INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 14, No. 6, p. 151-163, 2019

RESEARCH PAPER OPEN ACCESS

Effects of agronomic management practices on yield and field duration of mustard between fallow period of *T. Aman* and *Boro* rice

A.H.M. Motiur Rahman Talukder[1,2*], Mrityunjoy Biswas[1,3], Mohammad Noor Hossain Miah[1], Md. Abul Kashem[4], Lutfun Nahar[5], Md. Rafat-Al-Foysal[1]

[1]*Department of Agronomy and Haor Agriculture, Sylhet Agricultural University, Sylhet-3100, Bangladesh*

[2]*Plant Physiology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701, Bangladesh*

[3]*Department of Agro-product Processing and Technology, Jashore Science and Technology University, Jashore -7400, Bangladesh*

[4]*Department of Soil Science, Sylhet Agricultural University, Sylhet-3100, Bangladesh*

[5]*Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh*

Key words: Agronomic management, Yield, Field duration, Mustard.

http://dx.doi.org/10.12692/ijb/14.6.151-163 Article published on June 16, 2019

Abstract

Keeping in mind to grow the mustard after harvesting of long duration *T. Aman* rice for succeeding cultivation of *Boro* rice in optimum time through agronomic management practices an experiment was carried out during November, 2014 to January, 2015.The experiment was designed in split plot with three replications including treatments of factor A: two Sowing dates: D_1=3 November, 2014, D_2=15 November, 2014 and factor B: four harvesting stages: H_1=Green siliquae stage, H_2=Pale yellow siliquae stage, H_3=Golden yellow siliquae stage and H_4=Full maturity siliquae stage. The main plot and sub-plot consisted of sowing dates and harvesting stages, respectively. Sowing dates and harvesting stages significantly influenced the most of the parameters independently but their interaction showed non-significant effects. For sowing dates, D_1; 03 November sown crop produced the comparatively higher yield contributing character such as number of siliquae plant^{-1} (55.0) and seed yield (1.15 t ha^{-1}). In case of harvesting stages, subsequent to green siliquae stage rest all harvesting stages produced higher and almost similar values for all yield contributing characters and seed yield. So, considering the field uninhabited mustard would be harvested at pale yellow siliquae stage for succeeding cultivation of *Boro* rice in due time. But, their combined effect showed non-significant result for all phenological, morphological, yield contributing characters and yield of crop. Therefore, the present study showed possibility to grow mustard after harvest of *T. Aman* rice for succeeding cultivation of *Boro* rice in due time through sacrificing some mustard seed yield.

* **Corresponding Author:** A.H.M. Motiur Rahman Talukder ✉ motiurbari@yahoo.com

Introduction

Bangladesh is now self-sufficient in rice production (Bell *et al.,* 2015) and also gradually entering in to the export regime (BER, 2015). But the country is very much reliant in case of mustard edible oil to meet up the demand of existing population because there is a large gap between supply and demand. Malik (2013) stated that the country is producing about 0.36 million tons of mustard edible oil year^{-1} as against the total demand of 1.4 million tons still rapeseed-mustard ranked first among oilseed crops in Bangladesh as well as the second largest oilseed crop after soybean in the worldwide (FAO, 2015). To make a balance between supply and demand of oil yield, production potentiality of rapeseed-mustard can be increased possibly using HYV's and/or different agronomic management practices. Among the agronomic management practices sowing date and timely harvest may be a vital precondition for remarkable yields and quality of crops. Sowing date plays an important role to fully develop the genetic potentiality of any crop due to it provides the conductive condition for growth and development. Delayed sowing influences both the growth and development of crop by producing the weak plants with poor root system. The sowing or planting time research of any field crops is run not only for complimentary environment for its growth and development but also for creating the space to accommodate extra crop that escalate the cropping intensity. The effective usage of natural sources in agriculture can be made through sowing of two or more crops by adjusting the sowing date. Sowing date is known to influence the level of damage resulting from insect, pest attacks and makes the plant compensate for this damage. Proper time of sowing helps any crop to express its growth patterns to its full extent in a diverse setting of environment. Harvesting stage is one of the most important factor that influences the seed and nutritional quality of fruit and vegetables (Kader, 1986), rapeseed-mustard (price *et al.,* 1996). Price *et al.,* (1996) stated that seed or siliquae shattering is a major problem in rapeseed-mustard production in worldwide that reduce the 50% seed yield if harvesting is delayed. So, it is necessary to harvest the crop at a time as close as possible to the physiological maturity stage (after the stabilization of dry matter translocation to the seeds) (Marcos-filho *et al.,* 1981). Crop duration ratio is a fraction of the year in which the cropland is covered with crops that means of land use intensity, which takes also the length of cropping periods into account. Land use intensification is normally achieved either by increasing the yield per unit area of individual crops or by increasing the number of crops sown on a particular area of land, or both (Gregory *et al.,* 2002). Growth duration of crop is a major constraint in case of land use intensification through incorporating a large number of crops. Further Talukder (2018) stated that farmers usually cultivate the local long duration and/or HYV'S of *T. Aman* rice in northern part of Bangladesh for getting higher yield that may be harvested within last week of October to first week of November or in an extended period. As a result farmers' show the disinterestedness in rapeseed-mustard cultivation excusing the *Boro* rice cultivation in optimum time. As Choudhury and Guha (2000) stated that higher grain yield of *Boro* rice is obtained when transplanting is carried out no later than 25 January, after the date grain yield declines significantly. So, there would have the opportunity for cultivation of rapeseed-mustard crop after harvesting of *T. Aman* rice for optimum planting time of *Boro* rice in the last week of January.

Thus, the main objective of the present study was to view the effect of sowing dates (after harvesting of *T. Aman* rice) and harvesting stages of rapeseed-mustard (to cultivate the *Boro* rice in optimum time) that would have made space to fit rapeseed-mustard in fallow period of *T. Aman* and *Boro* rice in northern part of Bangladesh. The result of the study would be helpful for farmers' in accommodating of rapeseed-mustard in fallow period of *T. Aman* and *Boro* rice that will escalate our cropping intensity as well as edible oil yield.

Materials and methods

Experimental location and climatic condition

The experiment was conducted at Regional

Agricultural Research Station (RARS), Jamalpur under Bangladesh Agricultural Research Institute (BARI), located in between 24°34′ and 25°26′ North latitudes and between 40°89′ and 12°90′ East longitudes. The soil of the experimental area belongs to the Dark Grey Floodplain soil under AEZ-9 (UNDP & FAO, 1988).

The land type was medium high and above flood level. Soil samples of 0-15 cm depth were taken and analyzed in the laboratory prior to sowing of seeds to determine physical and chemical properties of soil. The soil of the experimental field was silty loam texture. Bulk density and particle density values were 1.39 and 2.62 g cc^{-1} respectively with 39.1% pore space. Initial soil moisture and field capacity were 24.68% and 29.4% respectively. The soil pH was 6.6 and contained 1.19% organic matter. Results also revealed that, the site was very low in nitrogen, medium in phosphorus, low in potassium and very low in boron (Table 1).

Experimental treatment

The experiment comprised of two factors *viz.* Factor A: two Sowing dates: D_1 = 3 November, 2014, D_2 = 15 November, 2014; Factor B: four harvesting stages: H_1= Green siliquae stage, H_2= Pale yellow siliquae stage, H_3= Golden yellow siliquae stage and H_4= Full maturity siliquae stage. Green siliquae stage was determined just at 7-10 days after when all flowers are droppings of crop plants while the pale yellow siliquae stage was determined when 40%-50% bearing turned into light yellow in color. The golden yellow siliquae stage was determined when 70%-80% bearing turned into deep yellow in color and full maturity siliquae stage was determined when lower bearing just burst out.

Land preparation

The land was opened on 25 October at 10 days prior of sowing rapeseed-mustard seed just after harvest of preceding *T. Aman* rice with a tractor drawn disc plough followed by disc harrowing during crop growing periods of 2014-2015. Before sowing of rapeseed-mustard seed again the corner of the plots were spaded, the land was harrowed, ploughed and cross ploughed 2-3 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 unit plot was spaded one day before planting for loosening the soils and incorporating the fertilizers applied as basal. The boundary around individual plots were made firm enough to control water movement between plots.

Experimental design

Split-plot design was used in the experiment. Sowing dates were assigned in main plot and harvesting stages were assigned in the sub-plot. The whole experimental plot was divided into three blocks each of which representing a replication. Each plot was measured in 5 m × 3 m. Line to line distance was 30 cm.

Fertilizer application

The crops were fertilized with Soil Test Based (STB) dose as per FRG (2012) by using the following formula:

$$F_r = U_f - \frac{C_i}{C_s} \times (S_t - L_s)$$

Where, Fr = Fertilizer nutrient required for given soil test value

U_f = Upper limit of the recommended fertilizer nutrient for the respective STVI class

C_i = Units of class intervals used for fertilizer nutrient recommendation

C_s = Units of class intervals used for STVI class

S_t = Soil test value

L_s= Lower limit of the soil test value within STVI class

Fertilizers were applied for the experimented rapeseed-mustard variety BARI Sarisha-14 at the rate of 99-10.6-58-8.71-0.48-0.7 kg ha^{-1} N-P-K-S-Zn-B 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 sowing of seeds. Well decomposed cowdung was applied @ 5.0 t ha^{-1} (FRG, 2012).

Seed treatment and seed sowing

Before sowing, seeds were treated with Provax 200-EC @ 2.5 g powder for kg^{-1} seed to prevent seed and soil borne diseases. With good tilth condition, furrows were made with hand rakes for sowing. Seeds were sown continuously in line @ 7.0 kg ha^{-1} at field capacity condition maintaining spacing 30 cm between lines. For confirmation of uniform germination, light watering was done in the furrows by a cane before sowing of seeds. After sowing, seeds were covered with soil and lightly pressed by hand.

Harvesting and sampling

The crops were harvested at different dates on the basis of harvesting stage (based on external color of siliquae). The harvesting time varied according to treatments among the harvesting stages.

Data recorded of field experiments

During crop growing period phenological parameters such as days to emergence, days to 50% flowering, and field duration (days to harvest) were recorded. During the harvesting ten plants were selected randomly from each plot for collecting of morphological, yield contributing and yield data of mustard.

The harvest index was calculated on the ratio of economic yield (seed yield) to biological yield (seed yield + stover yield) and expressed in terms of percentage. It was calculated by using the following formula (Sharma and Mittra, 1988).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (Grain weight)}}{\text{Biological yield (Grain + stover weight)}}$$

Statistical analysis

The collected data of each plot were compiled and tabulated in proper form for statistical analysis.

Statistical analysis was done find out the significance differences among the yield and other agronomic characters of the crop was made following analysis of variance technique with the help of computer program MSTAT-C developed by Russel (1986) and MS-excel. Mean differences among the treatments were tested with Least Significant Difference (LSD) test at 5% level of significance wherever F-values were significant.

Results and discussion

Effect of sowing dates

Days to emergence: Seedling emergence is the significant step in the life cycle of a crop. Emergence of seedling depends on soil moisture, seeding depth; climatic condition and seed size. Under this study insignificantly days required for emergences of seedling were 4.93 and 4.97 for 3 November and 15 November sown crops respectively (Table 2).

Table 1. Physical and chemical properties of initial soil samples (0-15 cm depth) of the research plot of RARS, 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	0.20	0.2	4.0	1.0	0.6

Days to 50% flowering: The results of the analysis of variance showed that sowing date did not significantly affect the days to reach 50% flowering stage of rapeseed-mustard variety. 3 November, sown rapeseed-mustard variety took 36.0 days to attain 50% flowering stage while 15 November sown crop took 37.0 days (Table 2).

Field duration (Days to harvest): Field duration (Days to harvest) varied from year to year depending upon the temperature was reported by Hang and Gilliand (1984). Mean values on field duration (Days to harvest) revealed that the number of days till to harvest (field duration) of crop was increased as sowing was extended from November first week to November second week. Indeed, the numbers of days until maturity were 78.0 and 81.0 days respectively for 3 November and 15 November sowing dates (Table 2). So, the number of days till to maturity was increased by 3 days due to extended sowing date.

The present findings showed the contradictory result with earlier literature of Alam *et al.,* (2014), Bala *et al.,* (2011) who were stated that delayed sowing rapeseed-mustard matured earlier.

Table 2. Effects of sowing dates on phenological characters of mustard variety irrespective of harvesting stages during (*rabi*) winter season.

Sowing dates (D)	Days to emergence	Days to 50% flowering	Field duration (Days to maturity)
D_1	4.93	36.0	78.0
D_2	4.96	37.0	81.0
CV (%)	1.60	3.89	3.60
$LSD_{0.05}$	NS	NS	NS

D_1=03 November, 2014, D_2=15 November, 2014; ^{NS}indicates non-significant.

Table 3. Effects of sowing dates on morphological characters of mustard variety irrespective of harvesting stages during (*rabi*) winter season.

Sowing dates (D)	Plant height (cm)	Number of branches plant^{-1}	Siliquae length (cm)
D_1	87.8 a	5.30	4.74
D_2	82.7 b	5.30	4.20
CV (%)	2.14	2.82	9.50
$LSD_{0.05}$	3.22	NS	NS

D_1=03 November, 2014, D_2=15 November, 2014; ^{NS}indicates non-significant.

Plant height (cm): Earlier literature of Bhuiyan *et al.,* (2008), Saran and Giri (1987) and Mohammad *et al.,* (1987) stated that the higher values of plant height were noted in earlier sowing of crops. Similarly, in this present study plant height of tested rapeseed-mustard variety significantly was 87.8 cm and 82.7 cm when sowing date was 3 & 15 November respectively (Table 3). But, Yousaf *et al.,* (2002) who gave a contradictory theory with the present research and stated that sowing dates did not significantly influenced the plant height.

Delay in sowing from 3 November to 15 November reduced the plant height by 5.81%.

Table 4. Effects of sowing dates on yield contributing characters of mustard variety irrespective of harvesting stages during (*rabi*) winter season.

Sowing dates (D)	Number of siliquae plant^{-1}	Number of seeds siliquae^{-1}	1000-seeds weight (g)
D_1	55.0	27.0	2.90
D_2	54.0	27.0	2.95
CV (%)	2.86	4.45	2.65
$LSD_{0.05}$	NS	NS	NS

D_1=03 November, 2014, D_2=15 November, 2014; ^{NS}indicates non-significant.

Number of primary branches plant^{-1}: Number of primary branches plant^{-1} did not differ significantly between two sowing dates. Both the two sowing dates produced same number of primary branches plant^{-1} (5.30) (Table 3).

Siliquae length (cm): Siliquae length (cm) of rapeseed-mustard variety showed insignificant variation between two sowing dates. The 3 November sown crop produced 4.74 cm long siliqua while 15 November sown crop produced 4.20 cm (Table 3).

Table 5. Effect of sowing dates on seed and stover yield; harvest index of mustard variety irrespective of harvesting stages during (*rabi*) winter season.

Sowing dates (D)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
D_1	1.15	2.50	32.0
D_2	1.03	2.31	31.0
CV (%)	2.90	6.20	3.32
$LSD_{0.05}$	0.05	NS	NS

D_1=03 November, 2014, D_2=15 November, 2014; ^{NS}indicates non-significant.

Number of siliquae plant^{-1}: Rapeseed-mustard variety sown on 3 November produced the higher number of siliquae plant^{-1} (55.0) compared to 15 November sowing (54.0) (Table 4). So, variation in sowing time from 3 November to 15 November was found to decrease the number of siliquae plant^{-1}. Number of seeds siliqua^{-1}: Number of seeds siliqua^{-1} did not differ significantly between two sowing dates. Similar values (27.0) are found between two sowing dates (Table 4).

1000-seed weight (g): 1000-seed weight of rapeseed-mustard varieties non-significantly varied from 2.90 to 2.95 g between two sowing dates (Table 4).

Table 6. Effect of harvesting stages on field duration and morphological characters of mustard variety irrespective of sowing dates during (*rabi*) winter season.

Harvesting stages (H)	Field duration (Days to harvest)	Plant height (cm)	Siliquae length (cm)	Number of branches plant^{-1}
H_1	67.0 d	83.2	4.45 b	5.30
H_2	76.0 c	85.2	4.50ab	5.10
H_3	87.0 b	86.4	4.77 a	5.43
H_4	90.0 a	86.3	4.50 ab	5.23
CV (%)	2.45	2.51	6.05	4.06
$LSD_{0.05}$	4.86	NS	0.33	NS

H_1= Green stage of siliquae, H_2= Pale yellow stage of siliquae, H_3= Golden yellow stage of siliquae, H_4= Full maturity stage of siliquae; ^{NS}indicates non-significant.

Seed yield (t ha^{-1}): The 3 November sown crop produced 11.7% higher yield than 15 November sown crop (Table 5). Seed yield 1.15 t ha^{-1} was obtained from 3 November sown crop and 1.03 t ha^{-1} was obtained from 15 November sown crop. Higher yield in 3 November was mainly attributed by the higher number of siliquae plant^{-1} (55.0). On the other hand, Gradual decrease in the yield with delay in sowing might be due to the relatively low temperature at vegetative phase could have adversely affected the plant growth and development.Stover yield (t ha^{-1}):

Mean values of stover yield (t ha^{-1}) of rapeseed-mustard variety did not show significant variation between two sowing dates (Table 5). Crop sown on 3 November showed comparatively higher stover yield of 2.50 t ha^{-1} than that of 15 November sown crop producing stover yield 2.31 t ha^{-1}.

Table 7. Effect of harvesting stages on yield contributing characters of mustard variety irrespective of sowing dates during (*rabi*) winter season.

Harvesting stages (H)	Number of siliquae plant^{-1}	Number of seeds siliquae^{-1}	1000-seed weight (g)
H_1	54.0	25.0 b	2.61 c
H_2	54.0	28.0 a	2.80 c
H_3	55.0	28.0 a	3.01 b
H_4	55.0	27.0 a	3.30 a
CV (%)	2.80	5.20	5.56
$LSD_{0.05}$	NS	1.80	0.203

Note: H_1= Green stage of siliquae, H_2= Pale yellow stage of siliquae, H_3= Golden yellow stage of siliquae, H_4= Full maturity stage of siliquae.

Harvest index (%): Harvest index (%) did not differ significantly between two sowing dates. The higher harvest index (32.0%) was observed from 03 November sown crop than 15 November sown (Table 5).

Effect of harvesting stages

Field duration (days to harvest): Field duration (days to harvest) of rapeseed-mustard variety differed significantly among different harvesting stages. Field durations (days to harvest) were gradually increased towards the harvesting stages.

The lowest 67.0 days was required when crop was harvested at green siliquae stage and the highest 90.0 days was needed when crop was harvested at full maturity siliquae stage (Table 6).

Table 8. Effect of harvesting stages on yield contributing characters of mustard variety irrespective of sowing dates during (*rabi*) winter season.

Harvesting stages (H)	Seed yield (t ha-1)	Seed yield loss (%) in H_2 stage than H_3	Seed yield loss (%) in H_2 stage than H_4	Stover yield (t ha^{-1})	Harvest index (%)
H_1	0.95 d	0.00	0.00	2.88 a	24.8 d
H_2	0.99 c	(-)17.5	(-) 23.8	2.30 b	30.3 c
H_3	1.20 b	0.00	0.00	2.30 b	34.1 b
H_4	1.30 a	0.00	0.00	2.20 b	36.7 a
CV (%)	3.20	-	-	0.20	4.13
$LSD_{0.05}$	0.04	-	-	5.80	1.63

H_1= Green stage of siliquae, H_2= Pale yellow stage of siliquae, H_3= Golden yellow stage of siliquae, H_4= Full maturity stage of siliquae.

Plant height (cm): Harvesting stage had significant influence on plant height and increased gradually with advancement of harvesting stage up to certain stage than static. The tallest plant (86.4 cm) was obtained when the crop was harvested at golden yellow siliquae stage followed by that of full maturity stage of siliquae (86.4 cm). The shortest plant (83.2 cm) was obtained when the crop was harvested at green siliquae stage (Table 6). Similarly, Ayub *et al.*, (2002) found the maximum height of sorghum when it was harvested at 75 DAS and minimum was found at 45 DAS.

Siliquae length (cm): Siliquae length differed significantly among different harvesting stages. The length increased progressively and reached their peaks at golden siliquae harvesting stage and subsequently decreased slightly. It might be due to shrinkage of siliquae at full maturity stage. The longest siliquae 4.77 cm was found when crop was harvested at golden yellow siliquae (H_3) stage and the shortest 4.45 cm was for green stage of siliquae (Table 6).

Number of primary branches plant^{-1}: Number of primary branches plant^{-1} did not differ significantly among different harvesting stages (Table 6). The highest number of primary branches plant^{-1} (5.43) was produced when rapeseed-mustard variety was harvested at golden yellow siliquae (H_3) stage.

The lowest number of primary branches plant^{-1} (5.10) was obtained at pale yellow siliquae stage (H_2).

Table 9. Interaction effect of sowing dates and harvesting stages on field duration and morphological characters of mustard variety during (*rabi*) winter season.

Interaction effect(D × H)	Field duration (days to harvest)	Plant height (cm)	Number of branches plant^{-1}	Siliquae length (cm)
$D_1 \times H_1$	66.0	85.5	5.30	4.70
$D_1 \times H_2$	75.0	87.6	5.13	4.43
$D_1 \times H_3$	85.0	89.5	5.33	5.30
$D_1 \times H_4$	89.0	88.8	5.13	4.60
$D_2 \times H_1$	67.0	80.9	5.30	4.23
$D_2 \times H_2$	78.0	82.8	5.10	3.93
$D_2 \times H_3$	89.0	83.3	5.53	4.23
$D_2 \times H_4$	92.0	83.9	5.33	4.40
CV (%)	2.45	2.15	4.10	6.05
$LSD_{0.05}$	NS	NS	NS	NS

D_1= 03 November, 2014, D_2= 15 November, 2014, H_1= Green stage of siliquae, H_2= Pale yellow stage of siliquae, H_3= Golden yellow stage of siliquae, H_4= Full maturity stage of siliquae; ^{NS}indicates non-significant.

Number of siliquae plant^{-1}: Number of siliquae plant^{-1} did not differ significantly among different harvesting stages of mustard variety. It ranged from 54.0 to 55.0 in plant^{-1} among the different harvesting stages (Table 7). It might be due to siliqua development already had completed when attained the green siliquae stage. After that stage no siliqua formation occurred because there would have no flowering and pollination takes place.

Number of seeds siliqua^{-1}: Number of seeds siliqua^{-1} differed significantly among different harvesting stages (Table 7). The crop harvested at green siliquae (H_1) harvesting stage produced the lowest 25.0 number of seeds siliqua^{-1} while subsequent harvesting stages produced the statistically similar and highest number of seeds siliqua^{-1}. Green siliquae (H_1) harvesting stage produced lowest number of seeds siliquae^{-1} might be due to seeds formation did not completely occurred at this stage.

1000-seed weight (g): 1000-seed weight differed significantly among different harvesting stages of mustard variety (Table 7). Significantly the highest weight of 1000-seed (3.30 g) was obtained when the crop was harvested at full maturity of siliquae (H_4) stage. It might be due to the best maturity and accumulation of maximum dry matter. The lowest (2.61 g) was found when crop was harvested at green siliquae stage (H_1) and it might be due to immaturity of seeds. Harvesting at pale yellow and golden yellow stages of siliquae produced significantly different 1000-seed weight. Thousand-seed weight increased from 2.80 g to 3.01 g with delay in harvesting from pale yellow stage to golden yellow stage of siliquae. Similarly, Aslam *et al.,* (2015) found that the continuous decrease of seed moisture content and increased of weight from milk stage to physiological maturity of maize indicated increase in biomass accumulation towards later stage of maturity. Seed yield (t ha^{-1}): Seed yield differed significantly among different harvesting stages of mustard variety. The highest seed yield (1.30 t ha^{-1}) was obtained when crop was harvested at full maturity stage of siliquae while the lowest seed yield (0.95 t ha^{-1}) was found when crop was harvested at green stage of siliquae (H_1) (Table 8). Pale yellow siliquae harvesting stage (H_2) reduced the seed yield 17.5% and 23.8% respectively than golden yellow (H_3) and full maturity (H_4) siliquae harvesting stages.

Table 10. Interaction effects of sowing dates and harvesting stages on yield contributing characters of mustard variety during (*rabi*) winter season.

Interaction effect (D × H)	Number of siliquae $plant^{-1}$	Number of seeds $siliquae^{-1}$	1000-seeds weight (g)
$D_1 \times H_1$	55.0	25.0	2.520
$D_1 \times H_2$	54.0	29.0	2.697
$D_1 \times H_3$	56.0	28.0	3.067
$D_1 \times H_4$	55.0	27.0	3.230
$D_2 \times H_1$	53.0	25.0	2.703
$D_2 \times H_2$	54.0	27.0	2.830
$D_2 \times H_3$	53.0	27.0	2.953
$D_2 \times H_4$	56.0	28.0	3.317
CV (%)	2.80	5.20	5.60
$LSD_{0.05}$	NS	NS	NS

D_1= 03 November, 2014, D_2= 15 November, 2014, H_1= Green stage of siliquae, H_2= Pale yellow stage of siliquae, H_3= Golden yellow stage of siliquae, H_4= Full maturity stage of siliquae; ^{NS}indicates non-significant.

Stover yield (t ha^{-1}): Stover yield differed significantly among different harvesting stages (Table 8). The highest stover yield (2.88 t ha^{-1}) was obtained when crop was harvested at green siliquae stage while the lowest stover yield (2.20 t ha^{-1}) was found when crop was harvested at full maturity siliquae stage (H_4) that was statistically at par with pale (H_2) and golden yellow (H_3) siliquae harvesting stage. The variation of stover yield among the harvesting stages was due to distribution of dry matter from vegetative stage to reproductive stage.

Harvest index (%): Harvest index (%) differed significantly among the different harvesting stages and showed an increasing pattern towards the later harvesting stages (Table 8). It indicates the positive dry matter distribution towards grain yield.

Significantly the highest and lowest harvest indices 36.7% and 24.8% were found when crop was harvested at full maturity siliquae harvesting stage (H_4) and green siliquae harvesting stage respectively.

Interaction effects of sowing dates and harvesting stages

Field duration (days to harvest): Field duration (days to harvest) did not differ significantly due to interaction effects of sowing dates and harvesting stages (Table 9). The 15 November (D_2) sown crop required the highest 92.0 days to reach the full maturity siliquae stage (H_4) followed by 89.0 days was required when 3 and 15 November sown crop was harvested at full maturity siliquae stage (H_4) and golden yellow siliquae stage (H_3). Both the sowing dates of crop required the lowest 66.0 and 67.0 days to reach the green siliquae harvesting stage.

Plant height (cm): Interaction effects of sowing dates and harvesting stages showed non-significant variation on morphological character in terms of plant height of mustard variety. Similarly, Sarkar *et al.,* (2007) found non-significant variation in plant height for interaction effects of sowing dates and harvesting stages of sesame. The tallest plant 89.5 cm was found when 3 November (D_1) sown crop was harvested at golden yellow siliquae stage (H_3) and the shortest plant 80.9 cm was found when 15 November (D_2) sown crop was harvested at green siliquae stage (H_1) (Table 9).

Number of primary branches plant^{-1}: The interaction effects of sowing dates and harvesting stages showed non-significant variation on the number of primary branches plant^{-1} (Table 9).

The 15 November sown crop produced the highest number of primary branches plant^{-1} (5.53) when it was harvested at golden yellow siliquae stage (H_3) followed by 5.33 was found for the interactions effect of $D_1 \times H_3$ and $D_2 \times H_4$. The lowest (5.10) was found in $D_2 \times H_2$ interaction.

Siliquae length (cm): Siliquae length did not differ significantly due to interaction effects of sowing dates and harvesting stages. The 3 November (D_1) sown crop formed the longest siliquae (5.30 cm) when harvesting was performed at golden yellow siliquae stage (H_3) (85.0 days after sowing).

The shortest stature of siliqua (3.93 cm) was found when 15 November (D_2) sown crop was harvested at pale yellow siliquae stage (H_2) (Table 9).

Table 11. Interaction effect of sowing dates and harvesting stages on yield and harvest index of mustard variety during (*rabi*) winter season.

Interaction effect ($D \times H$)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
$D_1 \times H_1$	0.99	3.00	24.8
$D_1 \times H_2$	1.05	2.35	31.0
$D_1 \times H_3$	1.25	2.36	35.0
$D_1 \times H_4$	1.32	2.24	37.2
$D_2 \times H_1$	0.90	2.76	24.7
$D_2 \times H_2$	0.93	2.21	30.0
$D_2 \times H_3$	1.09	2.20	34.0
$D_2 \times H_4$	1.20	2.11	36.3
CV (%)	3.20	5.80	4.13
$LSD_{0.05}$	NS	NS	NS

D_1= 03 November, 2014, D_2= 15 November, 2014, H_1= Green stage of siliquae, H_2= Pale yellow stage of siliquae, H_3= Golden yellow stage of siliquae, H_4= Full maturity stage of siliquae; ^{NS}indicates non-significant.

Number of siliquae plant^{-1}: Number of siliquae plant^{-1} also showed non-significant variation due to interaction effects of sowing dates and harvesting stages. The highest number of siliquae plant^{-1} (56.0) was found in the interaction of $D_1 \times H_3$ & $D_2 \times H_4$ and the lowest (53.0) was found in interaction of $D_2 \times H_1$ & $D_2 \times H_3$ (Table 10).

Number of seeds siliqua^{-1}: Number of seeds siliqua^{-1} did not show significant variation due to the interaction effect of sowing date and harvesting stage. It ranged from 25.0 to 29.0among the different interaction level (Table 10).

1000-seed weight (g): The 15 November (D_2) sown crop produced the highest 1000-seed weight (3.32 g) when it was harvested at full maturity siliquae stage (H_4) while the lowest (2.52 g) was found when 3 November (D_1) sown crop was harvested at green siliquae stage (H_1)(Table 10).

Seed yield (t ha^{-1}): Seed yield did not show significant variation due to interaction effects of sowing dates and harvesting stages. The crop produced the highest seed yield (1.32 t ha^{-1}) when sowing was done on 3 November (D_1) and harvesting was done at full maturity siliquae stage (H_4). The 15 November (D_2)

sown crop produced the lowest 0.90 t ha^{-1} seed yield when harvesting was done at green siliquae stage (H_1)(Table 11).

Stover yield (t ha^{-1}): Stover yield did not vary significantly due to interaction effects of sowing date and harvesting stage (Table 11). The highest stover yield 3.00 t ha^{-1} was found for the interaction effect of $D_1 \times H_1$ followed by that of 2.76 t ha^{-1} in $D_2 \times H_1$. The lowest Stover yield 2.11t ha^{-1} was found for the interaction of $D_2 \times H_4$ followed by 2.20 and 2.21 t ha^{-1} were for $D_2 \times H_2$ & $D_2 \times H_3$ respectively.

Harvest index (%): Harvest index (%) did not differ significantly due to interaction effect of sowing dates and harvesting stages (Table 11).

The highest harvest index (37.2%) was found in interaction of $D_1 \times H_4$ followed by 36.3% was found from $D_2 \times H_4$ interaction. The lowest harvest index (24.7%) was found from interaction effect of $D_2 \times H_1$ interaction.

Abbreviation

HYV'S = High Yielding Varieties, FAO=Food and Agricultural Organization, BER=Bangladesh Economic Review, CV= Co-efficient of variation, BARI= Bangladesh Agricultural Research Institute, RARS= Regional Agricultural Research Station, NS= Non-significant, *T. Aman= Transplanted Aman,* $year^{-1}$= Per year.

Conclusion

From the result of the experiment, it may be concluded that after harvest of BARI Sarisha-14 at pale yellow siliquae stage, the following crop *Boro*rice may be transplanted within last week of January if the rapeseed-mustard crop sown in between 01 November to 15 November.

BARI Sarisha-14 may be harvested at pale yellow siliquae stage considering 17.5% and 23.8% seed yield loss than golden yellow and full maturity siliquae stage respectively to backend the field for *Boro*rice transplantation in optimum time.

Acknowledgements

We acknowledge the "Research and Research Infrastructure Development and Extension Project" funded by Government of the People's Republic of Bangladesh, Implemented by Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, for providing fund to conduct the study at Regional Agricultural Research Station (RARS), Jamalpur, under BARI, Gazipur-1701.

References

Alam MM, Begum F, Roy P. 2014. Yield and yield attributes of rapeseed-mustard (*Brassica*) genotypes grown under late sown condition. Bangladesh Journal of Agricultural Research **39(2),** 311-336.
https://doi.org/10.3329/bjar.v39i2.20434

Aslam M, Maqbool MA, Cengiz R. 2015. Drought stress in maize (*Zea mays* L.): effects, resistance mechanisms, global achievements and biological strategies for improvements. University of Agriculture Faisalabad, Pakistan.
http://www.springer.com/qp/book/9783319254401

Ayub M, Nadeem MA, Tanveer A, Husnain A. 2002. Effect of different levels of nitrogen and harvesting times on the growth, yield and quality of sorghum Fodder. Asian Journal of Plant Sciences, **1** 304-307.
https://www.researchgate.net/.../26554978

Bala P, Azad AK, Hossain MF. 2011. Yield response of mustard to sowing date. Libyan Agriculture Research Center Journal International **2(3),** 112-117.

Bell AR, Bryan E, Ringler C, Ahmed A. 2015. Rice productivity in Bangladesh: What are the benefits of irrigation? Land Use Policy **48,** 1–12.
https://doi.org/10.1016/j.landusepol.2015.05.019

BER (Bangladesh economic review). 2015. Bangladesh Economic Review 2015. Ministry of finance, Government of the People's Republic of Bangladesh, Bangladesh, Secretariat, Bangladesh.

Bhuiyan MS, Mondal MRI, Rahman MA, Alam MS, Faisal AHMA. 2008. Yield and yield attributes of rapeseed as influenced by date of planting. International Journal of Sustainable Crop Production **3(3),** 25-29.

Choudhury PKD, Guha B. 2000. Performance of rice varieties under different time of planting in *Boro* season. Annals of Biology (Ludhiana) **16(1),** 41-44.

FAO (Food and Agricultural Organization). 2015. Food and Agriculture Organization of the United Nations, FAOSTAT|© FAO Statistics Division 2015| 28 February 2015.

FRG (Fertilizer Recommendation Guide). 2012. Fertilizer Recommendation Guide-2012, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215, 274.

Gregory PJ, Ingram JSI, Andersson R, Betts RA, Brovkin V, Chase TN. 2002. Environmental consequences of alternative practices for intensifying crop production. Agriculture, Ecosystem & Environment **88,** 279-290.
http://faostat3.fao.org/home/index

Hang AN, Gilliland GG. 1984. Planting date effects on yield and quality of oilseed *Brassica* spp. Washington State University, Agricultural Research Centre. Research Bulletin **9,** 1-12.

Kader AA. 1986. Maturity, ripening, and quality relationships of fruit vegetables. Acta Horticulturae **439,** 249 - 255.
https://doi.org/10.17660/ActaHortic.1996.434.30

Mallik MSA. 2013. Quality seed production of oilseed crops: An overview. Paper presented in the workshop on "Modern techniques for quality seed production of Oilseed crops". Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

Marcos-filho J, Amorim HV, Silvarolla MB, Pescarin HM. 1981. Relationship between germination, vigor and permeability of cell membranes during soybean maturation. Relationship between germination, vigor and permeability of cell membranes during soybean maturation. *In*: National seminar of Soybean research **2,** 676-688.

Mohammad F, Samiullah M, Afridi MRK, Khan NA. 1987. Morphology of mustard variety to three sowing dates. I. Growth characteristics. Bangladesh Journal of Agricultural Research **14(10),** 66-71.

Price JS, Hobson RN, Neale MA, Bruce DM. 1996. Seed losses in commercial harvesting of oilseed rape. Journal of Agricultural Engineering and Research **65,** 183-191.
https://doi.org/10.1006/jaer.1996.0091

Russel DG. 1986. MSTAT-C Package Programme. Crop and Soil Science Department, Michigan University, USA.
www.scirp.org/.../reference/ReferencesPapers.aspx?

Saran G, Giri G. 1987. Influence of date of siwing on *Brassica* species under semi-arid rainfed conditions of North West. Journal of Agricultural Science (Cambridge) **108,** 561-566.

Sarkar MNA, Salim M, Islam N, Rahman MM. 2007**.** Effect of sowing date and time of harvesting on the yield and yield contributing characters of sesame (*Sesamum indicum L.*) seed. International Journal of Sustainable Crop Production **2(6),** 31-35.
https://www.cabdirect.org/cabdirect/abstract/20083185008

Sharma AR, Mittra BN. 1988. Effect of combinations of organic materials and nitrogen fertilizer on growth, yield and nitrogen uptake of rice. Journal of Agricultural Science-Cambridge **111,** 495-501.

Talukder AHMMR. 2018**.** Productivity improvement of mustard through agronomic manipulation in Fallow-*Boro* rice-*T. Aman* rice cropping pattern. PhD thesis, Sylhet Agricultural University, Sylhet, 70.

UNDP (United Nations Development Program) and FAO (Food and Agriculture Organization). 1988. Land resources appraisal of Bangladesh for agricultural development. Report 2, Agro-ecological Region, Bangladesh. 570.

Yousaf M, Ahmad A, Jahangir M, Naseeb T. 2002. Effect of different sowing dates on the growth and yield of Canola (Sarson) Varieties. Asian Journal of Plant Sciences **1,** 634-635.