Effect of Sowing dates and Irrigation regimes on Agronomic traits of Indian mustard in semi-arid area of Takestan

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Abstract: The effect of four irrigation regimes (I_1-Irrigation after 70 mm, I_2-Irrigation after 100 mm, I_3-Irrigation after 130 mm and I_4-Irrigation after 160 mm evaporation from class A pan) and two dates of sowing (August 30 and January 27) were studied during growing season of 2009-2010 at I.A. University of Takestan, Iran. Among the irrigation treatments, irrigation after 70 mm evaporation from class A pan, gave significantly highest plant height, seed/siliqua, siliqua/plant, thousand seed weight and seed yield. The highest seed yield of 3034 kg/ha was obtained from August 30th sowing and decreased gradually thereafter. Findings suggest that, further research should be done on planting date of Indian mustard under different environmental conditions.

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1. Introduction

The increase in the planted area of oil seed crops is an indication of the success of plant breeders and agronomists in developing suitable cultivars and production methods in semi arid regions (Rao and Mendham, 1991). The average yield of oil crops in Iran is 245000 t (Area harvested 521000 ha), whereas the world average yield of oil crops is 261,099,000 t (Area harvested 157,382,000 ha) (FAO, 2010). Indian mustard (*Brassica juncea* L.) which is locally called as Khardal, belongs to Cruciferae family and genus *Brassica* (Iraddi, 2008) and introduced as an oily herb, which is appropriate for zones with short seasons and less rainfall (Burton et al., 1999). This crop along with other fast growing, high biomass plant species due to producing reasonably high biomass (Wright et al., 1995) can remove contaminants from the soil through accumulating high concentrations of metals in its above-ground tissues (Eid, 2011). It is cultivated in winter season and is a thermo as well as photosensitive crop (Ghosh and Chatterjee, 1998). Cultivation and application of Indian mustard as a medicinal plant with oily seeds and high nutritional value is increasing in the world. The important mustard growing countries of the world are India, Canada, China, Pakistan, Poland, Bangladesh and Sweden. Production potentiality of mustard can be fully-exploited with suitable agronomic practices. Among the different agronomic practices, optimum-sowing time plays an important role to fully-exploit the genetic potentiality of a variety as it provides optimum growth conditions such as temperature, light, humidity and rainfall (Iraddi, 2008).

Time of sowing is very important for mustard production (Mondal and Islam, 1993; Mondal et al., 1999). Sowing at proper time allows sufficient growth and development of a crop to obtain a satisfactory yield and different sowing dates provide variable environmental conditions within the same location for growth and development of crop and yield stability (Pandey et al., 1981). If the mustard is sown late, duration is reduced due to the high temperature during the reproductive phase with concomitant reduction in yield (Radha Kumari et al., 2004).Singh and Singh (2002) suggested that higher plant height recorded with 14th October sowing as compared to 29th October, 13th November and 28th November sowing. Although, Kurmi (2002) and Panda et al. (2004) emphasized that the taller plant height is as a result of the earlier sowing date (October> November> December). Shivani and Kumar (2002) stated that sowing on 25th September and 5th October recorded significantly higher number of seeds per siliqua as compared to 15th October, 25th October and 4th November sowing. Number of siliquae per plant recorded higher in 14 October sowing compared to 29th October, 13 November and 28 November sowing (Singh and Singh, 2002). Shivani and Kumar (2002) suggested that 1000-seed weight (g) recorded higher under 25th September and 5th October sowing as compared to 15 October, 25th October and 4th November sowing. Panda et al. (2004) observed that delay in sowing beyond 16th October reduced 1000-seed weight. Khan and Tak (2002) conducted a field experiment on a clay loam and suggested that the seed yield was higher with 20th October sowing than 5 th October and 5 th November sowing. In addition, the seed yield was significantly higher in 20 th October (2049.73 kg/ha) than 10 th November (1437.3 kg/ha) and 30 th November (915.08 kg/ha) sowing dates (Yadav Yogesh et al., 2011).

Water lent fertility to soil because it serves as a medium for nutrient absorption by the crop; most of the herbaceous plant parts constitute about 80-90% of water and almost every plant process is affected directly/indirectly by the water supply (Balasubramaniyan and Palaniappan, 2001). The flowering stage (post anthesis duration) is the most sensitive growth and development stage to water stress (Angadi et al., 2003; Cornish, 1987). Water shortage will cause severe decline in number of flowers, siliquae, seeds, and consequently it decreases 1000-seed weight and seed oil content (Brown et al., 2005). In this regard, Wright et al. (1996) and Maliwal et al. (1998) reported a reduction in *Brassica* species yield in response to water stress. Considering the other *Brassica* species, Indian mustard proved to have more tolerance in severe humidity trial (Iqubal et al., 2008; Wright et al., 1996). However, in another experiment Gunasekera et al. (2006) indicated that despite producing more dry matters to rapeseed, Indian mustard does not enjoy high seed yield. This is due to its low efficiency in converting and partitioning of dry matter to the seeds and low harvest index. Moreover, the decrease in number of siliquae per plant, number of seeds per siliqua and seed weight is reported under the drought stress condition (Albarrak, 2006; Sinaki et al., 2007). Fanaeia et al.(2009) in their study on two species of *Brassica napus* (Hyola 401 Hybrid) and *Brassica juncea* (landrace cultivar), under three irrigation regimes include control (irrigation after 50%), moderate stress, (irrigation after 70%), and severe stress (irrigation after 90% soil water depletion) showed that with increase in stress intensity, seed yield reduced significantly. Prihar et al.(1981) in a 3-year field study on mustard (*Brassica juncea* L.), with 11 post-sowing irrigation schedules based on pan evaporation and growth stages; asserted that, one-time irrigation three weeks after sowing gave maximum seed yield and water use efficiency, compared with no irrigation. Comparing to one-time irrigation, two- time irrigations (45 and 90 days after planting) had considerable increase in the number of siliquae per plant, 1000-seed weight and seed yield of Indian mustard (Piri, 2005). Whereas, Tahir et al. (2007) showed that, maximum number of seeds per siliqua, 1000-seed weight and seed yield were attained with three irrigations at early vegetative, flowering and seed formation (21, 56 &93 DAS).

Keeping all this in view, the present investigation was taken up to find out suitable irrigation regimes (irrigations scheduling) and optimum time of sowing for Indian mustard in the agro -climatic conditions of Takestan (semi-arid area) for realizing the maximum yield potential.

2. Material and Methods

This research was laid out with the aim of evaluating the planting season (sowing date) on the agronomic traits of Indian mustard (*Brassica juncea* L.) under different irrigation regimes in growing season of 2009-2010. The site is located at latitude of 36°18′ N, longitude of 49°57′ E and 1314 meters above the sea level in semi-arid climate (Alborz southern mountainsides) with having cold winters and warm (but not hot) and dry summers. (Mean Annual Precipitation: 312 mm, lowest and highest mean daily temperature over a 30-year period: 8.2 and 38.7 °C, respectively). The experiment was carried out as factorial based on a randomized complete block design (RCBD) with three replications in the research field of Takestan (I.A.U), Iran. The treatments were combination of 4 irrigation regimes (I_1-irrigation after 70 mm, I_2-irrigation after 100 mm, I_3-irrigation after 130 mm and I_4-irrigation after 160 mm evaporation from class A pan) and 2 cultivation seasons (D_1-autumn cultivation with sowing date of 30-Aug-2009, D_2-winter cultivation with sowing date of 27-Jan-2010). To prepare the field, it was irrigated before conducting the experiment and after the field got wet enough (puddling), it was ploughed deeply by Mollboard Plough. Next, to fragment hunks and to uniform soil condition, perpendicular disk was operated and land leveling was done afterwards. Then, the furrows and ridges constructed by Furrower. Two main irrigation ditches were made by ditchers in above and under of each block. Before sowing, soil sampling was taken from top soil (0-30 cm depth) and sub-soil (30-60 cm depth). According to soil analyses results, the amount of individual nutrients in the soil as well as pH and soil texture percentage of sand, silt and clay were determined (Table1). Due to the shortage of phosphorous, potassium and sulfur before the disk tillage, they were added to the soil by centrifuge-fertilizer spreader (including 150 kg/ha of triple super phosphate and 100 kg/ha of potassium solphate). Each block contains eight experimental plot including three stacks in each with 1 m width and 4 m length. In order to prevent irrigation water leaking, 6 m space between the blocks for creating irrigation ditch, and three unseeded stacks between the adjoining plots, were considered. Two planting lines (3cm apart from each other) were created in each stack (ridge) for sowing which was based on 1 cm space within the rows and maximum seed depth of 2 cm.

Table1. Physical and chemical properties of experimental soil before planting

Soil depth	EC ds/m	pH	T.N.V	S.P (%)	O.C (%)	T.N (%)	P Mg/kg	K Mg/kg	Clay (%)	Silt (%)	Sand (%)	Soil texture
0-30	1.33	7.8	8.25	35	0.83	0.08	14.2	165	29	45	26	Loamy-clay
30-60	1.15	7.4	8.46	37	0.96	0.06	15.3	148	27	46	27	Loamy-clay

Note. EC: Electric conductivity; T.N.V: Total Neutralizing Value; S.P: Saturation Percentage; O.C: Organic carbon

After the field preparation, the required concentration of super absorbent polymer (Hydro-gels) which was put in a bucket, for each planting lines were computed by precision scale. The required amount of water was added to it by graduate cylinder. Afterwards, with the use of hand Furrower, deep grooves were made on both sides of the stacks. The super gel along each line is placed inside the grooves uniformly and it covered by the soil. Immediately the seeds were placed on it and they were covered by soil again. Three days after the first irrigation, second irrigation was done for preparing the desired condition for seedling emergence and increasing seed germination percentage. The subsequent irrigation in each plot was performed based on experimental plan (irrigation treatment including $I_{1,}$ I_2, I_3, and I_4). After seedling emergence, for achieving desirable density (5cm in- row spacing), hand tinning was done. The first top dressing distribution at 4-6 true leaf stage (100 kg urea/ha) and the second was conducted at the time of reproductive organs appearance (100 kg urea /ha). Hand weeding was done at 4-6 true leaf stage as well as mid- stem elongation stage. At the end of growing season and prior to crop harvest, 10 plants were chosen randomly from each experimental unit and were cut from the surface. Then traits consisted of plant height, number of siliquae per plant and number of seeds per siliqua, were measured. On the other hand, the mean height of above-mentioned 10 randomly chosen plants was recorded as plant height for each plot. The number of siliquae per plant was estimated using the following relation:

Mean number of siliquae/main stem + Mean number of siliquae/lateral branches: Number of siliquae per plant.

In addition, mean number of seeds per siliqua in main stem and lateral branches were considered as number of seeds per siliqua. It should be mentioned that for computing the number of seeds in the main stem and lateral branches, 20 siliquae from the main stem and 30 siliquae from the lateral branches of the studied plants (10 plants) were selected randomly. At physiological maturity stage, for determining the seed yield, the crop was harvested from a 4.8 m^2 area per each plot and was left in the field for drying until constant weight (up to 12% moisture). In order to separate seeds form siliquae, a Treshing combine harvester was used. The harvested seeds from each experimental unit individually weighed with a precision scale and thereafter seed yield expressed as kg/ha. Finally, eight samples of 100 seeds were taken from each seed lot of the experimental units and then weighed. Their average multiplied by 10 recorded 1000-seed weight (g).

The collected data were analyzed statistically by using Fisher's analysis of variance technique (ANOVA) and differences among the treatment means were compared using Multiple Range Test of Duncan at 0.05 probability level. All statistics was performed with MSTATC software (version 2.10).

3. Results & discussion

Effects of date of planting and irrigation levels on plant height, yield and yield attributes of Indian mustard are presented in Table 2 and 3. Table 2 reveals that various irrigation levels and different sowing dates had highly significant effect on final plant height while sowing date (D) × Irrigation (I) interaction did not affect this trait. Maximum plant height (138.3 cm) was recorded in D_1 (first planting: 30 August) which was significantly different from the all other planting dates (D_2). Indeed, maximum use of the sources and appropriate growth condition for the timely and adequate growth, increase in the number of leaves and internodes due to their long-term growth period in an early planting date, can be considered as the main factors for increasing the plant height. In contrast, in the late planting dates, especially in January 27^{th}, because of the shortened growing season, the plant could not exploit the existing resources and environmental condition properly and this restriction was quiet evident as a decrease in the plant height. These results are in well agreement with the finding of Shirani Rad and Ahmadi (1996), Mondal and Islam (1993) and Shahidullah et al. (1997) who reported that, late sowing brings about a significance decrease in the plant height. In general, plant height increased with increase in irrigation frequency. On the other hand, the highest plant height (156.6 cm) was related to irrigation after 70 mm evaporation from class A pan as compared to the other irrigation levels (I_2, I_3 and I_4). This increase in plant height might have been due to more availability of moisture, higher crop growth rate and net assimilation rate at irrigation frequencies.

Table 2. The mean squares of ANOVA for Plant height, Seed/siliqua, Siliqua/plant, 1000-seed weight and Seed yield in data analysis of 2009–2010

S.O.V	df	Plant height	Seed/siliqua	Siliqua/plant	1000-seed weight	Seed yield
R	2	5.685ns	0.040ns	15.680ns	0.170ns	21064.625ns
D	1	8455.885**	26.042**	3482.450**	2.600**	5735970.375**
I	3	6610.350**	16.138**	5610.244**	4.277**	8023453.375**
DI	3	37.085ns	0.023ns	6.747ns	0.007ns	35411.375ns
E	14	11.228	0.078	4.406	0.110	55456.911
CV (%)		2.08	4.57	2.79	11.25	9.25

Note. ***** – $p < 0.05$, ****** – $p < 0.01$, ns – $p > 0.05$. R – repetition effect, D –date of sowing effect I–irrigation effect, D I– represent interaction terms between the treatment factors

Table3. Individual effect of sowing date and irrigation levels and interaction thereof on plant height, Seed/ siliqua, Siliqua/ plant, 1000-seed weight and Seed yield of Indian mustard in estimated means

Treatment	Plant height (cm)	Seed/ siliqua	Siliqua/ plant	1000-seed weight (g)	Seed yield (kg/ha)
Sowing date					
D_1=Aug.30	138.3a	7.15a	86.3a	3.28a	3034a
D_2=Jan.27	100.7b	5.07b	63.2b	2.64b	2057b
Irrigation					
I_1	156.6a	7.98a	110.5a	3.80a	3692a
I_2	135.1b	6.77b	87.3b	3.40b	3151b
I_3	105.4c	5.52c	63.6c	2.75c	2304c
I_4	80.9d	4.17d	39.5d	1.87d	1038d
D×I					
D_1I_1	173.8a	9.07a	102.3a	4.10a	4262a
D_1I_2	157.3b	7.87b	100.5a	3.70ab	3658b
D_1I_3	122.1d	6.53c	74.5c	3.10c	2796cd
D_1I_4	99.8f	5.13e	50.8d	2.33d	1423e
D_2I_1	139.4c	6.90c	97.5b	3.50bc	3121c
D_2I_2	112.8e	5.67d	74.4c	3.10c	2643d
D_2I_3	88.6g	4.50f	52.7d	2.40d	1812e
D_2I_4	62.1h	3.20g	28.1e	1.50e	625f

Means not sharing a common letter in a column differ significantly at 0.05 level of probability; I_1-irrigation after 70 mm, I_2-irrigation after 100 mm, I_3-irrigation after 130 mm and I_4-irrigation after 160 mm evaporation from class A pan; D×I: Interaction effect of sowing date× irrigation regimes

The results are supported by the findings of Rathore and Patel (1990).

It is also evident from the data (Table 2) that different sowing dates had highly significant effect on number of seeds per siliqua. Continually, the irrigation levels showed such effect on this parameter ($p<0.01$), thus, their interaction (D×I) was found to be non-significant. The comparison of individual treatment means reflects that the highest number of seeds (7.15) per siliqua was present in D_1 treatment where sowing date was August 30. The lowest seed number per siliqua was found in the plants of January 27 sowing, which was significantly different from first sowing date. These results are in agreement with the results of Mondal et al. (1999) and Shahidullah et al. (1997). Means comparison results showed that, the highest number of seeds per siliqua (7.98) was found in plots irrigated based on 70 mm evaporation from class A pan as compared to rest of treatments. More number of seeds per siliqua in plots with I_1 irrigation pattern may be attributed to the number of flowers, which were converted to seeds. Because in addition to the decrease in photosynthesis under the stress condition, water potential ,which can produce hydrostatic pressure and is essential in transferring photosynthetic material, is decreased as well, and at the time of flowering and seed filling duration, less distribution of photosynthetic materials which caused by stress ends to flower and siliqua abscission. The lack of photosynthetic materials in flowering period makes the fertilization hard to achieve and it can also decrease the number of seeds per siliqua and as a result there was also a decrease in the seed yield. It is worth mentioning that there is a close correlation between dry matter accumulation and the number of seeds per siliqua (Mendham et al., 1984). These findings are supported by those of Rathore and Patel (1990) and Dobariya and Mehta (1995), who reported higher number of seeds per siliqua at higher irrigation frequencies. The results are however, contradictory to those of Rahnema and Bakhshandeh (2006) who reported non-significant difference among irrigation treatments for number of seeds per siliqua. These contradictory results can be attributed to difference in fertility status and genetic makeup of the crop plants.

It should be noted that the number of siliquae per plant is one of the main components of seed yield since it comprises the number of seeds, supplies the required photosynthetic material and ultimately seed weight. A highly significant (p<0.01) effect of sowing dates and different irrigation regimes on number of siliquae per plant was observed in this study (Table 2) While, their interaction was found to be non-significant. The highest number of siliquae per plant (86.3) was obtained from the plants of first sowing (August 30), which was statistically differing to the second plantings. This finding was in conformity with the findings of Mondal et al. (1999) who stated that the plants of early planting produced the highest number of siliquae /plant and reduced in the late sowings. In this regard, Norton et al. (1991) reported that early sowing came out with large number of siliquae in which the intense competition between the siliquae may cause number of them to shatter. They have concluded that in an early sowing condition, the survival chances of seed and siliqua on the upper part of main stem and top branches are high. Number of siliquae per plant is the result of genetic makeup of the crop and environmental conditions, which is adversely affected by lack of soil moisture (Sana et al., 2003). Table 3 shows that, maximum number of siliquae per plant (110.5) were obtained in I_1 (Irrigation based on 70 mm water evaporation of pan) and it however, differed statistically from I_2, I_3 and I_4 treatments. The reduction in number of siliquae per plant, as a result of applied moisture stress by reducing the irrigation frequency, is due to the decrease in number of flowers converted into seeds finally. The results obtained from the study were partially in line with Clarke and Simpson (1978) and Sharma and Kumar (1989) who reported that irrigation increased siliquae/ plant.

1000-seed weight was found to be highly significant for all of the sowing dates (Table2). However, numerically maximum 1000-seed weight (3.28 g) was recorded from the first sowing (August 30). The January 27 sowing was recorded the lowest weight of 1000-seed indicating reduced weight with each drastic delay in sowing after August 30. Decrease in thousand seed weight as a result of delayed sowing of Indian mustard refers to the fact that, late sowing caused both siliqua formation and seed filling duration stages to encounter high temperature. In this condition, rate of respiration and assimilates consumption would increase and ultimately inadequate nutrients enters the seeds, so we would have hollow (unfilled) seeds (Whitfield, 1992). Robertson et al. (2004) and Bhuiyan et al. (2008) stated that 1000-seed weight reduced with the delayed planting time. In this study, according to the results derived from Table 2, it was observed that the 1000-seed weight is highly affected by irrigation levels. Data on Table 3 show that the 1000-seed weight increased with increasing in irrigation frequency (i.e., I_1). Thus, the highest (3.80 g) and lowest (1.87 g) values of 1000-seed weight were obtained from 70 and 160 mm evaporation from class A pan, respectively. It is apparent that, moisture stress in blooming stage and during seed filling is mainly through absorption of water and solutes by the plant and subsequently the decrease in production and transfer of assimilates to the seeds can reduce 1000-seed weight. 1000-seed weight can be dependent to genetic structure of a cultivar. On the other hand the plant can compensate the share of assimilates contributed by plant to the seeds via reduction of the number of seeds per siliqua rather than seed weight. Hence, weight of each seed is not as influenced as the seed number by drought stress. Seeds weight depends on growth rate and length of filling period, which is supplied by two sources of current photosynthesis and remobilization of stored material in the plant. Apparently, in the Irrigation treatments after water depletion equal to 100, 130 and 160 mm evaporation from class A pan, these components acquire a lower growth rate and duration comparing to mild stress condition (i.e., Irrigation after 70 mm evaporation from pan class A). In their experiments, Gunasekera et al. (2006) and Iqubal et al. (2008) individually noted that by increase in moisture stress intensity, 1000-seed weight decreases. Concerning the sowing date and irrigation regimes interaction, it should be reminded that even same as aforementioned traits, this interaction did not influence this characteristic (Table 2).

Sowing date is an important determinant of yield in Indian mustard. Regarding the seed yield (Table 2), results indicated that the individual effects of date of sowing and irrigation levels were highly significant on the crop seed yield (p<0.01). Clearly, in case of sowing dates highly significant difference in the yield of tow sowing dates were noted. The best sowing dates in comparison of tow sowing dates was appeared to be 30th August as it produced higher yield of 3034 kg/ha as compared to other sowing dates (January 28) . The higher seed yield (3034 kg/ha) produced by August 30 sowing might be attributed to higher number of siliquae in individual plants, number of seeds per siliqua and 1000-seed weight. Sowing on January 27 yielded the second highest yield /the lowest yield (2057 kg/ha). The decline of seed yield with delay in sowing date could be largely explained by the decline in biomass at maturity. Likewise, Shahidullah et al. (1997) reported that late sowing mustard faced higher temperature during seed filling period and caused forced maturity which results reduced growth period of mustard. The findings of the present study about seed yield were fully supported by Buttar and Aulakh (1999) and Mondal et al. (1999) as well as Degenhardt and Kondra (1981). Seed yield was also highly significantly ($p<0.01$) affected by irrigation regimes (Table 2). Data pertaining to seed yield of Indian mustard as affected by different irrigation levels presented in Table 3 shows that, the highest seed yield of 3692 kg/ha was obtained in case of irrigation after 70 mm evaporation of class A pan (I_1) and it differed statistically from rest of all the treatments under study. Increase in seed yield with increase in number of irrigations has been reported earlier (Hati et al., 2001; Panda et al., 2004). The minimum seed yield (1038 kg/ha) were observed in plots which received lower frequency of irrigation (irrigation after 160 mm evaporation from class A pan). Sinaki et al. (2007) reported that the greatest reduction in seed yield affected by water stress during stem elongation, blooming and siliqua development stages is largely due to the reduction in number of siliquae per plant and decrease in seed size during the seed development. This observation is similar to that of Gunasekera et al. (2006) where drought stress caused reduction in *Brassica juncea* seed yield. The interaction between date of sowing and irrigation levels (D×I) was found to be non-significant in terms of seed yield (Table2), though mean values for each treatment combination are presented in Table 3. D_1I_1 interaction recorded significantly higher seed yield of 4262 kg/ha as compared to over rest of the interactions. However, second sowing date (winter cultivation) coupled with irrigation regime according to 160 mm evaporation from class A pan (D_2I_4 interaction) resulted in the lowest seed yield (625 kg/ha).

Conclusion

It is concluded through this study that 30^{th} August, is the best sowing date of Indian Mustard for obtaining maximum yield. The late planting of Indian mustard adversely affects the yield and yield components due to its adverse effect on growth parameters, because different growth stages acquired enough time for their development. Among the irrigation levels, I_1 treatment recorded high yielding crop under the existing climatic condition.

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