutant genotype *i.e.* TM 204, and Cluster III included rest other high yielding rapeseed-mustard cultivars (Kranti and B 85).

Our results revealed that higher seed yield could be obtained with the adoption of mutant rapeseed-mustard cultivars than nationally popular high yielding varieties in coastal ecosystem of West Bengal, particularly under late sown condition (on December 1st week) on account of late harvesting of preceding Kharif paddy. Amongst the mutant rapeseed-mustard genotypes *i.e.* TM 143, TM 204 and TM 217 are most suitable for rice-fallow system in coastal region of West Bengal.

ACKNOWLEDGEMENT

The authors are highly grateful to Bhaba Atomic Research Centre (BARC), Trombay, Mumbai (India) for providing research grant.

REFERENCES

Annual Report. (2016-17). Department of Agriculture, Cooperation and Farmers Welfare, Government of India. Available on Web: Available on website: http://agricoop.nic.in/sites/default/files/Annual_rpt_201617_E.pdf

Banerjee, H., Chatterjee, S., Sarkar, S., Gantait, S. and Samanta, S. (2017). Evaluation of rapeseed-mustard cultivars under late sown condition in coastal ecosystem of West Bengal. *Journal of Applied and Natural Science* **9**(2): 940 – 949.

Crop Production Statistics Information System. (2016). Special Data Dissemination Standard Division, Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Govt. of India, New Delhi. Available from URL: (http://aps.dac.gov.in/APY/Index.htm). Accessed on 11 August 2016.

Dutta, A., Banerjee, H., Das, R., Dewanjee, S., Sarkar, S. and Mandal, S. (2017). Performance of yellow coated mustard (*Brassica juncea* L.) mutants under West Bengal condition. *Journal of Crop and Weed* **13**(1): 110-112.

Economic Review. (2015). Department of Statistics and Programme Implementation. Government of West Bengal. 65 p.

Jha, G. K., Pal, S., Mathur, V. C., Bisaria, G., Anbukkani, P., Burman, R. R. and Dubey, S. K. (2012). Edible Oilseeds Supply and Demand Scenario in India: Implications for Policy.

Lodhi, B., Thakral, N. K., Avtar, R. and Singh, A. (2014). Genetic variability, association and path analysis in Indian mustard (*Brassica juncea*). *Journal of Oilseed Brassica* **5**(1): 26-31.

Mishra, J. S., Thakur, N. S., Singh, P., Kubsad, V. S., Kalpana, R., Alse, U. N. and Nemade, S. M. (2014). Tillage and integrated nutrient management in rainy-season grain sorghum (*Sorghum bicolor*). *Indian Journal of Agronomy* **59**(4): 619-623.

Mittal, S. (2008). *Demand-Supply Trends and Projections of Food in India*. Indian Council for Research on International Economic Relations (ICRIER) Working Paper No. 209. New Delhi.

Pandey, S. and Singh, B. (2005). Inter-character association and path analysis in Indian mustard [*Brassica juncea* (L.) Czern & Coss]. *Advances in Plant Science* **18**: 511-514.

Samonte, S. O. P. B., Wilson, L. T. and McClung, A. M. (1998). Path analysis of yield and yield related traits of fifteen diverse rice genotypes. *Crop Science* **38**: 1130-1136.

Scheiner, S. M., Mitchell, R. J. and Callahan, H. S. (2000). Using path analysis to measure natural selection. *Journal of Evolutionary Biology* **13**: 423-433.

Shah, M. S., Verma, N. and Vishwkarma, S. K. (2015). Diversification of rice (*Oryza sativa*)-based cropping system for higher production efficiency, water productivity and economic viability in Madhya Pradesh. *Indian Journal of Agronomy* **60**(1): 5−30.

Sheoran, O. P., Tonk, D. S, Kaushik, L. S., Hasija, R. C. and Pannu, R. S. (1998). statistical software package for agricultural research workers. *Recent Advances in Information Theory, Statistics & Computer Application* D. S. Hooda and R. C. Hasija (eds.), Department of Mathematics & Statistics, CCSHAU, Hisar. pp 139-143.

Sheoran, P., Sardana, V. and Singh, R. (2014). Evaluating productivity potential of spring planted sunflower (*Helianthus annuus*) hybrids in response to sowing time under changing climate scenario. *Indian Journal of Agronomy* **59**(1): 124−132.

Singh, M., Srivastava, R. L., Prasad, L. and Dixit, R. K. (2003). Correlation and path analysis in Indian mustard [*Brassica juncea* (L.) Czern & Coss]. *Advances in Plant Science* **16**: 311-315.

Verma, R., Sharma, R. and Sharma, S. K. (2008). Association studies among yield and its component characters in Indian mustard [*Brassica juncea* (L.) Czern & Coss]. *Indian Journal of Genetics and Plant Breeding* **68**: 87-89.

Ward, J. H. (1963). Hierarchical grouping to optimize an objective function; *Journal of the American Statistical Association* **58**: 236-244.