

Growth and Yield Response by the Seeds Harvested at Different Stages of Siliquae Maturity of Rapeseed-Mustard Varieties

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Abstract: An experiment was conducted at the Regional Agricultural Research Station, Jamalpur, Bangladesh which geographic coordinates located between 24°34' and 25°26' north latitude and between 89°40' and 90°12' east longitude during the period from November, 2015 to March, 2016 to observe the growth and yield performances of the rapeseed-mustard varieties under field condition grown from the seeds of different stages of siliquae maturity of the previous year experiment. Four rapeseed-mustard varieties viz. BARI Sarisha-11 (V₁), BARI Sarisha-14 (V₂), BARI Sarisha-6 (V₃) and Tori-7 (V₄) and seeds of those varieties harvested at four stages of siliquae maturity viz. H₁ = Green stage of siliquae, H₂ = Pale yellow stage of siliquae, H₃ = Golden yellow stage of siliquae and H₄ = Full maturity stage of siliquae were included as the treatments in the experiment. Harvested seeds of the previous year were stored in air tight polythene under freezing condition till set up the experiment. Results revealed that four rapeseed-mustard varieties varied significantly for most of the parameters studied. Variety V₁ produced significantly the highest seed yield (1.99 t ha⁻¹) while the lowest (1.04 t ha⁻¹) was recorded from V₄. Seeds of H₂, H₃ and H₄ stages produced statistically similar and significantly higher seed yield ranges from 1.57-1.65 t ha⁻¹ (H₄>H₃>H₂) than that of H₁ stage which produced the lowest (1.34 t ha⁻¹) mainly due to the poor stand establishment. Interaction effects of varieties and seeds harvested at different stages of siliquae maturity did not show significant variation in expressions of seed yield and yield contributing parameters.

Keywords: Siliquae maturity, Plant establishment, Growth, Yield, Rapeseed-mustard.

INTRODUCTION

Maturity may be defined as the stage of crop growth at which it can be used by the consumers for direct consumption or for products manufacturing based on them. Maturity at the time of harvest is the most important factor that determines post harvest life and final quality of the produce. Harvesting stage of any crop depends on its maturity time and on physiological maturity which influences the quality of seed in relation to germination, vigour, viability and also storability. Optimum quality of seed can be maintained by proper field production practices; especially the appropriate time of seed harvest which allows the seed to escape from attack of pests and diseases. Seeds should be harvested as close as possible to physiological maturity point to obtain the highest seed quality [1]. On the other hand, seeds should be harvested at physiological maturity when it possesses maximum viability and vigour [2]. Harvest of crop at physiological maturity can increase the seed's production, because the ideal harvest period reduces the quantity of immature seeds. Studies on maturation and harvesting of seeds are important as it reaches their high quality in the field [3].

Understanding of mutual relations between the physiological processes associated with seed maturity attributes of seed and seedling vigour may help to enhance field emergence and attain uniform crop stand. As such, harvesting of seeds at right stage of maturity is the most important because harvest at too early or too late result in poor yield. On the other hand, earlier harvesting of any crops have several advantages, such as the reduction of insect and pest attack, yield loss due to field weathering and a better sowing time for the next crops. Under this situation earlier a research was done with the aim to reduce the field duration to accommodate the high yielding rapeseed-mustard varieties in between T. Aman (wet season rice) and Boro (dry season rice) through agronomic manipulations viz. harvesting at green, pale yellow and golden yellow stages of siliquae before attainment of full maturity stage. Early harvest prior to full maturity resulted lowered seed yield and quality on the account of seed immaturity but field performances of the seeds obtained from those stages of siliquae maturity were yet to be known. So, seeds of those siliquae maturity stages were collected and evaluated in the next season

to know the growth and yield performances of the rapeseed-mustard crops under field condition [4].

MATERIALS AND METHODS

The experiment was conducted at the Regional Agricultural Research Station, Jamalpur during *rabi* (winter) season from November, 2015 to March, 2016 to observe the growth and yield performances of the rapeseed-mustard varieties grown from the seeds collected from the crop of different stages of siliquae maturity of the previous season research. The geographic coordinates of the research

area located between 24°34' and 25°26' North latitude and between 89°40' and 90°12' East longitude. Soil samples of 0-15 cm depth were taken prior to sowing of seeds to analyze the physical and chemical properties. Results of the soil analysis have been shown in the Appendix I. All the elements were found above the critical values.

Appendix I: Physical and chemical properties of initial soil samples (0-15 cm depth) of the research plot of Regional Agricultural Research Station, Jamalpur

Physical properties

Soil (cm)	Bulk density (g cm ⁻³)	Particle density (g cm ⁻³)	Porosity (%)	Initial moisture content (%)	Field capacity (%)	Textural class
0-15	1.39	2.62	46.95	24.68	29.4	Loam

Chemical properties

pH	OM	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
		Meq/100g										
6.6	1.19	5.4	1.9	0.10	0.063	21.2	17.0	0.24	2.0	187	18	1.14
Critical value		2.0	0.5	0.12	-	7.0	10.0	0.2	0.2	4.0	1.0	0.6

The treatments of the experiment comprised four rapeseed-mustard varieties *viz.* V₁ = BARI Sarisha-11, V₂ = BARI Sarisha-14, V₃ = BARI Sarisha-6 and V₄ = Tori-7 and four seed sources *viz.* seeds were collected from field experiment of previous *rabi* season 2014-2015 of the above mentioned rapeseed-mustard varieties considering four stages of siliquae maturity i.e. at H₁ = Green siliquae stage harvested seed (BARI Sarisha-11, BARI Sarisha-14, BARI Sarisha-6 and Tori-7 were harvested at 87, 66, 81 and 65 days after sowing), H₂ = Pale yellow siliquae stage harvested seed (BARI Sarisha-11, BARI Sarisha-14, BARI Sarisha-6 and Tori-7 were harvested at 98, 75, 90 and 74 days after sowing), H₃ = Golden yellow siliquae stage harvested seed (BARI Sarisha-11, BARI Sarisha-14, BARI Sarisha-6 and Tori-7 were harvested at 104, 85, 99, 85 days after sowing) and H₄ = Full maturity siliquae stage harvested seed (BARI Sarisha-11, BARI Sarisha-14, BARI Sarisha-6 and Tori-7 were harvested at 109, 89, 102 and 89 days after sowing). Collected seeds from different stages of siliquae maturity were stored in air tight plastic polythene under freezing condition before set up of the experiment. To initiate the field experiment the land was opened on 28 October 2015 with a tractor drawn disc plough followed by disc harrowing. One week later, the land was harrowed, ploughed and cross ploughed several times by power tiller and laddering was done to attain a good tilth. All weeds, stubbles and crop residues were removed from the experimental field. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3m × 4m. The distances between plot to plot and replication to replication were 1m and 1.5m, respectively. As per treatment seeds of four rapeseed-

mustard varieties collected from four stages of siliquae maturity were sown in furrows under good tilth condition. Before sowing seeds were treated with Provax-200 @ 2.5 g powder for kg⁻¹ seed. Seeds were sown continuously in line according to treatments @ 7.0 kg seeds ha⁻¹ at normal *joe* condition of soil on 3 November, 2015. Germination test of the seeds was also performed variety wise in the laboratory before sowing in the field and average 86%, 97%, 99%. 99% germination was found at H₁, H₂, H₃ and H₄ stages of harvest in the previous season respectively. After sowing, the seeds were covered with soil and lightly pressed by hand. For uniform germination, a light irrigation was given in the furrows before sowing of seeds. Line to line distance was 30 cm and number of lines in each plot was ten. Soil Test Based (STB) fertilizer dosages were applied in the crop field [4]. Fertilizers were applied for BARI Sarisha-11 and BARI Sarisha-6 at the rate of 132-14-87-15-0.71-0.7 kg ha⁻¹ N-P-K-S-Zn-B, for BARI Sarisha-14 and Tori-7 at the rate of 99-10.6-58-8.71-0.48-0.7 kg ha⁻¹ N-P-K-S-Zn-B respectively through urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid respectively. Half urea and all other fertilizers were applied as basal during final land preparation. Remaining urea was top dressed at 22 days after emergence of seedlings. Two irrigations were applied at the flower initiation and siliquae development stages of the crop. Weeding and thinning were done at 5-7 days after first irrigation at *joe* condition. During crop growing period different phenological parameters *viz.* days to emergence, days to first flower, days to 50% flower, days to 50% siliquae initiation and days to harvest; plant growth parameters *viz.* plant height (cm) and above ground dry

matter accumulation (g m^{-2}) from 20 DAS to harvest at 20-day intervals were recorded. Prior to harvest, ten plants from each plot were collected randomly to record data on yield contributing parameters as well as morphological parameters like siliqua length. To record seed and stover yield, plants of whole plot were harvested at full maturity stage of crop. The harvested plants were dried in the field plot wise, then threshed and cleaned. The cleaned seeds were dried in the sun for 2-3 days and weighed separately. Dried straw weight was also taken plot wise. Finally seed and stover yields were converted into t ha^{-1} basis. The collected data on each plot were statistically analyzed to obtain the level of significance using the computer based software MSTAT-C [5]. Mean differences among the treatments were tested with Least Significant Difference (LSD) test at 5% level of significance.

RESULTS AND DISCUSSION

Growth parameters of rapeseed-mustard varieties Plant height (cm) at regular 20-day intervals and at harvest

Plant height varied significantly among the varieties at 20, 40, 60, and 80 DAS and at harvest (Fig-1). It increased rapidly from 20 DAS up to 60 DAS followed by a slow increasing pattern till to harvest in both BARI Sarisha-11(V_1) and BARI Sarisha-6(V_3). But in both BARI sarisha-14(V_2) and Tori-7(V_4) plant height increased sharply up to 40 DAS. Then it increased very slowly up to 60 DAS and afterwards, there was no increment up to harvest. BARI sarisha-11(V_1) produced the tallest plant (178.5 cm) at harvest which was superior from all other varieties and the shortest (52.1 cm) was recorded in the variety Tori-7(V_4).

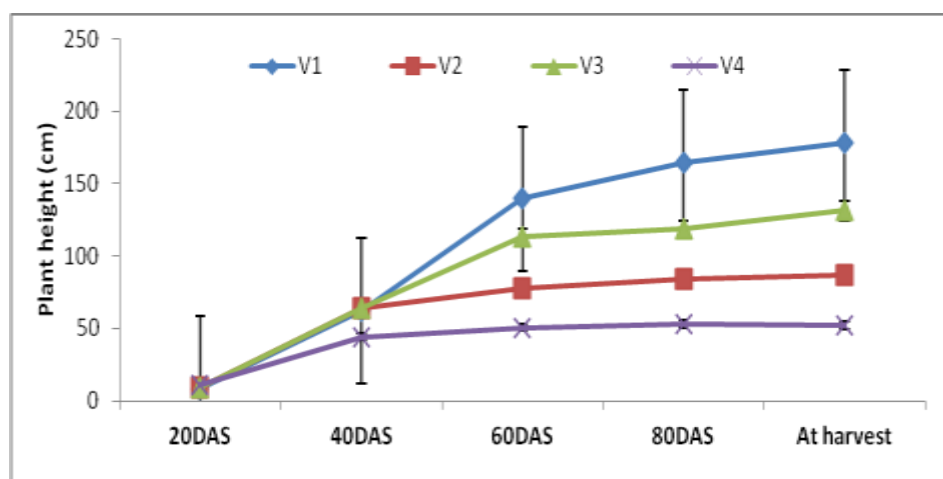


Fig-1: Plant height of different rapeseed-mustard varieties at 20-day intervals irrespective of seeds harvested at different stages of siliquae maturity

Above ground dry matter (AGDM) production (g m^{-2})

AGDM production differed significantly among the rapeseed-mustard varieties at different sampling dates (Fig-2). Results revealed that AGDM increased with age up to harvest. At 20 days after sowing the local variety Tori-7 (V_4) produced the highest dry matter (2.14 g m^{-2}) that was statistically similar with the variety BARI Sarisha-14 (V_2) (1.99 g m^{-2}). Whilst the variety BARI Sarisha-11 (V_1) produced the lowest dry matter weight (1.45 g m^{-2}). Results showed that high yielding varieties produced the higher AGDM than low yielding ones towards

maturity. Sampling at 60 and 80 DAS and at harvest the variety BARI Sarisha-11 (V_1) produced significantly the highest AGDM (151.5 , 243.5 and 579.8 g m^{-2} , respectively). The variety BARI Sarisha-6 (V_3) produced 129.96 , 227.31 and 468.98 g m^{-2} dry matter at 60 & 80 DAS and at harvest respectively. BARI Sarisha-14 (V_2) produced 119.75 , 201.88 and 345.8 g m^{-2} AGDM at 60, 80 DAS and at harvest respectively followed by Tori-7. High yielding genotypes produced greater total dry matter than low yielding ones [6]. The results obtained on AGDM production with different varieties might be due to variation of genetic potential of different species.

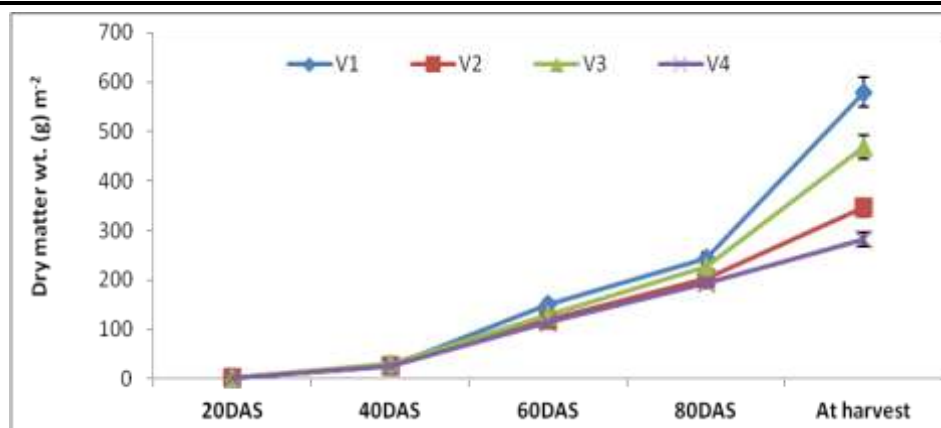


Fig-2: Above ground dry matter (AGDM) production at 20-day intervals in different rapeseed-mustard varieties as influenced by different harvesting stages of siliquae maturity

Phenological parameters of rapeseed-mustard varieties

Days to emergence

The result of the present study revealed that varieties did not differ significantly in terms of length of period to reach the stage of seedling emergence under field condition (Table-1). Numerically, the highest duration (5.08 days) was required for BARI Sarisha-11 (V_1) followed by BARI Sarisha-6 (V_3) (4.83 days). The local variety Tori-7 (V_4) took the lowest duration (4.50 days). Germination period among the varieties may vary due to seed size which varies with food reserves and depth of seed placement. The food reserves play a fundamental role for germination speed as well as seedling size [7, 8].

Days to first flower, 50% flower, 50% siliquae initiation and days to maturity

For each variety, a definite period requires to attain certain phenological stage of growth. Number of days for attainment of different phenological stages differed from variety to variety. The result revealed that days to first flower, 50% flower, 50% siliquae initiation and days to maturity differed significantly among rapeseed-mustard varieties (Table-1). The variety BARI Sarisha-11 (V_1) took significantly the longest period (34.0 days) to initiate first flower. Variety BARI Sarisha-6 (V_3) took the second highest period (32.0 days) to initiate first flower followed by the variety BARI Sarisha-14 (31.0 days). The local variety Tori-7 took the lowest period (22.0 days) to initiate the first flower (Table-1). There were highly significant differences for days to flower initiation in Ethiopian mustard [9]. In case of days to 50% flower and 50% siliquae initiation similar trends were observed as like as days to first flower initiation in this study. Studied with 20 rapeseed-mustard varieties of *B. campestris*, *B. juncea*, *B. napus* it was found that *campestris* group required lowest days to maturity (mean 88 days) followed by *napus* group (average 94 days) while *juncea* group took the longest days to

maturity (mean 100 days) [10]. Similarly, under this study the field duration for maturity (105.0 days) of BARI Sarisha-11 (*B. juncea*) was significantly higher from other varieties. The field duration for maturity (96.0 days) of BARI Sarisha-6 (*B. campestris*) was followed by BARI Sarisha-14 (*B. campestris*) (90.0 days) while the local variety Tori-7 (*B. campestris*) had the lowest (87.0 days) (Table-1).

Morphological parameter of rapeseed-mustard varieties

Siliquae length (cm)

Siliquae length differed significantly among the varieties (Table-1). The varieties differed significantly in respect of siliquae length [11]. The present research study expressed that variety BARI Sarisha-6 (V_3) produced significantly the longest siliquae (5.5 cm). BARI Sarisha-14 (V_2) produced the moderate length of siliquae (4.80 cm) which was at par with the variety Tori-7. The shortest siliquae (3.80 cm) was produced by BARI Sarisha-11 (V_1) (Table 1). Variation in siliquae length among the varieties was observed and it was recorded the longest (8.07 cm) and shortest (4.83 cm) siliquae in advanced lines BLN-900 and Hyola-401, respectively [12].

Yield and yield contributing parameters of rapeseed-mustard varieties irrespective of seeds harvested at different stages of siliquae maturity

Plant population m^{-2} at emergence and harvest

Number of plant population at emergence and harvest did not differ significantly among the rapeseed-mustard varieties (Table-2). At harvest plant population m^{-2} was slightly decreased than at emergence possibly due to survival capacity of plant under competition for surrounding soil moisture, light, nutrients and other microclimatic conditions. At emergence, the number of plant population ranged from 104.0 to 105.0 m^{-2} while at harvest it ranged from 86.0 to 88.0 m^{-2} .

Table-1: Phenological and morphological parameters irrespective of the seeds harvested at different stages of siliquae maturity of rapeseed-mustard during *rabi* (winter) season 2015-2016

Varieties (V)	Days to emergence	Days to first flower initiation	Days to 50% flower initiation	Days to 50 % siliquae initiation	Days to maturity	Siliquae length (cm)
V ₁	5.08	34.0 a	46.0 a	59.0 a	105.0	3.8 c
V ₂	4.50	31.0 c	37.0 c	45.0 c	90.0	4.8 b
V ₃	4.83	32.0 b	41.0 b	49.0 b	96.0	5.5 a
V ₄	4.50	22.0 d	25.0 d	36.0 d	87.0	4.6 b
CV (%)	11.7	2.48	4.45	3.40	2.07	9.62
LSD _{0.05}	-	0.61	1.37	1.34	2.07	0.37
LS	NS	**	**	**	*	**

Note: LS = Level of significance; NS = non-significant; *indicates 5% level of significance; **indicates 1% level of significance; V₁ = BARI Sarisha-11; V₂ = BARI Sarisha-14; V₃ = BARI Sarisha-6; V₄ = Tori-7

Number of siliquae plant⁻¹

Number of siliquae plant⁻¹ was directly related to seed yield and it differed significantly among the varieties (Table-2). The variety BARI Sarisha-11 (V₁) produced significantly the highest number of siliquae (352.0 plant⁻¹) followed by the variety Tori-7 (V₄) (176.0 plant⁻¹). Similarly, the highest number of siliquae plant⁻¹ was found in advanced line BJDH-05 of *B. juncea* [13]. In this study, number of siliquae plant⁻¹ was found 91.0 in the variety BARI Sarisha-6 (V₃). The variety BARI Sarisha-14 (V₂) produced the lowest number of siliquae (66.2 plant⁻¹).

Number of seeds siliqua⁻¹

Number of seeds siliqua⁻¹ also differed significantly among rapeseed-mustard varieties and the variety BARI Sarisha-14 (V₂) produced significantly the highest number of seeds siliqua⁻¹ (33.0). The lowest number of seeds siliqua⁻¹ (12.0) was produced by the variety BARI Sarisha-11 (V₁) (Table-2). In other studies it was found that the highest number of seeds siliqua⁻¹ (27.6) was found in SS-75 of *B. campestris* which was significantly different from all other varieties while the lowest (13.8) was found in J-5004 of *B. juncea* [14].

1000-seed weight (g)

Variations in 1000-seed weight among the varieties were statistically significant (Table 2). The variety BARI Sarisha-14 (V₂) produced significantly the highest 1000-seed weight (3.17 g). BARI Sarisha-6 (V₃) produced the lowest 1000-seed weight (2.53 g) that was statistically similar with the variety BARI Sarisha-11 (2.42 g). Local variety Tori-7 (V₄) produced the medium seed size having 1000-seed weight of 2.81 g. It was found that weight of 1000-seed varies from variety to variety and species to species. Thousand-seed weight ranged from 2.50-2.65 g in case of improved Tori-7 (*B. campestris*) and 1.5-1.80 g in case of Rai (*B. juncea*) [15].

Seed yield (t ha⁻¹)

Seed yield differed significantly among the varieties and the variety BARI Sarisha-11 (V₁) produced significantly the highest seed yield (1.99 t ha⁻¹) which was principally contributed by the highest number of siliquae plant⁻¹ (Table-2). The lowest seed yield (1.04 t ha⁻¹) was recorded from the local variety Tori-7. The variety BARI Sarisha-6 (V₃) produced seed yield (1.82 t ha⁻¹) significantly different from all others. Seed yield variation existed among rapeseed-mustard varieties, whereas the highest seed yield was observed in BARI Sarisha-7, BARI Sarisha-8 and BARI Sarisha-11 (2.00-2.50 t ha⁻¹) and the lowest yield in variety Tori-7 (0.95-1.10 t ha⁻¹) [16].

Stover yield (t ha⁻¹)

Stover yield also differed significantly among the varieties (Table-2). Dry matter production in crops importantly determined by varietal characteristics was reported [17]. In this study, the variety BARI Sarisha-11 (V₁) produced significantly the highest stover yield (5.02 t ha⁻¹) that was statistically similar with the variety BARI Sarisha-6 (4.90 t ha⁻¹). The stover yield 3.70 t ha⁻¹ was obtained from the variety BARI Sarisha-14 (V₂) while the lowest stover yield 1.98 t ha⁻¹ was obtained from the local variety Tori-7 (V₄).

Effects of seeds harvested at different stages of siliquae maturity on crop growth parameters

Plant height (cm) at regular 20-day intervals and at harvest

Plant height at all sampling dates did not show significant variation among the seeds harvested at different stages of siliquae maturity under field condition (Table 3). Seeds of the varieties V₁, V₂, V₃ and V₄ of the H₁ stage collected at 87, 66, 81 and 65 days after sowing in the previous season produced the shortest plant 9.1, 56.8, 91.4, 102.7 and 110.1 cm at 20, 40, 60, 80 DAS and at harvest while seeds of the H₄ stage collected at 109, 89, 102 and 89 days after sowing produced the tallest plant 9.8, 60.5, 100.2, 108.3 and 114.8 cm at 20, 40, 60, 80 DAS and at harvest respectively.

Table-2: Yield and yield contributing parameters irrespective of the seeds harvested at different stages of siliquae maturity of rapeseed-mustard varieties during *rabi* (winter) season 2015-2016

Varieties (V)	Plant population m ⁻² at emergence	Plant population m ⁻² at harvest	Number of siliquae plant ⁻¹	Number of seeds siliqua ⁻¹	1000-seed weight (g)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)
V ₁	104.0	88.0	352.0 a	12.0 c	2.42 c	1.99 a	5.02 a
V ₂	105.0	88.0	66.2 d	33.0 a	3.17 a	1.34 c	3.70 b
V ₃	106.0	88.0	91.0 c	19.0 b	2.53 c	1.82 b	4.90 a
V ₄	105.0	86.0	176.0 b	19.0 b	2.81 b	1.04 d	1.98 c
CV (%)	3.67	4.24	8.66	7.98	6.52	10.17	10.49
LSD _{0.05}	-	-	12.36	1.382	0.14	0.132	0.33
LS	NS	NS	**	**	**	**	**

Note: LS = Level of significance; NS = non-significant; ** = 1% level of significance; V₁ = BARI Sarisha-11; V₂ = BARI Sarisha-14; V₃ = BARI Sarisha-6; V₄ = Tori-7

Table-3: Plant height of rapeseed-mustard at regular 20-day intervals as influenced by the seeds harvested at different stages of siliquae maturity of rapeseed-mustard during *rabi* (winter) season 2015-2016

Harvesting stages of seeds (H)	Plant height (cm) at 20-day intervals				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
H ₁	9.1	56.8	91.4	102.7	110.1
H ₂	9.3	57.7	93.6	104.0	111.2
H ₃	9.5	59.6	96.0	105.6	112.6
H ₄	9.8	60.5	100.2	108.3	114.8
CV (%)	10.6	7.80	4.80	4.74	3.98
LS	NS	NS	NS	NS	NS

Note: LS = Level of significance; NS = non-significant; H₁ = Green siliquae stage harvested seed; H₂ = Pale yellow siliquae stage harvested seed; H₃ = Golden yellow siliquae stage harvested seed; H₄ = Full maturity siliquae stage harvested seed

Above ground dry matter (AGDM) production (g m⁻²)

The results presented in Table 4 revealed that AGDM weight differed significantly among the seeds harvested at different stages of siliquae maturity at 20, 40 and 60 days after sowing and later on it did not differ. At the earlier sampling dates the seeds of full maturity stage (H₄) produced the highest AGDM weight followed by seeds of golden yellow siliquae stage (H₃). The seeds of green siliquae stage produced

the lowest AGDM weight. These findings confirm that seed vigor may affect plant dry matter accumulation during the first stages of development. It might be due to most plant tissues involved in the production of dry matter are formed after seedling emergence and it seems unlikely that seed vigor would influence their ability to carry out physiological processes and accumulated dry matter during the whole vegetative stages of development [18].

Table-4: Above ground dry matter (AGDM) accumulation at regular 20-day intervals as influenced by the seeds harvested at different stages of siliquae maturity of rapeseed-mustard during *rabi* (winter) season 2015-2016

Harvesting stages of seeds (H)	AGDM (g m ⁻²) at 20-day intervals				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
H ₁	1.63 c	24.5 c	112.4 c	207.8	414.6
H ₂	1.72 bc	26.8 bc	116.5 c	209.9	416.7
H ₃	1.90 b	29.2 ab	131.6 b	220.2	415.4
H ₄	2.06 a	31.7 a	154.3 a	227.8	430.8
CV (%)	10.91	11.5	10.6	9.82	5.55
LSD _{0.05}	0.166	2.68	11.34	-	-
LS	**	**	**	NS	NS

Note: LS = Level of significance; NS = non-significant; ** indicates 1% level of significance; H₁ = Green siliquae stage harvested seed; H₂ = Pale yellow siliquae stage harvested seed; H₃ = Golden yellow siliquae stage harvested seed; H₄ = Full maturity siliquae stage harvested seed

Effects of seeds harvested at different stages of siliquae maturity on phenological and morphological parameters

The seeds of green siliquae stage (H_1) took the highest period (5.20 days) while the seeds of pale yellow stage of siliquae maturity (H_2) took the lowest period (4.42 days) to emerge under field condition (Table-5). Days to first flower initiation did not differ

significantly among seeds of different harvesting stages of siliquae maturity and it ranged from 29.0 to 30.0 days. Days to 50% flower, days to 50% siliquae initiation and days to maturity ranged from 36.0 to 37.0 days, 47.0 to 48.0 days and 94.0 to 95.0 days respectively. Morphological character of siliquae length did not differ significantly while it ranged from 4.64 cm to 4.70 cm (Table-5).

Table-5: Phenological and morphological parameters as influenced by the seeds harvested at different stages of siliquae maturity of rapeseed-mustard irrespective of varieties during *rabi* (winter) season 2015-2016

Harvesting stages of seeds (H)	Days to emergence	Days to flower initiation	Days to 50% flower initiation	Days to 50% siliquae initiation	Days to maturity	Siliquae length (cm)
H_1	5.20 a	30.0	37.0	48.0	95.0	4.70
H_2	4.42 b	29.0	36.0	47.0	94.0	4.70
H_3	4.70 b	30.0	37.0	48.0	94.0	4.70
H_4	4.75 ab	29.0	37.0	47.0	94.0	4.64
CV (%)	11.7	2.48	4.45	3.40	2.07	9.62
LSD _{0.05}	0.49	-	-	-	-	-
LS	*	NS	NS	NS	NS	NS

Note: LS = Level of significance; NS = non-significant; * = 5% level of significance; H_1 = Green siliquae stage harvested seed; H_2 = Pale yellow siliquae stage harvested seed; H_3 = Golden yellow siliquae stage harvested seed; H_4 = Full maturity siliquae stage harvested seed

Yield and yield contributing parameters of rapeseed-mustard varieties as influenced by the seeds harvested at different stages of siliquae maturity

The result revealed that at sowing seeds of the pale yellow stage of siliquae maturity (H_2) produced the highest population (109.0 plants m^{-2}) that was statistically similar with seeds of full maturity stage (H_4) (Table-6). Seeds of golden yellow stage of siliquae maturity (H_3) produced the medium population density (106.0 plants m^{-2}) that was also statistically similar with seeds of full maturity stage. Seeds of green stage of siliquae maturity (H_1) produced the lowest population at sowing (97.0 plants m^{-2}) and at harvest (79.0 plants m^{-2}) (Table 6). Number of siliquae plant⁻¹ ranged from 167 to 174, number of seeds

siliqua⁻¹ ranged from 20 to 21 and 1000-seed weight varied from 2.64 to 2.80 g among the treatments of seeds of different harvesting stages (Table 6). Harvesting stage of siliquae with advancement of maturity increased significantly the seed yield of rapeseed-mustard. The highest seed yield (1.65 t ha⁻¹) was obtained from full maturity stage (H_4) of siliquae maturity that was statistically similar with pale yellow (H_2) (1.57 t ha⁻¹) and golden yellow (H_3) (1.63 t ha⁻¹) stages of siliquae maturity. The increase in yield in H_2 , H_3 and H_4 stages compared to H_1 stage was 17%, 22.0% and 23.0% which might be attributed to number of siliquae plant⁻¹ and 1000-seed weight (g) [19, 20]. Stover yield ensured the trends as like as seed yield (Table-6).

Table-6: Yield and yield contributing parameters as influenced by the seeds harvested at different stages of siliquae maturity of rapeseed-mustard irrespective of varieties during *rabi* (winter) season 2015-2016

Harvesting stages of seeds (H)	Plant population m^{-2} at sowing	Plant population m^{-2} at harvest	Number of siliquae plant ⁻¹	Number of seeds siliqua ⁻¹	1000-seed weight (g)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)
H_1	97.0 c	79.0 c	167.0	21.0	2.64	1.34 b	3.34 b
H_2	109.0 a	92.0 a	171.0	20.0	2.75	1.57 a	3.91 a
H_3	106.0 b	88.0 b	174.0	21.0	2.80	1.63 a	4.06 a
H_4	107.0 ab	91.0 a	173.0	20.4	2.80	1.65 a	4.23 a
CV (%)	3.67	4.24	8.66	7.98	6.52	10.17	10.49
LSD _{0.05}	3.21	3.10	-	-	-	0.13	0.33
LS	**	**	NS	NS	NS	**	**

Note: LS = Level of significance; NS = non-significant; ** indicates 1% level of significance; H_1 = Green siliquae stage harvested seed; H_2 = Pale yellow siliquae stage harvested seed; H_3 = Golden yellow siliquae stage harvested seed; H_4 = Full maturity siliquae stage harvested seed

Interaction effects of rapeseed-mustard varieties and seeds harvested at different stages of siliquae maturity on crop growth parameters**Plant height (cm) and above ground dry matter (AGDM) weight (g m^{-2}) at regular 20-day intervals and at harvest**

Plant height did not differ significantly due to interaction of different rapeseed-mustard varieties and seeds of different harvesting stages of siliquae maturity (Table-7). It was found that at 20 DAS plant height ranged from 7.8 cm in the interaction of $V_1 \times H_1$ to 11.3 cm in $V_4 \times H_4$ interaction. At 40 DAS, $V_2 \times H_4$ interaction had the tallest plant (66.5 cm) while in $V_4 \times H_1$ had the shortest plant (42.3 cm). At 60, 80 DAS and at harvest $V_1 \times H_4$ interaction produced the tallest plant while $V_4 \times H_1$ interaction produced the shortest plant. AGDM weight did not differ significantly due to interaction of different mustard varieties and seeds of different harvesting stages of siliquae maturity (Table 7). However, numerically the highest AGDM weight 187.0, 267.0 and 603.7 g m^{-2} was recorded from $V_1 \times H_4$ interaction at 60, 80 DAS and at harvest respectively. At the same time the lowest AGDM weight 30.40, 53.9 and 75.1 g m^{-2} was recorded from $V_4 \times H_1$ interaction. The variety BARI Sarisha-6 along with seeds of full maturity stage produced medium AGDM weight of 101.2, 183.0 and 270.0 g m^{-2} at 60, 80 DAS and at harvest, respectively.

Interaction effects of varieties and seeds harvested at different stages of siliquae maturity on phenological, morphological, yield and yield contributing parameters

Days to emergence, days to first flower, days to 50% flower, days to 50% siliquae initiation, days to maturity and siliquae length did not differ significantly due to interaction effects of rapeseed-mustard varieties and seeds of different harvesting stages of siliquae maturity (Table 8). All varieties along with seeds of green stage of siliquae maturity took the longer period for studied parameters than other interaction. Numerically, days to first flower initiation were lowest in local Tori-7 variety followed by the variety BARI

Sarisha-14. The variety BARI Sarisha-11 along with all harvesting stages took the longer period. Similar trends were observed in case of days to 50% flower and 50% siliquae initiation. The highest field duration (106.0 days) was found for the interaction of $V_1 \times H_1$ and $V_1 \times H_3$ and lowest duration was found (85.0 days) for interaction of $V_4 \times H_3$ (Table 8). The longest siliquae (5.84 cm) was found for the interaction of $V_3 \times H_2$ and the shortest (3.53 cm) was found for the interaction of $V_1 \times H_3$ (Table-8). Plant population (m^{-2}) differed significantly due to the interaction effect of different rapeseed-mustard varieties and seeds of different harvesting stages of siliquae maturity (Table 9). At emergence, interaction of $V_1 \times H_2$ produced the highest population (112.2 plant m^{-2}) that was statistically similar with the interactions of $V_1 \times H_3$, $V_2 \times H_4$, $V_2 \times H_2$, $V_3 \times H_3$, $V_3 \times H_4$ and $V_4 \times H_3$. All the varieties along with seeds of green stage of siliquae maturity (H_1) produced the lowest population m^{-2} . At harvest trends were observed as like as emergence for all interactions of varieties and harvesting stages of seeds. Though in case of siliquae plant⁻¹, interaction effects of varieties and seeds of different harvesting stages of siliquae maturity showed no significant effect but numerically the highest number of siliquae (358.0 plant⁻¹) was observed in $V_1 \times H_3$ interaction and the lowest number of siliquae (64.0 plant⁻¹) was observed in $V_2 \times H_1$ interaction (Table-9). Interaction effects of varieties and seeds harvested at different stages of siliquae maturity on the number of seeds siliqua⁻¹ was statistically identical though numerically the highest number of seeds siliqua⁻¹ (35.0) was noted in $V_2 \times H_3$ interaction. The interaction effect of variety \times seeds of different harvesting stages of siliquae maturity was not significant in respect of 1000-seed weight. However, apparently 1000-seed weight was found higher 3.22 g in $V_2 \times H_2$ interaction and lower was 2.24 g in $V_1 \times H_1$ interaction. Interaction effects was not significant for seed yield and $V_1 \times H_4$ and $V_3 \times H_4$ gave the highest seed yield (2.06 t ha^{-1}) while $V_4 \times H_1$ gave the lowest (0.99 t ha^{-1}) (Table-9). The highest stover yield (5.63 t ha^{-1}) was found in $V_1 \times H_4$ interaction and the lowest 1.88 t ha^{-1} was found in $V_4 \times H_1$ interaction (Table-9).

Table 7: Interaction effects of varieties and seeds harvested at different stages of siliquae maturity on plant height and above ground dry matter (AGDM) accumulation of rapeseed-mustard at regular 20-day intervals during *rabi* (winter) season 2015-2016

Interaction (V × H)	Plant height (cm) at 20-day intervals					Above ground dry matter weight (g m ⁻²) at 20-day intervals				
	20DAS	40DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
V ₁ × H ₁	7.8	60.6	133.5	160.4	176.4	1.19	22.3	125.5	219.9	564.9
V ₁ × H ₂	7.9	62.6	136.7	162.0	177.2	1.30	24.7	130.0	229.7	564.6
V ₁ × H ₃	8.0	62.8	139.7	165.8	179.1	1.55	27.8	163.2	256.8	586.1
V ₁ × H ₄	8.9	63.1	148.1	170.5	181.1	1.74	30.6	187.2	267.8	603.7
V ₂ × H ₁	9.3	62.3	75.6	81.9	85.7	1.83	23.7	106.0	208.9	350.5
V ₂ × H ₂	9.4	62.6	76.3	83.6	86.1	1.83	25.1	108.5	198.4	350.1
V ₂ × H ₃	9.8	64.9	78.8	84.2	87.1	1.91	26.1	115.4	194.7	325.4
V ₂ × H ₄	9.8	66.5	81.2	87.5	90.9	2.41	31.2	149.0	205.3	356.9
V ₃ × H ₁	8.7	61.7	108.8	117.2	128.4	1.50	30.7	116.7	219.1	472.4
V ₃ × H ₂	8.8	62.4	112.1	118.4	130.4	1.55	32.9	124.6	224.4	467.7
V ₃ × H ₃	8.8	65.8	114.1	119.1	131.2	1.80	33.1	131.7	232.5	465.8
V ₃ × H ₄	9.2	65.7	116.9	120.9	133.0	1.91	35.3	146.8	233.2	469.9
V ₄ × H ₁	10.9	42.3	47.7	51.4	49.9	2.00	21.3	101.2	183.0	270.6
V ₄ × H ₂	10.9	43.5	49.3	52.1	51.1	2.19	24.6	102.7	186.9	284.4
V ₄ × H ₃	11.2	45.0	51.2	53.3	53.1	2.19	29.7	115.9	196.7	284.2
V ₄ × H ₄	11.3	46.6	54.3	54.3	54.3	2.19	29.7	133.9	205.1	292.6
CV (%)	10.6	7.76	4.80	4.74	3.98	10.9	11.4	10.6	8.63	5.55
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: NS = Non-significance; V₁ = BARI Sarisha-11; V₂ = BARI Sarisha-14; V₃ = BARI Sarisha-6; V₄ = Tori-7; H₁ = Green siliquae stage harvested seed; H₂ = Pale yellow siliquae stage harvested seed; H₃ = Golden yellow siliquae stage harvested seed; H₄ = Full maturity siliquae stage harvested seed.

Table-8: Interaction effects of varieties and seeds of different harvesting stages of siliquae maturity on phenological and morphological parameters of rapeseed-mustard during *rabi* (winter) season 2015-2016

Interaction (V × H)	Days to emergence	Days to first flower initiation	Days to 50% flower initiation	Days to 50 % siliquae initiation	Days to maturity	Siliquae length (cm)
V ₁ × H ₁	5.0	34.0	48.0	61.0	106.0	4.25
V ₁ × H ₂	4.70	34.0	44.0	56.0	103.0	3.70
V ₁ × H ₃	5.33	35.0	46.0	61.0	106.0	3.53
V ₁ × H ₄	5.00	34.0	45.0	57.00	103.0	3.80
V ₂ × H ₁	4.70	31.0	37.0	46.0	91.0	4.71
V ₂ × H ₂	4.33	30.0	36.0	45.0	91.0	4.59
V ₂ × H ₃	4.33	30.0	37.0	45.0	88.0	5.05
V ₂ × H ₄	4.70	31.0	37.0	46.0	90.0	4.71
V ₃ × H ₁	5.33	31.0	40.0	48.0	95.0	5.23
V ₃ × H ₂	4.33	32.0	40.0	49.0	95.0	5.84
V ₃ × H ₃	4.70	32.0	42.0	51.0	99.0	5.69
V ₃ × H ₄	5.00	31.0	40.0	48.0	96.0	5.30
V ₄ × H ₁	5.33	22.0	25.0	37.0	89.0	4.77
V ₄ × H ₂	4.33	22.0	25.0	37.0	86.0	4.65
V ₄ × H ₃	4.33	21.0	25.0	36.0	85.0	4.45
V ₄ × H ₄	4.33	21.0	25.0	36.0	86.0	4.76
CV (%)	11.7	2.48	4.45	3.40	2.07	9.62
F-test	NS	NS	NS	NS	NS	NS

Note: NS = Non-significance; V₁ = BARI Sarisha-11; V₂ = BARI Sarisha-14; V₃ = BARI Sarisha-6; V₄ = Tori-7; H₁ = Green siliquae stage harvested seed; H₂ = Pale yellow siliquae stage harvested seed; H₃ = Golden yellow siliquae stage harvested seed; H₄ = Full maturity siliquae stage harvested seed

Table-9: Interaction effects of varieties and seeds harvested at different stages of siliquae maturity on yield and yield contributing parameters of rapeseed-mustard during rabi (winter) season 2015-2016

Interaction (V × H)	Plant population m ⁻² at emergence	Plant population m ⁻² at harvest	Number of siliquae plant ⁻¹	Number of seeds siliqua ⁻¹	1000- seed weight (g)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)
V ₁ × H ₁	88.7 e	72.7 g	341.0	13.0	2.24	1.89	4.11
V ₁ × H ₂	112.2 a	96.9 a	352.3	12.0	2.44	2.00	5.10
V ₁ × H ₃	108.2 a-d	93.1 a-d	358.0	11.0	2.44	2.04	5.24
V ₁ × H ₄	105.0 b-d	90.1 b-e	355.4	12.0	2.58	2.06	5.63
V ₂ × H ₁	92.2 e	73.1 g	64.4	34.0	3.11	1.08	3.10
V ₂ × H ₂	110.6 a-c	95.0 ab	66.0	33.0	3.22	1.41	3.74
V ₂ × H ₃	104.6 cd	87.3 d-f	67.5	35.0	3.21	1.44	3.86
V ₂ × H ₄	111.9 a	96.5 a	67.1	33.0	3.20	1.44	4.02
V ₃ × H ₁	103.1 d	85.3 ef	91.0	20.0	2.50	1.40	4.30
V ₃ × H ₂	111.3 ab	94.0 a-c	91.4	20.0	2.50	1.84	4.92
V ₃ × H ₃	103.3 d	84.5 ef	92.2	19.0	2.59	1.97	5.13
V ₃ × H ₄	106.8 a-d	88.6 c-f	91.0	18.0	2.58	2.06	5.17
V ₄ × H ₁	105.3 b-d	85.3 ef	171.0	19.0	2.75	0.99	1.88
V ₄ × H ₂	103.6 d	83.6 f	176.0	18.0	2.85	1.04	1.91
V ₄ × H ₃	106.1 a-d	85.8 ef	177.0	20.0	2.81	1.06	2.03
V ₄ × H ₄	105.4 b-d	87.9 c-f	180.0	19.0	2.82	1.06	2.12
CV (%)	3.67	4.24	8.66	7.98	6.52	10.17	10.19
LSD _{0.05}	6.427	6.183	-	-	-	-	-
F-test	**	**	NS	NS	NS	NS	NS

Note: **indicates 1% level of significance; NS = non-significant; V₁ = BARI Sarisha-11; V₂ = BARI Sarisha-14; V₃ = BARI Sarisha-6; V₄ = Tori-7; H₁ = Green siliquae stage harvested seed, H₂ = Pale yellow siliquae stage harvested seed, H₃ = Golden yellow siliquae stage harvested seed, H₄ = Full maturity siliquae stage harvested seed

The result discussed ahead of revealed that the variety BARI Sarisha-11 took the longest period to attain all phonological stages and produced the highest seed yield. The seeds of H₂, H₃ and H₄ stages of siliquae maturity produced the highest and statistically similar seed yield. Interaction effects of varieties and seeds harvested at different stages of siliquae maturity showed non-significant variation among the maximum studied parameters.

CONCLUSION

The overall result revealed that the highest seed yield (t ha⁻¹) was observed in BARI Sarisha-11 which was supported by the highest number of siliquae plant⁻¹ and lowest yield was found in local variety Tori-7. Among the seeds harvested at different stages of siliquae maturity, the seeds harvested at pale yellow (H₂), golden yellow (H₃) and full maturity (H₄) stages of siliquae produced statistically similar and higher seed yield while seeds of green stage of siliquae (H₁) produced the lowest might be due to the lowest stand establishment under field condition. Hence, pale yellow siliquae maturity stage may be suggested for harvesting of rapeseed-mustard to reduce the field duration for successful cultivation of the next Boro (dry season) rice crop.

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