Siliqua and Seed Development in Rapeseed (*Brassica campestris* L.) as Affected by Different Irrigation Levels and Row Spacing

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Summary

Accumulation of dry matter in siliqua, number of siliqua per plant, length of siliqua and seeds per siliqua of rapeseed (*Brassica campestris* L.) plants were studied under three irrigation levels (no irrigation, one irrigation at 30 DAS and two irrigations at 30 and 60 DAS) and three row spacing (20 cm, 30 cm and 40 cm). The experiment was carried out at Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka-1207, Bangladesh during the period from October, 2005 to January, 2006. The results revealed that the maximum dry matter accumulation in siliquae observed with two irrigations (at 30 DAS and 60 DAS) with 40 cm row spacing. Number of siliquae per plant was affected by different irrigation levels and row spacing and the highest number of silique was produced by two irrigations (at 30 DAS and 60 DAS) with 40 cm row spacing. At harvest, two irrigations produced the highest number of siliquae (120.3) which was statistically different from one irrigation (76.14) and no irrigation (control) treatments (30.99) and the differences were 288.2% and 145.7%, respectively over control. Length of silique as well as number of seeds per siliqua were significantly affected by the combination of irrigation levels and row spacing.

Key words

rapeseed, siliqua, dry matter, irrigation, row spacing

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Introduction

Rapeseed and Mustard (*Brassica sp.*) rank first among the oilseed crops of Bangladesh. It covers about 61.2% of the total area under oil seed and 52.6% of the total oil seed production. Rapeseed contains 40 - 45% oil and 20 - 25% protein in seed. The annual oil seed production is 0.37 million metric tons of which rapeseed covers 62% (MoA, 2006). It is top of the list in respect of area and production of oilseed crops cultivated in this country. The average seed yield of rapeseed is 0.71 t ha^{-1} in Bangladesh (BBS, 2004) which is very low as compared to that of the advanced countries (FAO, 2006). The major reasons for such poor yield of rapeseed in Bangladesh may be attributed to the lack of using improved varieties and poor management practices in the farmers' field.

Among the developmental process of rapeseed plant, formation of siliquae and seeds are the ultimate consequence of resource mobilization. Number of siliquae per plant is the result of genetic makeup of the crop and environmental conditions (Sana et al., 2003). It is an important yield contributing character. Establishment of optimum plant population by maintaining proper row spacing is one of the important factors to secure a better translocation of photosynthate, which render better yield (Singh and Kumar, 1990; Alam, 2004). In Bangladesh, rapeseed is mostly grown on the residual soil moisture in Rabi (winter) season (Kaul and Das, 1986). But irrigation is a vital factor for proper growth and development of this crop in dry season (Roy and Tripathi, 1985). Mondal et al. (1988) reported that one irrigation at flowering and another at siliqua development stages of mustard gave the highest number of siliquae.

Therefore, the present study aimed to observe the impact of suitable row spacing and optimum irrigation levels on the siliqua development and seed production of the rapeseed.

Materials and methods

The experiment was conducted at the Sher-e-Bangla Agricultural University farm Dhaka (90^0 33′ E longitude and 23^0 77′ N latitude), Bangladesh during Rabi (winter) season (October to January) of 2005-2006. The soil of the experimental site was clay loam with a pH of 5.47-5.63. The experiment was done with a new variety of rapeseed (*Brassica campestris* L.) named 'SAU Sarisha-1'. There were two factors in this experiment, viz. irrigation level and row spacing. The irrigation levels were: no irrigation (I_0), one irrigation at 30 DAS (I_1) and two irrigations: at 30 and 60 DAS (I_2). Row spacing were: 20 cm (S_1), 30 cm (S_2) and 40 cm (S_3). The experiment was laid out in split plot design with four replications. Irrigation was given in main plot and row spacing in sub-plots. The experimental plots were fertilized with a recommended dose of 135, 85, 60, 35, 4 and 4 in kg ha^{-1} of N, P_2O_5, K_2O, S, Zn and B in the form of urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, zinc oxide (ZnO) and boric acid, respectively. Seeds were sown on October 26, 2005. Light irrigation was given immediate after sowing to ensure maximum germination. Others appropriate cultural management practices such as thinning, weeding, mulching and pest management were done properly to ensure a good stand of the crop.

Ten plants from each treatment were sampled periodically from 60 DAS to 90 DAS at an interval of 15 days to record data on number of siliquae and dry weight of siliquae. After counting the separated siliquae of the plants were dried in an electric oven (Perkin-Elmer Corporation, USA) at 70^0 C for 48 hours and the dry weight was measured with a digital balance (Kaifeng Group Co., Ltd., China) for different growth stage. Seeds per siliqua and length of siliqua were recorded at harvest.

The data were analyzed following Analysis of Variance (ANOVA) technique and mean differences were adjusted by using the statistical computer programme ALPHA and MSTAT-C v.2.10 (Russel, 1994). Means were compared using LSD test at 5% level of significance.

Results and discussion

Dry matter accumulation in siliquae

A significant difference was found in case of dry matter accumulation in siliquae at different times with different irrigation levels (Table 1). At every stage, maximum dry weight of siliquae was found with two irrigations at 30 and 60 DAS (I_2) while zero irrigation treatment (I_0) produced the lowest dry weight of siliqua. At advanced stages slower increasing trend was found at I_0 and I_1 which might be due to the deficiency of soil moisture at these stages. Paul and Begum (1993) reported similar result. In case of I_2 there was no deficiency of soil moisture at the advance stages, as a result dry matter accumulation trend was higher than those of other irrigation levels.

Significant dry matter accumulation in reproductive organs (siliqua) observed at 60 DAS and accumulation continued till 90 DAS (Table 1). After 60 DAS i.e. during seed development period, vegetative growth tended to decrease while siliqua dry weight started to increase. Wider spacing (40 cm) influenced plant to produce significantly highest siliquae dry weight at 60, 75 and 90 DAS. The next higher production found with S_2 treatment at the said growth stages. S_1 treatment gave the lowest siliquae dry matter. At 90 DAS maximum dry matter weight in siliquae was found. Similar results were obtained in rapeseed by Lodhi et al. (1979). In case of S_3 (40 cm spacing) the plant

Table 1. Dry weight of siliqua (in grams) per plant of rapeseed at different age as affected by irrigation levels, row spacing and their combined effects

Treatment	Days after sowing (DAS)		
	60	75	90
Irrigation levels			
No irrigation (I_0)	1.34 c	2.72 c	2.85 c
One irrigation at 30 DAS (I_1)	3.11 b	6.12 b	6.72 b
Two irrigation at 30 and 60 DAS (I_2)	3.91 a	7.18 a	10.40 a
$LSD_{0.05}$	0.31	0.17	0.25
Row spacing			
20 cm (S_1)	2.31 b	5.13 c	5.16 c
30 cm (S_2)	2.97 a	5.34 c	5.95 b
40 cm (S_3)	3.08 a	5.55 a	6.40 a
$LSD_{0.05}$	0.19	0.20	0.18
Irrigation levels × Row spacing			
I_0S_1	1.53 d	2.74 f	1.10 h
I_0S_2	1.12 e	2.16 g	1.52 g
I_0S_3	1.37 de	3.27 e	1.43 g
I_1S_1	2.77 c	5.72 d	4.98 f
I_1S_2	3.30 b	6.23 c	5.60 e
I_1S_3	3.24 b	6.41 c	6.57 d
I_2S_1	2.62 c	6.96 b	9.40 c
I_2S_2	4.48 a	7.01 b	10.70 b
I_2S_3	4.62 a	7.57 a	11.19 a
$LSD_{0.05}$	0.332	0.35	0.31
CV (%)	8.02	4.44	3.64

Table 2. Number of siliqua per plant of rapeseed at different age as affected by irrigation levels, row spacing and their combined effects

Treatment	Days After Sowing (DAS)		
	60	75	90
Irrigation levels			
No irrigation (I_0)	27.47 c	30.97 c	30.99 c
One irrigation at 30 DAS (I_1)	60.85 b	70.87 b	76.14 b
Two irrigation at 30 and 60 DAS (I_2)	66.98 a	115.90 a	120.30 a
$LSD_{0.05}$	5.27	4.63	8.81
Row spacing			
20 cm (S_1)	48.27 b	72.57	73.28 b
30 cm (S_2)	52.18 ab	73.43	74.63 ab
40 cm (S_3)	54.45 a	75.77	79.47 a
$LSD_{0.05}$	4.05	NS	5.00
Irrigation levels × Row spacing			
I_0S_1	34.05 f	43.90 f	27.05 f
I_0S_2	21.05 g	37.95 f	26.70 f
I_0S_3	27.30 fg	56.05 e	39.22 e
I_1S_1	53.15 e	78.15 c	61.41 d
I_1S_2	68.35 ab	96.15 b	79.95 c
I_1S_3	61.05 cd	68.30 d	87.05 c
I_2S_1	57.60 de	119.6 a	112.10 b
I_2S_2	67.15 bc	116.2 a	117.30 b
I_2S_3	75.00 a	111.9 a	131.40 a
$LSD_{0.05}$	7.02	8.66	8.67
CV (%)	9.16	7.20	7.70

could get adequate nutrient and space to produce highest number of siliquae with highest dry matter. At S_1 spacing (20 cm) the shortage of space and higher competition for nutrient reduced the dry matter accumulation in siliquae. Oad et al. (2001) observed more competition with closer row spacing in rapeseed.

Interaction between irrigation and spacing produced significant variation in dry matter accumulation in siliquae. Among the treatments, two irrigation with 40 cm row spacing (I_2S_3) produced the highest dry matter in siliquae which was followed by I_2S_2 for all the growth stages (60 DAS, 75 DAS and 90 DAS). Two irrigations, one at 30 DAS and other at 60 DAS, provided favourable soil moisture and S_3 (40 cm) provided the maximum space for plant growth and development of the reproductive organs, which might be the causes of accumulating highest dry matter. This result was supported by Paul and Begum (1993).

Number of siliquae

Number of siliquae is an important factor for increasing yield, which is adversely affected due to lack of soil moisture. In the present study, number of irrigation showed significant variation in producing siliquae plant^{-1} (Table 2). At every growth stage number of siliqua increased due to the increase of irrigation levels. At 90 DAS, I_2 produced the highest number of siliquae (120.30) which was statistically different from I_1 (76.14) and I_0 (30.99) and the differences were 288.2% and 145.7% more over control. The treatment I_0, which received no irrigation throughout the life cycle, produced the lowest number of siliquae. In case of I_2 the second irrigation at siliqua formation stage helped in producing higher number of siliquae. But in case of treatment I_1 only one irrigation was applied at flowering stage and at later stage (siliqua formation) insufficient soil moisture reduced the number of siliquae per plant. Second irrigation also reduced the dropping of siliquae. The results obtained from the study were partially in agreement with Clarke and Simpson (1978), Joarder et al. (1979), Sarker and Hassan (1988), Sharma and Kumar (1989a) and Dobariya and Mehta (1995) who reported that irrigation increased siliquae plant^{-1}. Tomer et al. (1992) concluded that number of siliquae per plant was significantly increased up to two irrigations at pre-flowering and fruiting stage.

Significant difference was found in number of siliquae per plant at different row spacing. The number of total siliquae per plant gradually declined with the increase in number of plants per unit area due to closer spacing. This result confirmed the findings of Ali et al. (1990), Singh and Dhillon (1991), Misra and Rana (1992), Chauhan et al. (1993) and Roy et al. (1993). Increase in population by closer row spacing exerted a detrimental effect in siliqua fertility in rapeseed (Siddiqui, 1999). Table 2 showed that number of siliquae per plant decrease with the increase of population per unit area. The highest number of siliquae per plant (79.47) was recorded at wider spacing of 40 cm (S_3) and the lowest (73.28) at closest spacing (20 cm). Number of siliquae plant^{-1} directly correlates with dry matter production by the plants (Mumier-Jolain et al., 1998). Gupta (1988) obtained higher number of siliquae plant^{-1} at lower plant density. The treatment S_1 produced the lowest number of siliquae per plant, because mutual shading reduced the light interception. As a result, photosynthesis was affected and siliqua formation was hampered. The widest spacing (S_3) produced more number of siliquae plant^{-1} than closer row spacing because of the fact that wider spacing facilitates maximum utilization of solar energy by providing sufficient space to intercept light as well as other environmental resources that helped photosynthesis and ultimately produced more dry matter that eventually partitioned towards sink (siliqua). This result was corroborated with the results found by Alam (2004).

Significant differences were also found due to the interaction of irrigation and row spacing at 60 and 90 DAS (Table 2). Two irrigation, at 40 cm row spacing (I_2S_3) produced the highest number of siliquae per plant (131.40), which about was 392.1% greater than that of I_0S_2, which confirmed the results of Tomer et al. (1992). The lowest number of siliquae (26.70) was found from the treatment I_0S_1. Even wider space with no irrigation could not improve the siliquae number. At I_2S_3 second irrigation provided sufficient soil moisture and S_3 provided more space and light that helped in producing more siliquae. Andrews (1972) reported the positive effect of irrigation water towards siliqua formation.

Length of siliqua

Siliquae length was differed due to variable irrigation levels and row spacing. The significantly highest siliqua length was observed with two irrigations at 30 DAS and 60 DAS while the lowest siliqua length was observed in the plots having no irrigation (I_0). The increase of siliqua length due to soil moisture was also reported by Paul and Begum (1993). Misra and Rana (1992) also found similar results. Variable row spacing did not significantly affect the siliquae length in this study. However, numerically the highest siliqua length was observed from wider row spacing (30 cm).

The interaction effect of irrigation levels and row spacings had a significant effect on siliqua length of rapeseed (Table 3). Among the treatment combination, two irrigation coupled with 30 cm row spacing (I_2S_3) produced the longest siliquae which was statistically identical with I_2S_2, I_2S_1 and I_2S_3. The interaction of no irrigation and 20 cm row spacing (I_0S_1) produced the shortest siliqua in this study. It might be due to the less elongation of siliqua at water stress condition. This result was corroborated with the results of Paul and Begum (1993), Siddiqui (1999) and Alam (2004).

Table 3. Number of siliqua length and seeds per siliqua of rapeseed at harvest as affected by irrigation levels, row spacing and their combined effects

Treatment	Length of siliqua (cm)	No. of seeds siliqua^{-1}
Irrigation levels		
No irrigation (I_0)	3.12 c	17.51 c
One irrigation at 30 DAS (I_1)	4.33 b	19.69 b
Two irrigation at 30 and 60 DAS (I_2)	5.26 a	21.37 a
$LSD_{0.05}$	0.87	0.964
Row spacing		
20 cm (S_1)	4.02	18.01 b
30 cm (S_2)	4.34	20.25 a
40 cm (S_3)	4.92	20.30 a
$LSD_{0.05}$	NS	0.96
Irrigation levels×Row spacing		
I_0S_1	3.13 e	19.26 c
I_0S_2	3.78 de	16.06 d
I_0S_3	3.99 cde	17.20 d
I_1S_1	4.34 bcd	20.70 bc
I_1S_2	4.65 bcd	22.25 ab
I_1S_3	4.87 abc	16.11 d
I_2S_1	5.04 ab	20.95 ab
I_2S_2	5.32 ab	22.44 a
I_2S_3	5.68 a	20.72 b c
$LSD_{0.05}$	1.02	1.663
CV (%)	2.54	5.73

Number of seeds per siliqua

The number of seeds per siliqua was increased with the increase of irrigation number (Table 3). The significantly highest number of seeds (21.37) was found with two irrigations at 30 DAS and 60 DAS while the lowest number of seed per siliqua (17.51) was found from the control treatment (no irrigation). Seed per siliqua increased with increasing levels of irrigation due to the supply of adequate soil moisture which helped to be the siliquae longer and have more number of seeds. The second irrigation at 60 helped in the formation of seeds in siliqua. Tomer et al. (1992) found a significant increase of seeds siliqua^{-1} with two irrigations-one at pre-flowering stage and another at fruiting stage. A number of researchers (Clarke and Simpson, 1978; Prasad and Eshanullah, 1988; Sarker and Hassan, 1988; Sharma and Kumar, 1989b; Dobariya and Mehta, 1995) also observed that irrigation increased number of seed siliqua^{-1}.

It is evident that the number of seeds per siliqua significantly decreases with the increase of population density for closer row spacing (Table 3). The highest number of seeds per siliqua (20.30) was recorded from the widest row spacing of 40 cm, which was statistically identical with the seeds per siliqua found from 30 cm row spacing. The lowest number of seeds per siliqua (18.01) was found from the closest row spacing of 20 cm. Decrease in row spacing increase population density which decreases the number of seeds per siliqua because increasing population density exerted a detrimental effect on siliqua formation in rapeseed (Siddiqui, 1999) . Singh and Singh (1984) reported that the number of seeds siliqua^{-1} increased as the plant density decreased. At higher densities inter-plant competition was also highest which eventually caused reduction in number of seeds per siliqua. Reduction in number of seeds per siliqua in rapeseed and mustard with increasing population density was reported by Singh and Dhillon (1991), Misra and Rana (1992) and Sharma (1992).

Irrigation as well as row spacing significantly interacted with each other to produce seeds per siliqua in rapeseed in the study (Table 3). The highest number of seeds per siliqua (22.44) was found when two irrigations were applied with 30 cm row spacing (I_2S_2) which was followed by I_1S_2 (22.25) and I_2S_1 (20.95). The lowest number of seeds per siliqua (16.06) was found from the treatment I_0S_2 which was statistically identical with I_0S_3 and I_1S_3. It revealed that irrigation had contributed more in the formation of seed in the siliqua of wider spaced plant. The increasing demand of moisture for siliqua setting was only fulfilled in the plots provided by two irrigations. This result was supported by Shrief et al. (1990).

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