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Effect of irrigation frequency and zinc fertilization on growth and yield of Indian mustard (*Brassica juncea* (L.)

Maneesh Yadav, KK Yadav, DP Singh, SS Lakhawat and AK Vyas

Abstract
A field experiment was conducted at Instructional Farm, Agronomy, Rajasthan College of Agriculture, Udaipur during *rabi* 2020-21. The experiment was laid out in split plot design having 12 treatment combinations replicated four times. The experiment having three levels of irrigation (one irrigation at seedling stage, two irrigations at seedling + pod formation stage and three irrigations at seedling+50% flowering+ pod formation stage) in main plots and four levels of zinc (control, 4 kg Zn ha^{-1}, 8 kg Zn ha^{-1} and 12 kg Zn ha^{-1}) in sub plots. The significant increase in plant height, branches plant^{-1}, leaf area index, dry matter accumulation, siliqua plant^{-1}, seeds siliqua^{-1}, test weight, seed yield, stover yield and biological yield was observed with the application of three irrigations given at seedling, 50% flowering and pod formation stage along with 8 kg Zn ha^{-1} as compared to control.

Keywords: Mustard, irrigation, zinc, growth, yield

Introduction
Indian mustard (*Brassica juncea* L.) belongs to family "Cruciferae" is one of the most important oilseed crop in India. The rapeseed-mustard is an important group of oilseed crops in India. During 2018-19, it contributes 24.7% to total area and 29.4% to total production of oilseeds. Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, West Bengal, Assam and Gujarat are the main rapeseed-mustard growing states in India, accounting for 92.7% of the area and 95.8% of production in 2017-18, with Rajasthan alone accounting for 36.6% and 40.9% of the area and production, respectively (Anonymous, 2019) [3]. Water scarcity affects each and every aspect of life (Kookana *et al.* 2016) [11]. The morphometric characteristics of an area greatly affect the availability of groundwater (Kumar *et al.* 2015) [13]. Water stress during the crop growth period is the major constraint to long-term mustard productivity, especially in rainfed areas. Unavailability of adequate irrigation water is one of the primary causes for low productivity of mustard. Further, the quality of water plays an important role in production of crops (Yadav and Singh 2018) [28]. In semi-arid climate of Northern India, water stress and the deficiency of nutrients are two main constraints which affect mustard production (Garnayak *et al*. 2000) [9]. The soils of this belt are also deficient in organic carbon with poor microbial population (Chandar *et al.* 2012) [7]. Increase in irrigation levels significantly increased plant height of mustard (Singh and Meena, 2020 [21]; Nautiyal *et al*. 2020 [19]). The number of irrigations is critical for determining mustard's most effective water usage. Zinc is an important micronutrient with specific physiological roles in all living systems, including maintaining the structural and functional integrity of biological membranes, as well as facilitating protein synthesis and gene expression (Alloway, 2008) [2]. Zinc plays an important role in synthesis of tryptophan, a precursor of Indole Acetic acid (Brown *et al*. 1993) [6]. Zinc is essential for mustard growth, yield characteristics, quality, and oil content. Mustard is especially vulnerable to micronutrient deficiencies, particularly zinc because it is found deficient many areas of Rajasthan (Singh *et al.* 2013) [22]. Therefore, the present study was under taken to evaluate the effect of irrigation frequency and zinc fertilization on growth and yield of mustard.

Materials and Methods
Description of the study area
The experiment was conducted during *rabi* season of 2020-21 at Instructional Farm, Agronomy, Rajasthan College of Agriculture, Udaipur. The experimental location coordinates

are 24˚34' N latitude and 73˚42' E longitude with an altitude of 582.17 m above mean sea level. The region falls under the agro-climatic zone IV-a of Rajasthan having hard-rock area (Machiwal *et al.* 2017) [18]. The maximum and minimum temperature ranged between 32.3 ˚C and 4.1 ˚C. Mean weekly maximum and minimum relative humidity ranged between 90.6% and 22.7% respectively and the total rainfall received during the crop period is 12.6 mm. The soil analysis confirmed that soil of experimental field was clay loam belongs to *Typic Haplustepts*, alkaline in reaction, medium in available nitrogen and phosphorus and high in available potassium and low in zinc.

Experimental details

The experiment consisting of three levels of irrigation (I_1= one irrigation at seedling stage, I_2= two irrigations at seedling + pod formation stage and I_3= three irrigations at seedling+50% flowering+ pod formation stage) in main plots and four levels of zinc (Zn_0= control, Zn_4= 4 kg Zn ha^{-1}, Zn_8= 8 kg Zn ha^{-1} and Zn_{12}= 12 kg Zn ha^{-1}) in sub plots, thereby making 12 treatment combinations, were laid out in split plot design with 4 replications. The seed was sown manually on 22 October 2020 by placing 2 seeds at a depth of 3–4 cm. Thinning was done after 25-30 days after sowing maintaining row to row and plant to plant distance 30 x 10 cm. In order to minimize weed competition, a hand weeding was done at the time of thinning. Three irrigations were given to mustard crop according to the treatments. Recommended dose of NPS *viz.*, 60 kg N, 40 kg P_2O_5 and 250 kg gypsum per hectare was applied uniformly through urea, DAP and gypsum, respectively. Growth, yield attributes and yield were recorded and statistically analyzed. The field water balance equation was used to calculate evapo-transpiration (ET), as given below:

$$ET = (P + I + C) - (R + D + \Delta S)$$

Where, ET = evapo-transpiration in mm, P = precipitation (mm), I = irrigation (mm), C= capillary rise (mm), R = runoff (mm), D = deep percolation (mm) and ΔS = change in profile soil moisture (mm). C was considered to be negligible because the groundwater table was so shallow (10–15 m). The field plots had no runoff (R) because they were bunded to a sufficient height, and no bund overflow was observed during the study period. The deep percolation out of the root zone is regarded negligible because the applied irrigation water was always substantially below the field capacity of the soil profile. Thus the above equation simplifies to,

$$ET = (P + I) - \Delta S$$

Irrigation was provided via surface method of irrigation at critical stages of crop growth. The gravimetric method was used to calculate changes in soil moisture content (ΔS) and water use efficiency (WUE) was calculated as,

$$WUE = \frac{Y}{ET}$$

Where, Y= yield

Results and Discussion

Effect of irrigation frequency Growth

The findings of the experiment (Table 1) revealed that a significant improvement in plant height, branches $plant^{-1}$, leaf area index and dry matter accumulation were observed with successive increase in irrigation numbers from I_1 to I_3. The highest plant height, branches $plant^{-1}$, leaf area index and dry matter accumulation were recorded with three irrigations given at seedling, 50% flowering and pod formation stage. The plant height, branches $plant^{-1}$, leaf area index and dry matter accumulation were increased to an extent of 17.25, 40.02, 22.77 and 21.04 percent due to three irrigations given at seedling, 50% flowering and pod formation stage over only one irrigation given at seedling stage, respectively. Water supplied to plants in a timely and enough manner by irrigation and/or rainfall increases cell turgidity and cell expansion, as well as meristematic activity, resulting in increased photosynthesis and improved plant development (Slatyer, 1967) [24]. A sufficient and timely supply of irrigation water assure cell turgidity and, as a result, increased meristematic activity, resulting in improved morphological parameters such as increased plant height, more number of branches $plant^{-1}$, more foliage development, higher photosynthesis, higher dry biomass production and ultimately better plant growth (Agarwal and Gupta, 1991; Kumawat and Yadav, 2009). Singh and Thenua (2017); Tyagi and Upadhyay (2017); Singh and Meena (2020) [1, 12, 23, 26, 21] also observed that plant height, branches $plant^{-1}$, leaf area index and dry matter accumulation were increased as a result of increasing number of irrigations in mustard crop.

Yield attributes and Yield

The experimental results (Table 2 and 3) proved that increasing number of irrigations significantly improved yield attributes and yield of mustard. The maximum yield and yield attributes were obtained with three irrigations applied at seedling, 50% flowering and pod formation stage. Under water stress condition when crop was irrigated only at seedling stage, attributes *viz.* silique $plant^{-1}$, seeds $siliqua^{-1}$ and test weight were not fully developed. Further, when crop was irrigated at seedling and pod formation stage, the development was improved to some extent resulted in better growth of yield attributes. The results are in close conformity with those of Yadav *et al.* (2012); Singh and Thenua (2017); Tyagi and Upadhyay (2017); Verma *et al.* (2018) and Nautiyal *et al.* (2020) [29, 23, 26, 14, 19].

The seed, stover and biological yield increased to an extent of 16.33, 10.79 and 12.40 percent due to application of three irrigations at seedling, 50% flowering and pod formation stage over only one irrigation at seedling stage, respectively. This might be due to the fact that seed yield is the function of dry matter and yield attributes of plant which were significantly increased with increasing number of irrigations. Further it could be related to greater photosynthates and photosynthetic translocation to reproductive structures due to enough soil moisture in the mustard crop's rhizosphere. The stover yield also increased substantially with increasing number of irrigations. This rise was ascribed to increased moisture availability, which resulted in a better nutritional environment during critical growth stages of the crop, resulting in improved vegetative growth. These findings are in line with those of Hossain *et al.* (2013); Singh and Thenua (2017); and Shivran *et al*. (2018) [10, 26, 20].

Effect of zinc fertilization

Growth

The results of field experiment (Table 1) showed significant influence on plant height, branches plant^{-1}, leaf area index and dry matter accumulation with increasing levels of zinc up to 8 kg Zn ha^{-1} over control. The maximum plant height, branches plant^{-1}, leaf area index and dry matter accumulation were recorded with application of 12 kg Zn ha^{-1}. These growth parameters increased to an extent of 9.55, 29.64, 18.47 and 10.41 percent due to application of 12 kg Zn ha^{-1} over control, respectively. Increased growth with application of zinc might be due to its role in various metabolic processes as a result of catalytic activities in plant. Zinc is important for synthesis of Indole acetic acid, a precursor of auxin, which ultimately responsible for increasing plant height, development of branches and enhance dry matter accumulation of mustard. Zinc is essential for cellular growth, differentiation and metabolism, resulting in rapid plant growth and a strong root system, as well as enhanced growth characteristics (Kuldeep *et al.* 2018) [12]. Increase in plant height, branches plant^{-1}, leaf area index and dry matter accumulation were in consonance with the findings of Tripathi *et al.* (2014) [25]; Kumar *et al.* (2016) [15]; Kumar *et al.* (2018) [12] and Verma *et al.* (2018) [14].

Yield attributes and Yield

The results (Table 2 and 3) revealed that yield and yield attributes of mustard increased significantly with increasing rate of zinc up to 8 kg Zn ha^{-1} over control except harvest index. The maximum yield and yield attributing characters *viz.* siliqua plant^{-1}, seeds siliqua^{-1} and test weight were obtained under 12 kg Zn ha^{-1} over control. The seed, stover and biological yield of mustard increased by 22.55, 20.16 and 20.85 percent due to application of 12 kg Zn ha^{-1} over control, respectively. Seed yield is the resultant of plant dry matter and yield attributes which was improved substantially with increasing levels of zinc. Seed and stover of mustard produced the biological yield. Significant increase in biological yield could be due to relative increase in seed and straw yield. The positive effect of zinc on yield attributing characters could be ascribed to its catalytic or stimulatory effect on metabolic processes in plants. Zinc is requisite by meristematic tissues where synthesis of protein and nucleic acid is taking place. Zinc plays an important role in flowering and seed production which are severely affected in zinc-deficient plants (Alloway, 2008) [2]. The beneficial effect of zinc on mustard yield could be attributed to its role in a variety of enzymatic reactions, growth processes, hormone development and protein synthesis, as well as the translocation of photosynthates to seed, resulting in increased seed yield (Bhadauria *et al.* 2012) [5]. Similar results are also reported by Aswal and Yadav (2007) [4], Dubey *et al.* (2013) [8]; Kumar *et al.* (2014) [16]; Tripathi *et al.* (2014) [25]; Kumar *et al.* (2016) [15], Verma *et al.* (2018) [27] and Yadav *et al.* (2021) [30].

On the basis of statistical data, it can be concluded that farmers of Zone IVa (sub -humid Southern Plains and Aravalli Hills of Rajasthan) can get significantly higher seed, stover and biological yield with the application of two irrigations at seedling and pod formation stage along with 8 kg Zn ha^{-1}.

Table 1: Effect of irrigation frequency and zinc application on plant height, branches plant^{-1}, LAI and dry matter accumulation

Treatments	Plant height (cm)	Branches plant^{-1}	LAI	Dry matter accumulation (g plant^{-1})
Irrigation frequency				
I_1= One irrigation	173.94	12.07	2.81	63.83
I_2= Two irrigations	193.49	15.85	3.38	74.65
I_3= Three irrigations	203.95	16.90	3.45	77.26
S.Em±	3.56	0.33	0.03	1.08
C.D. (P = 0.05)	12.33	1.13	0.11	3.74
Zinc application				
Zn_0 = Control	180.12	12.82	2.87	67.80
Zn_4= 4kg Zn ha^{-1}	188.58	14.42	3.20	71.02
Zn_8= 8 kg Zn ha^{-1}	195.80	15.90	3.37	73.96
Zn_{12}= 12 kg Zn ha^{-1}	197.33	16.62	3.40	74.86
S.Em±	2.29	0.26	0.03	1.01
C.D. (P = 0.05)	6.65	0.76	0.08	2.93

Table 2: Effect of irrigation frequency and zinc application on siliqua plant^{-1}, seeds siliqua^{-1} and test weight

Treatments	Siliqua plant^{-1}	Seeds siliqua^{-1}	Test weight (g)
Irrigation frequency			
I_1 = One irrigation	126.20	11.10	3.37
I_2 = Two irrigations	136.15	11.88	3.54
I_3 = Three irrigations	138.15	12.00	3.60
S.Em±	2.33	0.17	0.03
C.D. (P = 0.05)	8.05	0.60	0.11
Zinc application			
Zn_0 = Control	124.00	10.97	3.31
Zn_4 = 4 kg Zn ha^{-1}	133.00	11.57	3.43
Zn_8 = 8 kg Zn ha^{-1}	137.72	12.04	3.62
Zn_{12} = 12 kg Zn ha^{-1}	139.28	12.07	3.63
S.Em±	2.38	0.15	0.03
C.D. (P = 0.05)	6.90	0.44	0.08

Table 3: Effect of irrigation frequency and zinc application on seed yield, stover yield, and biological yield

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Irrigation frequency			
I_1 = One irrigation	1814.51	4455.31	6269.82
I_2 = Two irrigations	2006.46	4827.85	6834.31
I_3 = Three irrigations	2110.82	4936.24	7047.06
S.Em±	48.77	97.53	86.83
C.D. (P = 0.05)	168.77	337.49	300.48
Zinc application			
Zn_0 = Control	1737.99	4203.04	5941.03
Zn_4 = 4 kg Zn ha^{-1}	1923.11	4681.81	6604.92
Zn_8 = 8 kg Zn ha^{-1}	2118.09	5024.10	7142.20
Zn_{12} = 12 kg Zn ha^{-1}	2129.85	5050.25	7180.10
S.Em±	24.54	73.63	68.52
C.D. (P = 0.05)	71.22	213.65	198.83

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