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Water use efficiency and nutrient uptake of yellow mustard (*Brassica juncea* L.) as influenced by different irrigation schedules through non weighing lysimeters associated with varying water table conditions

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Abstract
To analyse the effect of different irrigation schedules on water use efficiency and nutrient uptake of yellow mustard (*Brassica juncea* L.) cv. Pant Pili Sarson-1, a lysimeter experiment was conducted at Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (29^0 N latitude 79^0 30' E longitude and at an altitude of 243.8 m above the mean sea level) during *rabi* season of 2015-16. The experiment was initiated under three irrigation schedules (IW: CPE as 0.5, 0.75 and 1.0) with two irrigation methods (flood and sprinkler) in non weighing lysimeters associated with 30±1.5, 60±1.5 and 90±1.5 cm water table depths under three factorial randomized block design with six irrigation treatments**.** Water use efficiency (WUE) of crop was maximum (2.92 kg $ha^{-1}mm^{-1}$) grown in lysimeters where irrigations were given at IW: CPE 0.75 under deep water table condition (90±1.5 cm) using sprinkler method of irrigation. Maximum uptake of nutrients by crop was observed under IW: CPE 0.75 associated with deep water table condition (90±1.5 cm) using sprinkler method of irrigation. Irrigation scheduling based on IW: CPE ratio of 0.75 using sprinkler method of irrigation in lysimeters associated with shallow water table depth was found to be ideal for contribution of maximum nutrient uptake of yellow mustard cv. Pant Pili Sarson-1.

Keywords: Yellow mustard, evapotranspiration, water use efficiency, crop coefficient, irrigation schedules, irrigation method

Introduction
Among the oilseed crops, *Brassica juncea* L. is one of the leading crop grown in India. Rapeseed and mustard crops account for about 21 percent of oil seed production. Their average yield in India is 968 kg ha^{-1}, which is not satisfactory because it is much below the world average yield of 1343 kg ha^{-1} (Damodaram and Hegde, 2000) [5]. In India mustard is predominantly grown in Rajasthan, UP, Haryana, Madhya Pradesh, and Gujarat. It is also cultivated under some non- traditional areas of South India including Karnataka, Tamil Nadu, and Andhra Pradesh. The country witnessed yellow revolution through a phenomenal increase in production and yield from 2.68 MT and 650 Kg ha^{-1} in 1985-86 to 6.41 MT and 1022 kg ha^{-1} in 2011-12, respectively. In-spite of these performances there exists a gap between production potential and actual realization. In India now, oilseed crop is grown on an area of 24.65 million ha with production of about 31.31 million tonnes (Directorate of Economics and Statistics, 2018) [8].

Water is one of the crucial and valuable input which is needed by the crop during the growing season, therefore, it is important to guide the judicious use of water in such a way by which the water requirement of crop is fulfilled. Systematic use of irrigation water is useful in assisting for growing agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during period of inadequate rainfall. Evapotranspiration (ET) is a considerable amount of moisture lost from a plant canopy where evaporation and transpiration are simultaneously occurring process. At the initial stage of crop, the major loss of water occur through evaporation from soil surface, but at fully developed crop cover, more loss of water results through transpiration. Crop coefficient value helps in determining irrigation requirement of particular crop at different growth stages.

Crop coefficient is calculated by empirical ratio of actual evapotranspiration (ET) to the potential evapotranspiration (ETp). Jensen and Haise (1963) [13] proposed a methodology for computing potential evapotranspiration (ETp). The non-weighing type of lysimeters are used to determine evapotranspiration by measuring all components of soil water balance, including water inputs (rain and irrigation), outputs (drainage and runoff), and change in soil water storage (Garcia *et al*., 2004) [9]. This study is useful in obtaining the relationship between water use and its productivity. Therefore, the study is focused on establishing the information on water requirement for yellow mustard (*Brassica juncea* L.) grown in non-weighing lysimeters associated with shallow, medium and deep water table conditions with object, to study the effect of irrigation schedules, water table depths and irrigation methods on yield, water use efficiency and nutrient uptake of yellow mustard cv. Pant Pili Sarson-1.

Material and Method

Experimental Site

An experiment was conducted in a non-weighing type of lysimeters in during *rabi* season of 2015-16 at Norman E. Borlaug crop research centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (29^0 N latitude 79^0 30` E longitude and at an altitude of 243.8 m above the mean sea level), District Udham Singh Nagar, Uttarakhand. N.E. Borlaug Crop Research Centre is situated in *tarai* belt of Uttarakhand.

Climate of the region

The climate of the region is humid sub-tropical with dry hot summers and cold winters. It has a dry season from early October to mid June and a wet season from mid June to early October. Average annual rainfall of the area is 1433.4 mm. Relative humidity is highest during July - August and lowest during April - May.

Experimental setup

Lysimeters are constructed in 6 batches each containing 6 lysimeters in number, arranged in two rows. The inner wall dimension of tanks of rectangular lysimeters is 1.8 x 1.5 m (2.7 m^2) in area and 1.5 m deep. Lysimeters associated with 30±1.5 cm, 60±1.5 cm and 90±1.5 cm water table conditions using water table maintenance tanks were used for this study. The run-off collection tank have 10 cm thick wall, with a inner wall of dimension 0.8m by 0.8m by 0.8m with sloppy roof.

Soil of lysimeters

The soil which has been filled in lysimeter is classified as silty clay loam (Deshpande *et al.,* 1971) [7]. The data on Physico-chemical analysis of lysimeter soil is given in Tables 1 & 2, respectively. The soils are weakly developed with Mollic epipedons and Cambic subsurface horizons and are classified as Mollisols. The application of nutrients to soil were 80:50:40 NPK (Kg ha^{-1}) RDF & 200 kg ha^{-1} Split application of nitrogen was given i.e., 50% as basal and remaining as top dressing after 30 DAS, and full doses of P_2O_5 and K_2O were applied as basal.

Crop varietal characteristics

Pant Pili Sarson-1 one of the assuring variety of mustard that shows better response to irrigation that is why it is selected as experimental material. Pant Pili Sarson-1 performs well in agro- *tarai* soils, was sown on 21 October 2015 at spacing of 30×10cm. Plant population maintained in each lysimeter were 90. All required cultural operations were done as per standard agronomic practices. The crop was harvested on 8 February 2016.

Experimental treatments

Lysimeter experiment consisted of 6 treatments T_1, T_2, T_3, T_4, T_5 and T_6. Each treatment had three factors which are : (a) First factor – Three irrigation levels, viz. IW:CPE 0.5, IW:CPE 0.75 and IW:CPE 1.0 (b) Second factor- Three water table depth (30±1.5 cm, 60±1.5cm and 90±1.5cm), and (c) Third factor- Two irrigation method i.e., Flood (5 cm irrigation water) and Sprinkler (2 cm irrigation water). In Factorial Randomized Block Design total 18 treatment combinations were laid out and each treatment was replicated two times and in all 36 lysimeters was used for the study. The experimental data was analyzed statistically for three factorial randomized block design.

Computation of Crop Coefficient (Kc), Water Use Efficiency and Nutrient Uptake.

Kc was computed for yellow mustard cv. Pant Pili sarson-1 from ratio of crop evapotranspiration (ET) measured through non-weighing lysimeters and computed potential evapotranspiration (ETp) from observed weather data observed during the *rabi* season 2015-16 ($Kc = ET/ET_P$) (Jensen, 1973) [12]. Under all irrigation treatment combinations, the water use efficiency (kg ha^{-1} cm^{-1} water use) was calculated by working out the ratio of seed yield (kg ha^{-1}), and water use (mm) during crop growing season. Total nutrient uptake was calculated by using the relation : Uptake by straw or seed (kg ha^{-1}) = Per cent nutrient in grain or straw × Grain or straw yield (kg ha^{-1})/100. Total nutrient uptake by plant (kg ha^{-1}) = uptake by straw (kg ha^{-1}) + Uptake by grain (kg ha^{-1}).

Table 1: Physical properties of the silty clay loam soil filled in lysimeters experiment in 1971. (Deshpande, *et al.,* 1971) [7]

Properties	Soil depth (cm)			Method used
	0-20	20-40	40-60	
Texture	Silty clay loam			Bouyoucos Hydrometer method (Blake, 1986)
Bulk density(Mg m^{-3})	1.33	1.42	1.58	Core-tube method (Blake,1986)
Saturated hydraulic conductivity (cm hr^{-1})	0.818	0.210	1.13	Constant-head method (Klute and Dieksen, 1986)
Moisture content at field capacity (% by weight)	25.2	21.6	19.4	Pressure plate apparatus (Richards, 1954)
Moisture content at permanent wilting point (% by weight)	8.4	8.3	8.1	Pressure plate apparatus (Richards, 1954)

Table 2: Chemical properties of silty clay loam soil filled in lysimeters experiment in 1971.

S. No	Chemical properties	Value (initial)	Method used
1	pH (1:2 soil water suspension)	7.16	Jackson, 1967
2	Electrical conductivity (dS m^{-1})	0.21	Bower and Wilcox (1965)
3	Organic carbon (%)	0.79	Walkley and Black method, 1934
4	Available nitrogen (N kg ha^{-1})	217.6	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
5	Available phosphorus (P_2O_5 kg ha^{-1})	15.12	Olsen *et al.* (1954)
6	Available potassium (K_2O kg ha^{-1})	177.7	Ammonium acetate method (Hanway and Heidel, 1952)

Results and Discussion

Water Use Efficiency

Results as shown in **Table 3** indicated that maximum water use efficiency (2.92 kg ha^{-1} mm^{-1}) was found under irrigation scheduled at IW:CPE 0.75 (5 cm under flood and 3 cm under sprinkler) and low (2.38 kg ha^{-1} mm^{-1}) under IW:CPE 0.5 and was lowest (2.29 kg ha^{-1} mm^{-1}) with irrigation schedule at IW:CPE 1.0. Optimum applied irrigation helped in improving the water use efficiency by maintaining the supply of adequate amount of moisture in soil profile. Similar trend in results has been supported by findings of Mila *et al.* (2010) [15]. Water table depths significantly influenced water use efficiency of yellow mustard. Highest value (2.72 kg ha^{-1} mm^{-1}) of WUE was observed under deep water table depth (90 ±1.5 cm) as compared with water table depth at 60 ±1.5 cm (2.54 kg ha^{-1} mm^{-1}) and at 30 ±1.5 cm (2.33 kg ha^{-1} mm^{-1}). Deep water table depth helped in obtaining optimum average yield in spite of lesser availability of water supply resulting increase in water use efficiency of yellow mustard. Results also showed that WUE was maximum (2.69 kg ha^{-1} mm^{-1}) under sprinkler method of irrigation as compared to flood method of irrigation (2.37 kg ha^{-1} mm^{-1}). Under sprinkler method of irrigation, water was applied over the crop uniformly, covering whole surface of soil which helped in increasing the water use efficiency of crop. Above research study were supported by the findings of Dasila *et al.* (2016) [6].

Yield

Seed yield was maximum under the irrigation scheduled at IW:CPE 0.75 in lysimeters associated with shallow water table depth using sprinkler method of irrigation. Percent increase in seed yield was 34.99 under IW:CPE 0.75 over IW:CPE 0.5 (Table 3). Sprinkler method of irrigation increased seed yield of yellow mustard by 14..1 % over flood method of irrigation. Above research findings were supported by study of Choudhary *et al.* (2016) [4], who have reported that with two irrigations (one each at pre-flowering and pod filling stage) gave highest seed yield (2069.25 kg ha^{-1}) of mustard. Yadav *et al.* (2010) [20] also reported that two irrigations given at flower initiation and seed development stage resulted in 8.78 % and 24.18 % higher seed yield over one irrigation applied at flower initiation stage and siliquae development stage, respectively. Optimum availability of water under IW:CPE 0.75 led to increase in the yield attributing characters that enhanced the yield of yellow mustard. Sprinkler method of irrigation supply the water in the form of rainfall, striking action of water helped in uniform distribution of water over the crop as well as over the soil thus providing favourable conditions for growth and development of mustard.

Table 3: Water use efficiency and seed yield (Kg ha^{-1}) of yellow mustard (*Brassica juncea* L.) as influenced by irrigation schedules and irrigation methods in lysimeters under shallow, medium and deep water table conditions

Treatments	Water use efficiency (Kg ha^{-1} mm^{-1})	Seed yield (Kg ha^{-1})
Irrigation Schedules		
IW:CPE = 0.5	2.38	741.28
IW:CPE = 0.75	2.92	1000.68
IW:CPE = 1	2.29	924.20
S.Em ±	0.096	0.172
CD 5%	0.287	0.512
Water table depths		
30 ± 1.5 cm	2.33	898.30
60 ± 1.5 cm	2.54	887.18
90 ± 1.5 cm	2.72	880.65
S.Em ±	0.096	0.172
CD 5%	0.287	0.512
Irrigation Methods		
Flood	2.37	830.04
Sprinkler	2.69	947.40
S.Em ±	0.079	0.140
CD 5%	0.234	0.418

Crop Coefficient for yellow mustard cv. Pant Pili sarson-1

Crop coefficient (Kc) for yellow mustard cv. Pant Pili sarson-1 was computed from crop evapotranspiration (ET) and potential evapotranspiration (ETp) suggested by Jensen, (1973) [12] (Table 4). Daily, weekly and seasonal ET for yellow mustard cv. Pant Pili sarson-1 were calculated from daily observations taken from lysimeters associated with 30±1.5 cm, 60±1.5 cm and 90±1.5 cm water table conditions during Rabi season of 2015-16. The average value of Kc (crop coefficient) for mustard cv. Pant yellow sarson-1 is 0.63 ranging from 0.14 after Ist week of sowing to 1.04, during 7th week after sowing. Also Kc values increased till 11th week and decreased. Crop coefficient accounts the properties of plants that helps in calculating the evapotranspiration and total water use in order to compute the water requirement of mustard in growing season.

Table 4: Crop Coefficients (Kc) for yellow mustard c.v. Pant Pili Sarson-1

Week after sowing	Kc for yellow mustard c.v. Pant Pili Sarson-1
1	0.14
2	0.19
3	0.30
4	0.42
5	0.60
6	0.95
7	1.04
8	0.77
9	0.76
10	0.72
11	0.88
12	0.94
13	0.79
14	0.31
Av.	0.63

Nutrient Uptake

Nutrient uptake were significantly influenced by different irrigation schedules, water table depth and irrigation methods (Table 5). Maximum uptake (76.39, 6.33, 62.86 and 18.11 kg ha^{-1},) of nitrogen, phosphorus, potassium and sulphur uptake were observed under irrigation scheduled at IW:CPE 0.75 and the minimum (68.67, 4.50, 54.66 and 10.67 kg ha^{-1}, respectively) under irrigation scheduled at IW:CPE 0.5. These trend of results observed in nutrient uptake were endorsed by the findings of Ray *et al.* (2015) [17] reported that with increase in number of irrigations, there was increased in sulphur uptake, when one irrigation was applied the sulphur uptake was 15.39 Kg ha^{-1} which increased to 17.51 Kg ha^{-1} when irrigation was given thrice. Choudhary *et al.* (2018) [3] also reported a significant influence of water table depth and irrigation methods were found on nutrient uptake. Yaseen *et al.* (2014) [21] also supported the findings of nutrient uptake of yellow mustard analysed during the study. Due to better availability of nutrient, higher nutrient content and yield under irrigation scheduling with five irrigations, associated with shallow water table depth with sprinkler method of irrigation resulted in higher uptake of nutrient by yellow mustard.

Table 5: Nutrient uptake (Kg ha^{-1}) of yellow mustard (*Brassica juncea* L.) as influenced by irrigation schedules and irrigation methods through lysimeters under shallow, medium and deep water table conditions

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	S uptake (kg ha^{-1})
Irrigation Schedules				
IW:CPE = 0.5	68.67	4.50	54.66	16.55
IW:CPE=0.75	76.39	6.33	62.86	18.11
IW:CPE = 1	75.12	5.52	62.35	16.25
S.Em ±	0.012	0.019	0.012	0.005
CD 5%	0.036	0.056	0.035	0.014
Water table depths				
30 ± 1.5 cm	76.73	5.86	60.47	18.41
60 ± 1.5 cm	73.01	5.54	60.41	16.92
90 ± 1.5 cm	70.44	4.95	59.00	15.50
S.Em ±	0.012	0.019	0.012	0.005
CD 5%	0.036	0.056	0.035	0.014
Irrigation Methods				
Flood	72.80	5.17	59.76	16.70
Sprinkler	73.99	5.71	60.16	17.24
S.Em ±	0.010	0.015	0.010	0.004
CD 5%	0.029	0.046	0.029	0.012

Conclusion

It is concluded from this study that among different irrigation treatment combinations, irrigation schedule based on IW: CPE 0.75 produced maximum seed yield under 30±1.5 cm water table depth using sprinkler method of irrigation. However, irrigation methods, sprinkler method was found to be superior over flood method for maximizing seed yield of yellow mustard. The maximum water use efficiency was found in yellow mustard scheduled at IW:CPE 0.75 under 90±1.5 cm of water table depth using sprinkler method of irrigation. It was also found that under irrigation scheduled at IW:CPE 0.75 in lysimeters associated with shallow water table depth with sprinkler method of irrigation helped in more uptake of nutrients as compared to other treatments.. This study provides a guide to farmers towards the regulation of water supply, thus saving one of the valuable agricultural input and enhancing the crop yield.

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