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Effect of irrigation regimes and fertilizer levels on water use efficiency and yield of Mustard

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Abstract
Under rainfed conditions, the yields of mustard are generally low. Optimum irrigation increases the yield of the mustard crop, which necessitates adequate knowledge of crop water production function for optimum returns from mustard crop. The study titled "Performance of mustard under varying levels of irrigation and fertilizer levels in Telangana state" was conducted during *rabi* 2020-21 at College Farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana. The experiment comprised 12 treatment combinations in Randomized Block Design (factorial concept) with three replications. The results showed that irrigating the crop at IW/CPE=1.0 along with 125% RDF registered significantly highest siliqua plant^{-1} (127), seed and stover yield (1695 and 5499 kg ha^{-1}) as compared with other treatments. The best fitted water production function was found to be linear (R^2=0.45) and water use efficiency was also found to be more (0.675 kg ha^{-1} mm^{-1}) in the crop irrigated at IW/CPE=1.0 along with 125% RDF.

Keywords: Fertilizer, mustard, water production function, water use efficiency, yield

1. Introduction

Rapeseed-mustard is the key oilseed crop that can help in addressing the challenge of demand-supply gap of edible oil in India. India is one of the four major oil producing countries in the global scenario in terms of cultivation, production, imports and exports. India stands among the largest vegetable oil economies across the world accounts for about 14% of the world's oilseed area and 8% of oilseed production and ranks second in rapeseed-mustard production (DRMR, 2015) [4]. The major mustard growing states in India are Rajasthan, Uttar Pradesh and Madhya Pradesh. The oil contains 80 to 94% carbohydrates and 2.2 to 4.4% protein (Prasad, 2018) [8]. In the state of Telangana, mustard is cultivated in an area of 3000 ha with production of 5000 tonnes (Agriculture statistics at a glance, 2018-19) [1] and hence gaining momentum in Telangana state which was hither to nontraditional crop.

Traditionally in India, mustard is raised under rainfed conditions on marginal soils with low productivity. Raising mustard during *rabi* (winter) season using high yielding varieties and hybrids with proper resource management added new dimension to higher productivity. However, both water stress and excess water leads to problems of cessation of growth, raising water table, soil salinity and alkalinity consequently affecting yield attributes and yield. This necessitates adequate knowledge of the crop water production function to make appropriate decisions on resource allocation in terms of quantity and timing for maximizing returns. In addition to this, optimum time and optimum quantity of fertilizer application was also found to be crucial for higher yields. Hence, the present study was undertaken to find effect of irrigation and fertilizer on yield attributes, yield along with studies on water production functions.

2. Materials and Methods

The field experiment was conducted at college farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana (17º 32'N, 78º 41' E and 541.6 altitude) during *rabi* season of 2020-21onsandyclaysoils. The soil was low in N, medium in P and high in K status and neutral in reaction (pH7.11). The treatments consisted of three irrigation regimes *viz.*, I_1 –IW/CPE = 1.0, I_2 –IW/CPE = 0.8, I_3 –IW/CPE = 0.6 and four levels of fertilizer application *viz.*, F_1 – control, F_2 – 75% RDF (Recommended dose of fertilizer) (60-30-30 kg N- P_2O_5-K_2O ha^{-1}), F_3 100% RDF (80-40-40 kg N- P_2O_5-K_2O ha^{-1}) and F_4– 125% RDF (100-50-50 kg N- P_2O_5-K_2O ha^{-1}). The treatments were laid out in Randomized Block Design with Factorial concept and replicated thrice. Buffer channels of width 1.5 m and 2 m were laid between treatments and replications respectively to avoid the influence of one treatment on the other. Variety Pusa Agrani was used in the study. Effective rainfall received during experimental period was13.16 mm. Mustard evapotranspiration (ET_c) was calculated using the water balance equation (Praveen Rao, 2011) [7].

$$ET_c = I + P \pm DSW - Dp - Ro$$

Where, I=Amount of irrigation water applied (mm)
P= Precipitation (mm)
DSW = Change in soil water content (mm) in the 0- 0.60 m soil profile
Dp = Deep percolation (mm)
Ro=Amount of runoff (mm).

Runoff was assumed to be zero since the amount of irrigation water was controlled. Monitoring soil water content in the experimental plots revealed that Dp was negligible below 0.60 m in depth. On the other hand, water ET_c was estimated by monitoring soil moisture before and after each irrigation using gravimetric method in the effective crop root zone depth of 0.6 m.

3. Results and Discussions

Yield attributes

Maximum number of siliqua $plant^{-1}$ (94) was obtained with the treatment I_1 - IW/CPE=1.0 which was significantly highest than I_3 - IW/CPE= 0.6 (82) and was on par with treatment I_2 - IW/CPE= 0.8 (72) (Table 1). Higher number of siliqua $plant^{-1}$ observed in I_1 - IW/CPE=1.0 treatment might be due to extended and proportionate supply of water in effective root zone depth through frequent irrigations and lower number of siliqua $plant^{-1}$registered in I_3 - IW/CPE= 0.6 irrigation given plot may throw light as a result of moisture stress by reducing the irrigation frequency, which might lead to decrease in number of flowers converted in to seeds finally. The above data is in close accordance with findings of Somayeh *et al.* (2011) [10], Mankar *et al.* (2018) [6] and Bharat *et al.* (2019) [3]. Among fertilizer treatments, higher number of siliqua $plant^{-1}$ (114) was obtained from the treatment F_4 - 125% RDF which was found significantly superior to F_3- 100% RDF (97), F_2 - 75% RDF (85) and F_1 - control (33). The successive increase in the number of siliqua $plant^{-1}$ in higher dose of fertilizer treatment plot might be due to accessibility of more nutrients for proper growth of plants at different stages of crop growth. Similar findings have been reported by Shorna *et al.* (2020) [9]. Considering an interaction effect between irrigation and fertilizer, significant higher number of siliqua $plant^{-1}$ (127) was observed with treatment combination I_1F_4 (Irrigation scheduled at IW/CPE 1.0 along with 125% RDF) which was on par with I_2F_4 (Irrigation scheduled at IW/CPE 0.8 along with 125% RDF) (116) and I_1F_3 (Irrigation scheduled at IW/CPE 1.0 along with 100% RDF) (111.86) treatment plots followed by I_3F_4 (Irrigation scheduled at IW/CPE 0.6 along with 125% RDF) (101) and I_1F_2 (Irrigation scheduled at IW/CPE 1.0 along with 75% RDF) (98.62) and least number of siliqua $plant^{-1}$ (31) was recorded in I_3F_1 (Irrigation scheduled at IW/CPE 0.6 along with control). However, no significant differences in seeds $siliqua^{-1}$, siliqua length and test weight of mustard were found either due to irrigation or fertilizer level and their interaction. These results were in consonance with findings of Somayeh *et al.* (2011) [10].

Table 1: Number of siliqua $plant^{-1}$ of mustard as influenced by interaction between irrigation regimes and fertilizer levels

Treatments	F_1- Control	F_2- 75%RDF	F_3-100% RDF	F_4- 125%RDF	Mean
I_1- IW/CPE=1.0	38.76	98.62	111.86	127.00	94.06
I_2- IW/CPE=0.8	31.52	87.00	95.99	116.00	82.63
I_3- IW/CPE=0.6	31.00	72.00	86.00	101.00	72.50
Mean	33.76	85.87	97.95	114.66	
SEm±	9.68				
CD (*P=0.05)	22.88				

Seed Yield

Significant higher seed yield (1695.40 kg ha^{-1}) was obtained in treatment combination of I_1F_4 (Irrigation scheduled at IW/CPE 1.0 along with 125% RDF) followed by I_2F_4 (Irrigation scheduled at IW/CPE 0.8 along with 125% RDF) (1503.36 kg ha^{-1}) and I_1F_3 (Irrigation scheduled at IW/CPE 1.0 along with 100% RDF) (1398.60 kg ha^{-1}) treatment plots and after that I_2F_3 (Irrigation scheduled at IW/CPE 0.8 along with 100% RDF) followed the order while least seed yield (204.60 kg ha^{-1}) was recorded in I_3F_1 (Irrigation scheduled at IW/CPE 0.6 along with control) (Table 2). These results were in line with those reported by Mandal *et al.* (2006) [5]; Verma *et al.* (2018) [11].

Significant higher stover yield (5499.98 kg ha^{-1}) was recorded in treatment combination of I_1F_4 (Irrigation scheduled at IW/CPE 1.0 along with 125% RDF) followed by I_1F_3 (Irrigation scheduled at IW/CPE 1.0 along with 100% RDF) (5170.33 kg ha^{-1}) which was on par with I_2F_4 (Irrigation scheduled at IW/CPE 0.8 along with 125% RDF) (5099.55 kg ha^{-1}) treatment combination, thereafter I_1F_2 (Irrigation scheduled at IW/CPE 0.8 along with 125% RDF) and I_2F_3 (Irrigation scheduled at IW/CPE 0.8 along with 125% RDF) followed the order while least stover yield (791.42 kg ha^{-1}) was recorded in I_3F_1 treatment combination (Irrigation scheduled at IW/CPE 0.6 along with control -No fertilizer application) (Table 2). These results were in line with those of Ahmadi and Bahrani (2009) [2].

Water use efficiency

Water use efficiency increased with increasing irrigation and fertilizer levels (Table2). Treatment I_1F_4 (Irrigation scheduled at IW/CPE 1.0 along with 125% RDF) recorded highest water use efficiency followed by I_2F_4 (Irrigation scheduled at IW/CPE 0.8 along with 125% RDF) and least was observed in I_3F_1 treatment combination (Irrigation scheduled at IW/CPE 0.6 along with control).

Table 2: Seed yield, stover yield, Evapotranspiration and WUE as influenced by interaction between irrigation regimes and fertilizer levels

Treatment	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	ET (mm)	WUE (kg ha^{-1} mm^{-1})
I_1F_1 (I_1-IW/CPE=1.0 and F_1 – Control)	259	1035	242	0.107
I_1F_2 (I_1-IW/CPE= 1.0 andF_2 – 75% RDF)	1116	4505	245	0.455
I_1F_3 (I_1-IW/CPE=1.0 andF_3 – 100% RDF)	1398	5170	250	0.559
I_1F_4 (I_1-IW/CPE=1.0 andF_4 – 125% RDF)	1695	5499	251	0.675
I_2F_1 (I_2-IW/CPE= 0.8 andF_1 – Control)	244	984	230	0.106
I_2F_2 (I_2-IW/CPE= 0.8 andF_2 – 75% RDF)	947	3175	233	0.406
I_2F_3 (I_2-IW/CPE= 0.8 andF_3 – 100% RDF)	1223	3897	241	0.507
I_2F_4 (I_2-IW/CPE= 0.8 andF_4 – 125% RDF)	1503	5099	242	0.621
I_3F_1 (I_3-IW/CPE=0.6 andF_1 – Control)	204	791	216	0.094
I_3F_2 (I_3-IW/CPE=0.6 andF_2 – 75% RDF)	770	2365	219	0.351
I_3F_3 (I_3-IW/CPE=0.6 andF_3 – 100% RDF)	969	3184	232	0.417
I_3F_4 (I_3-IW/CPE=0.6 andF_4 – 125% RDF)	1149	3805	235	0.489
SEm ±	16.12	75.18	-	-
CD (*P=0.05)	47.59	221.94	-	-

*IW/CPE: Irrigation water/Cumulative Pan Evaporation
*RDF: Recommended dose of fertilizer

Water production functions

The data were further used for developing water production Functions (linear, quadratic functions):

Table 3: Water production Functions

Water production function	Equation	R^2	F value	Sig.	RMSE	Constant	b1	b2
Linear	Y = -6281.300 + 30.63 (ETc)	0.45	8.45	.016	387.25	-6281.300	30.630	-
Quadratic	Y = = 0.4799 (ETc)^2 - 193.66 (ETc) + 19868	0.47	4.01	.056	403.10	19883.625	-193.791	0.480

Where, Y=Mustard seed yield (kg ha^{-1})
ET_c= Seasonal crop evapotranspiration (mm)
R^2 = Coefficient of determination
F = Variance ratio for testing R^2 in both the functions.

The test statistics (R^2 and F-value) indicated that linear production function was statistically significant while quadratic production function was found to be non-significant (Table 3). The fitted linear function has lowest RMSE value of 387.25 and explained total variation (R^2) in seed yield was 45% by linear (Figure 1) suggesting that in the present study linear production function was best fitted and the mustard seed yield increased with increase in crop evapotranspiration.

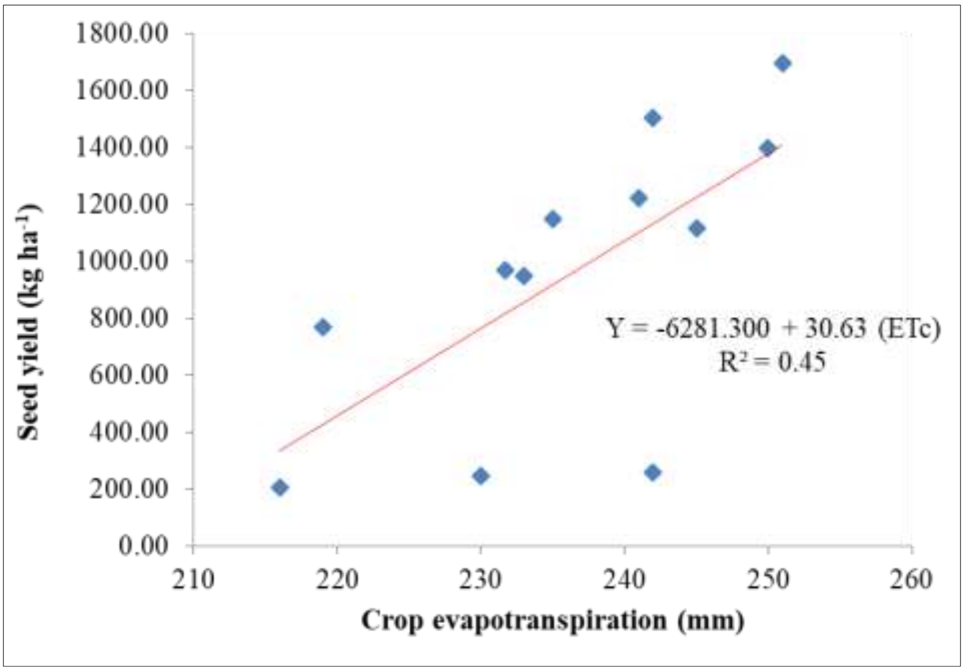

Fig 1: Linear water production function between seed yield and ET_c of mustard

4. Conclusions

The results show cased that, irrigating mustard crop at IW/CPE=1.0 along with 125% RDF registered significantly highest number of siliqua plant^{-1} (127), seed and stover yield (1695 and 5499 kg ha^{-1}) as compared with other treatments. The best fitted water production function was found to be linear (R^2 =0.45) and more water use efficiency (0.675 kgha^{-1}mm^{-1}) with the same treatment. However, further research needs to be done for conformity.

5. Author's contribution

Conceptualization and designing of the research work (Dr. Baby Akula, Dr. Indudhar Reddy and Dr. T. Sri Jaya); Execution of field/lab experiments and data collection (Srujana Puppala); Analysis of Data and interception (Dr.

Baby Akula and Dr. Indudhar Reddy); Preparation of manuscript (Srujana Puppala)

6. Declaration: The authors have declared no conflict of interest exists.

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