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Research Paper

Influence of water management, planting methods and mulching on growth, root dry weight, root density, yield and yield attributes and water-use in yellow sarson (*Brassica rapa*)

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ABSTRACT

A field experiment was conducted on sandy loam soils during two consecutive winter seasons (*rabi)* of 2014–15 and 2015–16 at G.B. Pant University of Agriculture and Technology, Pantnagar to evaluate the effect of irrigation scheduling, planting methods and mulching on growth, root characteristics, yield and yield attributes and consumptive use of water (CUW) of yellow *sarson* (*Brassica rapa* L. var. yellow sarson) in sandy loam soil. Number of branches/plant, relative leaf water content (RLWC), root dry weight, root density, yield attributing characters, seed and stover yields, were influenced significantly due to irrigation levels, being the maximum at 1.2 IW: CPE ratio followed by 0.9 IW: CPE ratio. The maximum number of branches/plant, root dry weight, root density, RLWC, yield attributing characters and seed and stover yields were found with raised-bed planting compared to flat-bed planting. Yellow sarson sown with mulch produced significantly higher values of growth, root dry weight, root density and yield-attributing characters, seed and stover yields and CUW than no-mulch treatment.

Key words **:** Consumptive use of water, Irrigation levels, Mulching, Root density, Seed yield

Rapeseed-mustard is the main oilseed crop of winter (*rabi*) season. It is mainly grown in Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana and Gujarat, accounting for more than 70% of total rapeseed-mustard acreage in the country. Rapeseed-mustard occupies 6.42 million ha area with the production of 6.33 million tonnes and average productivity of 1,250 kg/ha (MOA & FW, GoI, 2017). Optimum moisture availability is needed in root zone, to meet the crop water requirements for achieving higher yield potential as well as mitigation of stress at critical stages of crop. It is possible only through adopting the improved water management and moisture conservation practices like mulching. Water requirement of mustard crop is not so high, but to exploit full potential of this crop, it is essential to provide sufficient water at least at the time of the critical stages of the crop. Ray *et al.,* (2015) reported higher mustard yield under irrigated condition compared to control. The potential agronomic benefits derived from raised bed planting are facilitation in seed germination, proliferation of root growth, reducing the mechanical resistance to plant roots, increased soil porosity and encouragement of crop growth, prevention of water stagnation after irrigation and reducing water requirement of crop. There was a 35% saving in water, resulting in 32% increase in water-use efficiency in bed planting (Butter *et al*., 2006). Mulches play an important role to conserve soil moisture and supply to the plant for longer duration which as a result increase the water use efficiency. Mulches prevent soil erosion, reduce evaporation losses, increase infiltration, decreases weed population and eventually increases crop yields. Mulches increase soil fertility after decomposition in the soil, improve nutrient supplying capacity of soil by maintaining sufficient moisture in the soil. Studies on mulching carried out in India under rainfed agriculture have concentrated on the measurement of crop responses rather than on the manner in which crop responses are influenced. Rice-straw mulch increased the production and productivity of mustard (Sharma *et al.,* 2014). Most of the area where the cultivation of mustard is going on, has limited water for irrigation. Especially semi-arid regions of the country, suffer from the water scarcity around the year be-

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cause of erratic rainfall and poor water conserving techniques. Therefore, there is need to achieve good crop yield under resource limited condition by comprehensive approach of irrigation management, effective conservation techniques to conserve soil moisture like mulching and planting methods.

MATERIALS AND METHODS

A field experiment was carried out during winter seasons (*rabi*) of 2014–15 and 2015–16 at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, which is geographically located at an altitude of 243.8 m above mean sea level, 29° N latitude and 79.3° E longitudes. The climate of Pantnagar is sub-humid, sub-tropical with hot and dry summer, cold winters and heavy rains during rainy season (June–September). The weekly average weather parameters, viz. rainfall, minimum and maximum temperature, relative humidity, sunshine-hours, pan-evaporation and wind-velocity were recorded during the course of experimentation during 2014-15 October–February and 2015-16 (October-January) at the meteorological observatory located at the Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The soil of experimental field was sandy loam and had 238.3 kg available N/ha, 15.71 kg available P/ha, 185.6 kg available K/ha, 0.87% organic carbon with 7.4 *p*H of soil (1: 2.5 soil: water). Treatments were laid out in split-plot design with 3 replications. The treatments consisted of 4 irrigation levels (0.3, 0.6, 0.9 and 1.2 IW : CPE ratios) in the main plots and combinations of two planting methods (flat bed and raised bed) and two levels of mulching (mulch with rice straw @ 5 tonnes/ha and no mulch). During 2014–15, 81.1 mm and during 2015–16, 7 mm rainfall was received during the crop growing season. Raised beds having width of 60 cm were prepared with the help of tractor-drawn bed maker. Inverted furrows of 10 cm in between the raised bed were utilized for irrigation purpose. Yellow *sarson* variety 'Pant Pili *Sarson* 1' was sown at 30 cm × 10 cm spacing. Rice straw mulch (@ 5 tonnes/ha) was applied according to the treatment at 25 days after sowing (DAS) of crop. Total number of branches (primary and secondary branches) was counted by selecting 4 plants from the tagged plants of the observational rows of each plot at 90 DAS and at maturity. Roots studies were done at 90 DAS by taking soil sample from 0–15 cm root zone depth through core sampler from each plot. The root portion of plants along with soil mass was put in a fine-meshed plastic nylon bag. The bags containing entire contents was immersed in running water in a nearby cemented channel for about 1 hour to loosen the soil mass for recovery of entire root mass during washing. After thorough cleaning, the roots were separated out from soil by washing in running water and then oven dried at 70± 2°C weighed and expressed in mg/cm^3. Length of 10 siliquae, taken out from the randomly selected tagged plants of each plot was measured with the help of threads and meter scale. Then the average was worked out and expressed as length of siliqua in cm. The seeds were obtained after threshing the siliquae of tagged plants and after taking weight their average was worked out to find out the seeds/plant. After threshing and weighing the net plot yield, a random sample of seeds was drawn from the produce. From the individual plot, the net plot area was harvested separately and produce was sun dried. The sun dried crop was threshed and produce was cleaned. The weight was recorded in kg/plot and finally converted into t/ha by using conversion factor. After recording the seed yield, the stover yield was recorded for the respective plots. The stover yield obtained from the net plot area of 6 m^2 was expressed in t/ha. The ratio of economic yield to the total biological yield (harvest index) was computed and presented in per cent by using the formula given below:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

Consumptive use of water = (Total water use - PMC±) + Effective rainfall + ET (48 hr)

Relative leaf water content was measured before application of each irrigation in to the field. Fully expanded fresh leaves were selected and cut from randomly chosen plants in each plot. Out of this 3 g leaves sample was taken and dipped in distilled water in petri dish until fully turgid or rehydrated after full rehydration of leaf, turgid leaf was weighed and then oven dried at 70 ± 2 °C till constant weight and weighed again.

$$\text{RLWC (\%)} = \frac{\text{FW - DW}}{\text{TW - DW}} \times 100$$

Where, RLWC, Relative leaf water content; FW, fresh weight of sample; DW, oven dry weight of sample; TW, turgid weight of sample

RESULTS AND DISCUSSION

Growth attributes: Primary and secondary branches recorded significantly higher number with 1.2 IW : CPE ratio as compared to remaining irrigation levels but remained at par with 0.9 IW : CPE ratio at 90 DAS and at harvest stage (Table 1). The increase in number of primary branches/plant is the resultant effect of better plant growth conditions. Moisture has a unique role to play for plant growth by influencing improved nutrient availability followed by higher metabolic activity and growth and ultimately with more number of branches. The result agreed with the finding of Yadav *et al.* (2010) and Verma *et al.* (2014) and they observed the positive effect of irrigation water towards branches formation. Raised bed planting method registered significantly higher number of primary and secondary branches/plant, than flat bed planting method at 90 DAS and at harvest, respectively. Raised bed resulted in better soil physical condition, by root proliferation, growth and nutrient and water transport for metabolic activities. Buttar *et al.* (2006) and Shekhawat *et al.* (2016) also noticed significant effect of planting methods on primary branches. Significantly higher number of primary and secondary branches/plant were reported as compared to no mulch at 90 DAS and at harvest, respectively. These results are in close conformity with the findings of Choudhary *et al*. (2008) and Tetrawal *et al*. (2013).

Root study: The data pertaining to root dry weight (g) and root density (mg/cc) at 90 DAS was affected significantly by various treatments (Table 1). Root dry weight and root density increased significantly at 1.2 IW : CPE ratio as compared to remaining irrigation levels, i.e. 0.9, 0.6 and 0.3 IW: CPE ratio while root density remained at par with 0.9 IW: CPE ratio. The minimum root dry weight and root density were reported at 0.3 IW: CPE ratio due to no irrigation. The beneficial effect of optimum moisture in soil resulted in better root proliferation and root activities and thereby more dry matter accumulation and root density. Mandal *et al.* (2006) reported that root mass increased under sufficient supply of moisture to the mustard crop. Yellow *Sarson* sown on raised bed, significantly higher root dry weight and root density were reported as compared to flat bed panting methods. Raised bed planting registered 28.2% more root dry weight over flat bed planting method. Root dry weight and root density were also significantly influenced by mulching. Application of mulch reported 11.4% higher root dry weight as compared to no mulch.

Relative leaf water content: Irrigation levels significantly influenced relative leaf water content. The relative leaf water content decreased with the decrease in irrigation frequency (Table 2). The higher relative leaf water content was recorded at 1.2 IW : CPE ratio which was significantly superior over 0.3 and 0.6 IW : CPE ratio while at par with 0.9. Significantly lower relative leaf water content was recorded at 0.3 IW : CPE ratio. The maximum relative leaf water content was obtained under raised bed planting method which was significantly superior over flat bed planting method. Application of mulch recorded significantly increased relative leaf water content as compared to no mulch.

Consumptive use of water: The consumptive use of water was influenced significantly by irrigation levels (Table 2). Consumptive use of water increased with successive increase in moisture supply. Significantly higher amount of water was consumed at 1.2 IW: CPE ratio as compared to remaining irrigation levels followed by 0.9 IW: CPE ratio. It was associated with greater evapo-transpiration under adequate moisture supply. Dudwal *et al.* (2013) reported that the consumptive use of water of mustard increased

Table 1. Effect of irrigation levels, planting methods and mulching on primary and secondary branches, Root dry weight/plant, Root density/plant (data pooled over 2 years)

Treatment	Primary branches/plant		Secondary branches/plant		Root dry weight/plant (gm)	Root density/plant (mg/cm^3)
	90 DAS	Harvest	90 DAS	Harvest		
Irrigation level (IW : CPE ratio)						
0.3 IW : CPE	6.85	7	5.65	6	1.30	1.10
0.6 IW : CPE	8.3	8.65	9.3	9.85	1.98	1.68
0.9 IW : CPE	10.85	11.3	12.1	12.7	2.31	1.96
1.2 IW : CPE	11.4	11.65	12.9	13.45	2.62	2.23
SEm±	0.35	0.25	0.45	0.45	0.06	0.05
CD (*P*=0.05)	1.1	0.8	1.6	1.55	0.20	0.17
Planting method						
Flat bed	8.8	9.15	9.05	9.55	1.80	1.53
Raised bed	9.95	10.2	10.95	11.45	2.31	1.96
SEm±	0.2	0.2	0.3	0.3	0.04	0.04
CD (*P*=0.05)	0.6	0.5	0.85	0.9	0.12	0.1
Mulching						
No Mulch	8.9	9.1	9.3	9.75	1.94	1.65
Mulch	9.85	10.2	10.7	11.25	2.16	1.84
SEm±	0.2	0.2	0.3	0.3	0.04	0.04
CD (*P*=0.05)	0.6	0.5	0.85	0.9	0.12	0.1

with increasing number of irrigations. Consumptive use of water influenced significantly due to planting methods. The maximum consumption of water was reported under raised bed planting method over flat bed planting method. Mulching had significant influence on consumptive use of water. Application of mulch reported lower consumptive use of water as compared to no mulch.

Yield attributes: Irrigation application influenced length of siliqua and seed weight. Length of siliqua and seed weight were higher at 1.2 IW: CPE ratio compared to remaining treatments but at par with 0.9 IW: CPE ratio (Table 2). Irrigation application also resulted in a better translocation and partitioning of photosynthates from source to sink, which enhanced the length of siliqua. On the other hand the moisture stress conditions created under no irrigation application ended up with a shorter length of siliquae. More seed weight/plant might be due to the better availability of nutrients along with a better translocation of photosynthates from source to sink, and helped in higher accumulation of photosynthates in the seeds with the application of irrigation. Yadav *et al.* (2010) reported increase in seed weight per plant with two irrigations as compared to one irrigation.

Tetrawal *et al*., (2013) and Sharma *et al.,* (2014) recorded 4.15% increase in length of siliqua, 24.35% more seed weight/plant with mulch than no mulch. Similar findings were also reported by Verma *et al.,* (2014). Raised bed planting registered 3.75% more length of siliqua and 21.4% more seed weight/plant over flat bed planting method. Shekhawat *et al.* (2016) reported maximum length of siliqua in furrow irrigated raised bed planting method than conventional tillage.

Seed yield, stover yields and harvest index: Seed yield and stover yield differed significantly due to irrigation levels in both the years (Table 2). In 2014–15, seed yield increased significantly at 1.2 IW : CPE ratio over 0.6 IW : CPE ratio and 0.3 IW : CPE ratio but remained at par with 0.9 IW : CPE ratio. The seed yield did not exhibit significant difference between 0.6 IW : CPE ratio and 0.3 IW : CPE ratio. In 2015–16, higher seed yield was obtained at 1.2 IW : CPE ratio as compared to remaining irrigation levels followed by 0.9 IW : CPE ratio. This might be attributed to the timely and adequate moisture availability which helped in proper utilization of nutrients and also in formulation and partitioning of photosynthates to the sink. Improvement in seed yield might be a consequence of the increased number of siliquae/plant, number of seeds/siliqua, length of siliqua and the 1,000-seed weight. Similar findings were also illustrated by Piri (2012) and Ray *et al.* (2015) who reported higher seed yield obtained with increase in irrigation frequency.

Irrigation at 1.2 IW : CPE ratio produced higher stover yield than remaining irrigation levels followed by 0.9 IW : CPE ratio in both years. The stover yield exhibited difference between 0.6 IW: CPE ratio and 0.3 IW : CPE ratio. A proper supply of moisture with irrigation, letting an in-

Table 2. Effect of irrigation levels, planting methods and mulching on length of siliqua, seed weight per plant and harvest index, relative leaf water content and conductive use of water (data pooled over 2 years)

Treatment	Length of siliqua (cm)	Seed weight/plant (gm)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index	RLWC (%)	CUW (cm)
Irrigation level (IW: CPE ratio)							
0.3 IW: CPE	5.4	6.4	0.96	1.37	41.35	77.15	19.35
0.6 IW: CPE	5.8	8.05	1.15	1.72	40.05	79.30	20.39
0.9 IW: CPE	6.1	10.95	1.39	2.46	36.25	80.70	23.56
1.2 IW: CPE	6.2	11.65	1.51	2.85	34.65	82.30	25.67
SEm±	0.05	0.3	0.03	0.05	0.69	0.73	0.19
CD (*P*=0.05)	0.17	1.04	0.09	0.18	2.36	2.52	0.65
Planting method							
Flat bed	5.75	8.35	1.20	1.99	38.2	79.2	21.93
Raised bed	5.95	10.15	1.31	2.20	38.05	80.5	22.55
SEm±	0.05	0.28	0.02	0.05	0.41	0.40	0.10
CD (*P*=0.05)	0.16	0.81	0.055	0.16	NS	1.16	0.27
Mulching							
No Mulch	5.75	8.25	1.18	1.99	37.9	78.5	23.14
Mulch	5.95	10.25	1.33	2.20	38.25	81.2	21.35
SEm±	0.05	0.28	0.2	0.05	0.41	0.40	0.10
CD (*P*=0.05)	0.16	0.81	0.55	0.16	NS	1.16	0.27

*NS, Non-significant.

creased growth and development of the crop plants got evident in the form of higher straw yields. Such increased trends with irrigation frequency were also reported by Yadav *et al.,* (2010) and Ray *et al.,* (2015).

Raised bed planting method registered 9.3% more seed yield over flat bed planting method. The superiority of raised bed planting method could be ascribed to proper drainage of excess water coupled with adequate aeration at the time of excess rainfall, and moisture conservation. Similar effects of planting methods have also been reported by Kuotsua *et al*. (2014). Raised bed planting method registered 10.6% more stover yield over flat bed planting method. Similar findings were also reported by Parihar *et al.* (2009)

Application of mulch produced 12% more seed yield than no mulch. Mulch slowed down the energy exchange at soil surface, thermal diffusion and provided insulation, making uniform soil temperature that minimized evaporation losses. The higher seed yield obtained under paddy straw mulch in this study conformed to earlier report by Regar *et al.,* (2007), and Sharma *et al.,* (2014). Application of mulch recorded 10.1% more stover yield than no mulch. Tetrawal *et al*., (2013) also reported significantly higher stover yield in mulch than no mulch.

The lowest harvest index was recorded with 1.2 IW : CPE ratio than remaining irrigation levels but it was at par with 0.9 IW : CPE ratio. The maximum harvest index was recorded at 0.3 IW : CPE ratio followed by 0.6 IW : CPE ratio. Planting methods and mulching did not cause significant variation in harvest index.

Interaction effect between irrigation levels and planting methods on grain yield was found to be significant (Table 3). Irrigation at 1.2 IW: CPE ratio reported higher seed yield over remaining irrigation levels under raised bed than flat bed planting method. Irrigation at 0.9 IW: CPE ratio increased the seed yield over 0.6 IW : CPE.

Table 3. Interaction effect between irrigation levels and planting methods on seed yield (t/ha)

Irrigation level (IW : CPE ratio)	Planting method	
	Flat bed	Raised bed
0.3 IW : CPE	0.96	0.95
0.6 IW : CPE	1.01	1.19
0.9 IW : CPE	1.29	1.49
1.2 IW : CPE	1.42	1.59
SEm±	0.04	0.035
CD (P=0.05)	0.12	0.103

Based on the findings of present study, it can be inferred that in a sandy loam soil, yellow *sarson* should be irrigated at IW : CPE ratio 0.90 in a good rainfall season (requiring 2 irrigations) and 1.2 IW: CPE ratio in a low rainfall season (requiring 4 irrigations). Yellow *sarson* sown on raised bed along with application of rice straw mulch @ 5 t/ha after thinning (25 DAS) was more productive and economic over flat bed and no mulch.

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