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Impact of Irrigation and Zinc on Soil Fertility and Water Use Efficiency under Mustard Cultivation

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Abstract: A field experiment trial was carried out at Instructional Farm of Rajasthan College of Agriculture, Udaipur during rabi 2019-20. The trial was laid out in split plot design with 12 treatment combinations. The 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 replicated four times. The results revealed that water use efficiency of mustard decreased significantly with increasing levels of irrigation but the soil fertilityparameters remained statistically unchanged with the irrigation. The available nitrogen,potassium, sulphur and zinc in soil after harvest of mustard crop increased significantly with application of zinc. The available phosphorus in soil after harvest decreased with increasing levels of zinc whereas, water use efficiency of mustard was increased significantly with increasing levels of zinc up to 8 kg Zn ha -1 .

Key words: Irrigation, zinc, soil fertility, water use efficiency, mustard

Introduction

Indian mustard is widely growing as oilseed crop in India. It was perhaps cultivated as early as 5000 BC, according to many ancient scriptures and available literature. India has the world's fourth largest vegetable oil economy. In India oilseeds accounted for 16.7%, 12.9% and 18.3% of total arable land, gross cropped area and net cropped area, correspondingly (Anonymous, 2019). During 2018-19, it contributes 24.7% to total area and 29.4% to total production of oilseeds. Mustard is grown in diversified climatic conditions from north-eastern or north western hills and plains to downward south under irrigated

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or rainfed, timely or late sown, even in saline soils and mixed or inter-cropping situations aswell. The scarcity of water in Rajasthan is one of the most critical factors affecting all facet of life (Kookana et al. 2016). Further, the morphometric distinctiveness of an area considerably affects the accessibility of groundwater (Kumar et al. 2015). Sufficient irrigation water is not available for irrigation results into low productivity of crops. Further, the quality of irrigation water plays an imperative role in production of crops (Yadav and Singh 2018). In semi-arid climate of Northern India, water stress and the insufficiency of nutrients, particularly of micronutrients are two foremost constraints which affect mustard production (Garnayak et al. 2000). Paucity of organic carbon with poor microbial population is the sign of poor soil health (Chandar et al. 2012). The number of irrigations is affecting the soil fertility and water use efficiency to a great extent. Further, zinc is a key micronutrient with specific physiological functions in all living systems, including maintaining the structural and functional integrity of biological membranes. Zinc plays an important role in oil content, protein content, nutrient content and uptake of mustard (Aswal and Yadav, 2007). Mustard is highly vulnerable to micronutrient deficiencies, particularly zinc because it is found deficient many areas of Rajasthan (Singh et al. 2013). Therefore, the present study was under taken to find out the impact of irrigation and zinc on soil fertility and water use efficiency under mustard cultivation.

Materials and Methods

Description of the study area

The trial was conducted during *rabi* season of the year 2019-20 at Instructional Farm of Rajasthan College of Agriculture, Udaipur. This region is covered the agro-climatic zone IV-a of Rajasthan having hard-rock characteristics (Machiwal*et al.* 2017). The soil of experimental field was clay loam with slightly alkaline reaction, medium in available nitrogen and phosphorus whereas high in available potassium and low in DTPA zinc.

Experimental details

The experimental set up comprises of three levels of irrigation viz. one irrigation at seedling stage, two irrigations at seedling + pod formation stage and three irrigations at seedling+50% flowering+ pod formation stage applied in main plots and four levels of zinc viz. control, 4 kg Zn ha^{-1}, 8 kg Zn ha^{-1} and 12 kg Zn ha^{-1} applied in sub plots, thereby making 12 treatment combinations. The trial was laid out in split plot design with 4 replications. Irrigations were given to mustard crop according to the treatments. NPS were applied uniformly at the rate of 60 kg N, 40 kg $P_2O_5$and 250 kg gypsum per hectare using urea, DAP and gypsum, respectively. Soil fertility parameters viz. EC, pH, organic carbon, available N, P, K, S and Zn and water use efficiency 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, I = irrigation (mm), P = precipitation (mm), C= capillary rise (mm), ET = evapo-transpiration in mm, D = deep percolation (mm), R = runoff (mm) and ΔS = change in profile soil moisture (mm). C was believed to be negligible as the groundwater table was fairly deep (10–15 m). The field plots had no runoff (R) because they were bunded to anenough height, and no overflow was observed on bund during the experimentation period. The deep percolation out of the root zone is considered insignificant because the applied irrigation water was always considerably below the field capacity of the soil profile. Thus the above equation simplifies to,

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

The gravimetric method was used to calculate the changes in soil moisture content (ΔS) and water use efficiency (WUE) was calculated as,

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

Where, Y= yield

Results and discussion

The data in Table 1 revealed that pH, EC, organic carbon, available N, P, K, S and Zn did not significantly change with increasing levels of irrigation. The water use efficiency (Table 2) gradually decreased as the number of irrigations increased. However, the water use efficiency decreased as the number of irrigations increased, as more water was consumed by evapo-transpiration without a corresponding increase in seed yield of mustard. Although under stressful conditions (only one irrigation at seedling stage) the plants were able to develop deep roots and take advantage of the moisture in deeper soil layers than with regular irrigation and achieve higher yields per unit of water, thus resulting in greater water use efficiency. The results are in compliance with Sharma et al. (2019). It is apparent from outcomes of Table 1 that application of zinc at increasing rate has no any significant effect on EC, pH and organic carbon in soil after harvest. Available N, K, S and Zn increased significantly with increasing dose of zinc up to 8 kg Zn ha -1 over control whereas, available P in soil after harvest of crop decreased with increasing rate of zinc. The maximum available N, K, S and Zn were recorded under application of 12 kg Zn ha -1 . The decrease in available P after harvest of mustard crop due to increased zinc application might be due to its antagonistic relationship with zinc. The increase in available nitrogen, potassium, sulphur and zinc after harvest of crop might be due to synergistic relationship of zinc with these nutrients (Yadav et al. 2005). The increased DTPA-Zn content in soil after harvest of crop might be due to its more solubility, diffusion and mobility of applied zinc (Yadav et al. 2012).

Results revealed that water use efficiency of mustard increased significantly with increasing levels of zinc up to 8 kg Zn ha -1 over control. It is well known fact that water use efficiency is a function of ET and seed yield, so, probably increase in seed yield was proportionally more as compared to ET under higher levels of zinc, which might be the reason of higher water use efficiency with increasing levels of zinc. The results are in compliance with the findings of Yadav et al. (2020).

Table 1. Effect of irrigation frequency and zinc application on post-harvest soil fertility

Treatments	pH	EC (dS/m)	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available S (pp m)	Available Zn (pp m)
Irrigation frequency								
One irrigation	8.24	0.566	0.651	298.65	19.06	425.29	9.40	1.82
Two irrigations	8.26	0.571	0.654	301.17	19.31	427.86	9.65	1.84
Three irrigations	8.26	0.581	0.659	302.65	20.09	428.60	9.80	1.84
SE m±	0.09	0.007	0.006	1.92	0.26	5.84	0.13	0.01

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C.D.(P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Zinc application								
Control	8.27	0.568	0.648	249.89	21.35	404.36	7.30	0.51
4 kgZnha^{-1}	8.26	0.571	0.650	301.99	20.63	418.18	8.63	1.81
8 kgZnha^{-1}	8.24	0.574	0.657	324.75	18.57	439.25	11.19	2.50
12kgZnha^{-1}	8.24	0.578	0.664	326.66	17.39	447.22	11.36	2.52
SE m±	0.06	0.006	0.006	2.00	0.26	4.61	0.10	0.01
C.D.(P= 0.05)	NS	NS	NS	5.81	0.74	13.37	0.30	0.03

Table 2. Effect of irrigation frequency and zinc application on evapo- transpiration, water use efficiency and economics

Treatments	**Evapo-transpiration**	**Water use efficiency (kg ha^{-1}mm^{-1})**
Irrigation frequency		
One irrigation	258.61	7.07
Two irrigations	297.47	6.62
Three irrigations	337.85	6.40
SE m±	3.71	0.07
C.D.(P= 0.05)	12.83	0.23
Zinc application		
Control	295.66	5.91
4 kgZnha^{-1}	297.62	6.54
8 kgZnha^{-1}	299.31	7.17
12kgZnha^{-1}	299.31	7.17
SE m±	4.31	0.06
C.D.(P= 0.05)	NS	0.17

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