Indian Journal of Agronomy **64** (1): 123–128 (March 2019)

Research Paper

Influence of different irrigation levels, planting methods and mulching on yield, water-use efficiency and nutrient uptake in yellow *sarson* (*Brassica rapa*)

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Received : April 2017; Revised accepted : January 2019

ABSTRACT

A field experiment was conducted for 2 consecutive winter (*rabi)* seasons of 2014–15 and 2015–16 at G.B. Pant University of Agriculture and Technology, Pantnagar to evaluate the effect of irrigation levels, planting methods and mulching on growth, yield, water-use efficiency, economics and nutrient uptake in yellow *sarson* {*Brassica rapa* (L.) var. trilocularis (Roxb.) Kitam}. Plant height, total dry matter, yield attributing characters, seed and stover yields, nutrient uptake by seed and stover, net returns and benefit: cost ratio were influenced significantly due to irrigation levels being the maximum at 1.2 IW/CPE ratio followed by 0.9 IW/CPE ratio. Higher water-use efficiency (WUE) was recorded with irrigation at 0.9 IW/CPE ratio, which was at par with 1.2 IW/CPE ratio. The maximum plant height, total dry matter, yield attributing characters, WUE and seed and stover yields, C assimilation and N uptake by seed and stover, net returns, B:C ratio were found with raised bed planting compared to flat bed planting. Yellow *sarson* sown with mulch produced significantly higher values of growth and yield attributing characters, seed and stover yields, WUE, nutrient uptake and economics compared to no mulch treatment.

Key words: C–assimilation, Irrigation levels, Methods of planting, Mulch, N-uptake, Yellow *sarson*, Yield

Oilseed crops play a vital role in Indian economy. They occupies second position in agricultural commodities after cereals with 13% share to the country's gross cropped area, nearly 5% to gross national product and 10 % of the value of all agricultural products. Rapeseed-mustard occupies 6.5 million hectare area with 7.91million tonnes production in 2016–17. However, its average productivity is 1184 kg/ha (GOI, Ministry of Agriculture, 2016), which is very low than the world average productivity. Rapeseed-mustard is mainly grown in north-west parts of India. Rajasthan, Madhya Pradesh, Haryana and Uttar Pradesh are the major producing states in the country (GOI, Ministry of Agriculture, 2016). Many areas especially semi-arid region of the country, suffer from the water scarcity. About 28%, rapeseed-mustard area is rainfed, where crop is grown on residual soil moisture on marginal and sub-marginal land in winter (*rabi)* season. There is a need to maintain optimum moisture in the root zone, to meet the crop water requirements for higher crop productivity. It can be achieved through adopting improved irrigation scheduling and moisture conservation practices Ray *et al.,* (2015) found maximum mustard yield under irrigated condition compared to control. The raised bed planting method can be a viable practice in reducing water losses and utilizing conserved soil moisture. This practice facilitate in seed germination, proliferation of root growth, help in reducing the mechanical resistance to plant roots, encourages crop growth, prevents water stagnation after irrigation and reduces irrigation requirement of crop. There was 35% saving in water resulting in 32% increase in water-use efficiency in bed planting (Butter *et al*., 2006). Mulch can increase production and productivity, water-use efficiency and maintain soil moisture regime, while simultaneously decreasing weed pressure in field. Raised bed supplemented with mulch further play very important role to mitigate soil moisture deficit in dry season. Rice straw mulch increased the production and productivity of mustard due to favourable effect of mulch on soil moisture (Sharma *et al.* 2014) during winter (*rabi)* season. Various studies are available where these factors have been tested in isolation. Very limited results are available on their in-

Based on a part of Ph.D. thesis of the first author, submitted to Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand in 2017 (unpublished)

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tegrated uses. Therefore, there is need to study these inputs such as irrigation scheduling, mulching out and planting techniques in integrated approach to findout their effects on productivity, water-use efficiency, economics and nutrient uptake.

MATERIALS AND METHODS

A field experiments was carried out during winter (*rabi)* seasons of 2014–15 and 2015–16 at Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The experimental site is geographically located at an altitude of 243.8 meter above mean sea level, 29.0° N latitude and 79.3° E longitude. The climate of Pantnagar is characterized by a sub-humid, sub-tropical with hot and dry summer, cold winters and heavy rains during rainy season (June-September). The mean annual rainfall is about 1420 mm, of which 80–90% is received during rainy season (June-September) and rest is received during winter and summer seasons with occasional showers. 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 2 planting methods (flat bed and raised bed) and 2 levels of mulching (mulch with rice straw @5 tonnes/ha and no mulch). In 2014-15, 81.1 mm and in 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 10cm 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 as per treatment after 25 DAS of yellow *sarson*. Randomly 4 plants were selected for plant height and dry matter observation at 60, 90 DAS and at harvest. For dry matter, plants were cut from ground level, cleaned, sun dried for 48 hours and thereafter dried in the oven at 65 ± 5 ^oC temperature for 48–72 hours or till the samples attained a constant weight, and weighed. Number of siliquae was recorded from the 4 sampled plants and the average number of siliquae per plant was worked out. Number of seeds in 10 siliquae were taken out from the 4 randomly selected plants of each plot, were counted and their average was worked out to find out the seeds per siliqua. From the individual plot, the net plot area was harvested separately and produce was sun dried. After threshing and weighing the net plot seed and stover yields were converted to seed and stover yield/ ha. A random sample of seeds was drawn from the produce and one thousand seeds were counted using electronic seed counter and weighed to record the 1000-seed weight. Water-use efficiency (kg /ha-cm of water use) was calculated using the following formula:

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

Where, Y = Grain yield (kg/ha) and U = Seasonal consumptive use of water (cm)

The total C and N in seed and stover was estimated by using the CHNS analyzer. The standard technique for preparing samples into small tin capsules, in the form of tiny pellets was followed. These samples ran with the help of a software programme of the CHNS analyzer instrument. The reading was displayed on the monitor and total C and N in plant expressed in percentage. Total carbon assimilation and N uptake (kg/ha) was calculated by using their C and N concentration values and seed or stover yield of crop on hectare basis, using the following formula:

$$\text{C or N uptake (kg/ha)} = \frac{\text{C assimilation or N concentration (\%)} \times \text{seed or stover yield (kg/ha)}}{100}$$

Net returns was obtained by subtracting the cost of cultivation from gross returns and expressed as ₹/ha. Benefit: cost ratio was worked out to assess the economics of yellow *sarson* due to various treatments and computed by dividing net returns obtained from the respective treatment with respective cost of cultivation.

RESULTS AND DISCUSSION

Crop growth parameters

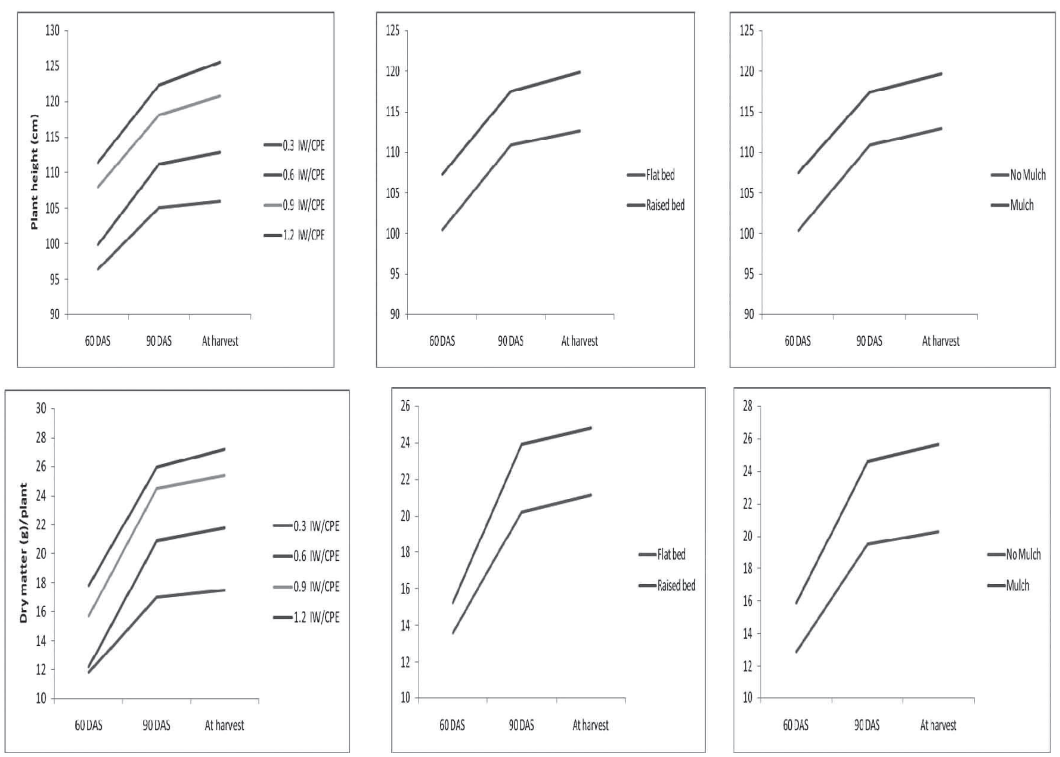
Plant height and dry-matter production recorded was significantly higher with 1.2 IW/CPE ratio as compared to remaining irrigation levels, but remained at par with 0.9 IW/CPE ratio at 60, 90 DAS and at harvest stage. In 2014–15, 1, 1, 2 and 3 irrigations were applied at 0.3, 0.6, 0.9 and 1.2 IW: CPE ratio, respectively while in 2015–16 the number was 1, 2, 3 and 4 irrigations. This increase in plant growth and dry matter accumulation were owing to more water supplies with frequent irrigations providing congenial growth environment which improved the cell turgidity, opening of stomata and finally the partitioning of photosynthates efficiently to the sink. Yadav *et al*. (2010), Piri *et al.* (2011) and Ray *et al.* (2015) also reported significantly higher growth parameters with increase in irrigation frequency. Planting methods significantly influenced plant height and dry matter accumulation. Raised bed planting method registered 4.9 and 7.05 and 7.2% more plant height than flat bed at 60, 90 DAS and at harvest stage. Similar findings were also reported by Regar *et al*. (2007). Raised bed planting method also registered

12.4, 18.2 and 18.0 % higher total dry matter accumulation than flat bed planting method at 60 , 90 DAS and at harvest. Plant height and total dry matter accumulation significantly affected due to application of mulching at all growth stages of crop. Application of mulch significantly increased plant height by 7.1, 5.8 and 5.9% over no mulch at 60, 90 DAS and at harvest stage. Favourable effect of mulches was also significant on dry matter accumulation which improved by 23.3, 26.4 and 26.6% as compared to no mulch at 60, 90 DAS and at harvest (Fig. 1).This may be owing to the reduction of evaporation under mulching leading to higher soil moisture content. Mulching also caused reduction in weed growth and the decomposition of mulches also contributed to increase the supply of nutrients . These results are in accordance with the finding of Tetrawal *et al*. (2013) and Sharma *et al.* (2014).

Yield attributes

Irrigation levels caused significant effect on yield attributes viz number of siliquae/plant, number of seeds/siliqua and1000-seed weight. Irrigation at 1.2 IW: CPE ratio being at par with 0.9 IW: CPE ratio produced significantly more no. of siliquae/plant, number of seeds/siliqua and 1000-seed weight over remaining irrigation levels. Irrigation not only enhanced the growth and development of crop plants but also ensured a higher availability of nutrients, which produced more number of branches and culminated in a better sink development leading to more number of siliquae/plant. Application of irrigation ensured the moisture availability with a better translocation of photosynthates from source to sink, which led to more number of seeds per siliqua. Less number of seeds per siliqua might have been experienced due to moisture stress conditions (Table 1). Such a response at 1.2 IW: CPE and 0.9 IW: CPE ratio might be ascribed to adequate supply of the moisture to the crop at growth and reproductive phase, favorably induced number of physiological process viz., transpiration, photosynthates, translocation of nutrient to sink, which produced the optimum number, size and length of siliquae per plant, because of the availability of more photoassimilates. Besides, an increased supply of photosynthates to the siliquae also provided an opportunity for seeds to grow to their full potential, with an obvious increase in 1000-seed weight as observed in the study. Similiar effect of irrigation levels on yield attributes was also reported by Sultana *et al.* (2009), Verma *et al.* (2014) and Ray *et al.* (2015.

Raised bed planting method recorded more number of siliquae/plant, number of seeds/siliqua and 1000- seed weight than flat bed method. Raised bed planting registered 8.0% more siliquae/plant, 5.2% more number of seeds/siliqua and 8.25% more 1,000-seed weight over flat



Days after sowing (DAS)

Fig 1. Effect of irrigation levels, planting methods and mulching on plant height (cm) and dry-matter accumulation (g)/plant of crop at different days after sowing (mean data of 2 years) bed planting. Similar findings were also illustrated by Buttar *et al.* (2006), who found 6.1% higher number of pods/plant in bed planting than conventional method. Shekhawat *et al.* (2016) observed that FIRB planting method produced more number of siliquae, more number of seeds /siliqua over conventional planting.

Favourable effect of mulch was observed on number of siliquae/plant, number of seeds/siliqua and 1000- seed weight. Application of mulch recorded 10.5% more siliquae/plant, 12.1% more number of seeds/siliqua and 11.6% more 1000 seed weight than no mulch. It may be due to more availability of moisture during crop growth and high water status in the root zone. Similar results of highest siliquae/plant, number of seeds/siliqua and 1000-seed weight in mulch than no mulch were reported by Choudhary *et al*. (2008), Sarangi *et al.* (2010) and Tetrawal *et al*. (2013).

Seed and stover yields

The seed and stover yields differed significantly owing to irrigation levels (Table 2). Significantly higher seed and stover yields 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 a formulation and partitioning of photosynthates to the sink. Significant improvement in seed and stover yields might be a consequence of the increased number of siliquae / plant, number of seeds/siliquae, length of siliqua and the 1000-seed weight. Similar findings were also illustrated by Yadav *et al* (2010), Piri *et al* (2012) and Ray *et al.* (2015), who reported significantly higher seed and stover yields with increase in irrigation frequency.

Raised bed planting method registered 9.3 % and 10.6% more seed and stover yields 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 Parihar *et al.,* (2009) and Kuotsua *et al*., (2014). Mulch had significant influenced on seed and stover yields. Application of mulch produced 12.0 and 10.10% more seed and stover yields 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), Tetrawal *et al*. (2013) and Sharma *et al.* (2014), who reported that the seed yield of mustard was higher with the application of paddy straw mulch.

C-assimilation and N-uptake by crop

C-assimilation and N-uptake by seed and stover, differed significantly due to irrigation levels. The maximum C-assimilation in seed and stover was recorded at 1.2 IW/CPE ratio over remaining irrigation levels followed by 0.9

Table 1. Effect of irrigation level, planting methods and mulching on number of siliquae/plant, number of seeds/siliqua, 1,000-seed weight and C assimilation by plant (mean data of 2 years)

Treatment	Siliquae/ plant	Seeds/ siliqua	1,000-seed weight (g)	C-assimilation by plant (kg/ha)	
				Seed	Stover
Irrigation level (IW: CPE ratio)					
0.3 IW: CPE	93.6	30.1	2.55	417.5	481.0
0.6 IW: CPE	129.5	32.6	3.00	513.0	617.0
0.9 IW: CPE	150.8	34.0	3.15	638.0	909.5
1.2 IW: CPE	155.8	34.8	3.3	699.5	1,065.5
SEm±	2.0	0.5	0.06	10.5	19.4
CD (P=0.05)	6.9	1.6	0.22	36.1	66.8
Planting method					
Flat bed	127.3	32.0	2.90	538.0	722.5
Raised bed	137.5	33.7	3.15	596.5	814.0
SEm±	1.6	0.4	0.04	9.1	20.0
CD (P=0.05)	4.6	1.3	0.12	26.5	57.9
Mulching					
No Mulch	125.8	31.0	2.85	528.5	722.5
Mulch	139.0	34.7	3.20	606.0	814.0
SEm±	1.6	0.4	0.04	9.0	20.0
CD (P=0.05)	4.6	1.3	0.12	26.5	57.9

Mulch, Rice straw @ 5 tonnes/ha; IW: CPE ratio; irrigation water/cumulative pan evaporation

IW: CPE ratio (Table 1). The minimum amount of C-assimilation in seed and stover was recorded at 0.3 IW: CPE ratio. N uptake by seed and stover increased significantly at 1.2 IW: CPE ratio over remaining irrigation levels. The minimum N-uptake by seeds and stover was recorded at 0.3 IW: CPE ratio. Verma *et al.* (2014) reported significantly higher N-uptake with increase in irrigation frequency. C-assimilation and N-uptake by seed and stover affected significantly by the planting methods. Higher carbon assimilation in seed and stover was recorded under raised bed planting method, which was significantly superior over flat bed planting method. Raised bed planting method registered significantly more N-uptake by seed and stover over flat bed planting method. Raised bed planting resulted in better utilization of available resources like water, nutrients and sunlight owing to favourable microclimate. Similar findings were also illustrated by Kantwa *et al.* (2006) and Parihar *et al.* (2009), who found maximum uptake of N under raised beds and ridge and furrow. Mulching application had significant influence on C-assimilation and N-uptake by seed and stover. Higher carbon assimilation in seed and stover was recorded with mulch which was significantly superior over no mulch. Application of mulch recorded significantly more N uptake by seed and stover than no mulch. Nutrient uptake by mustard is mainly a function of yield and nutrients concentration in seed and stover. It might be because of nutrient uptake is correlated with yield which in turns resulted in increase in dry matter and nutrient uptake. The results confirm the findings of Tetrawal *et al.* (2013). They also recorded a higher uptake of N under mulch than no mulch.

Economics

The net returns and benefit: cost ratio (B: C ratio) was affected significantly due to irrigation levels (Table 2). The highest net returns (₹24,400/ha) and B: C ratio was recorded at 1.2 IW: CPE ratio, which were significantly superior over remaining irrigation levels. The lowest net returns and B: C ratio was observed with 0.3 IW: CPE ratio. Perceptible effect of planting methods was noticed on net returns and B: C ratio. Under raised bed planting, 18.4% increase in net return was recorded over flat bed planting method. B: C ratio was also significantly higher with raised bed planting method. Dodwadiya and Sharma (2012) also reported higher net returns under raised bed planting method. Mulching had significant influence on net returns. Mulched plots recorded 19.6% more net returns over no mulch. Similar increase in B: C ratio was also noticed. Our results confirm the findings of Tetrawal *et al.* (2013), Sharma *et al.* (2014) and Singh *et al.* (2015).

Water-use efficiency

The water-use efficiency (WUE) was influenced by irrigation levels as given in table 2. The highest WUE was recorded with 0.9 IW: CPE ratio, which was significantly higher than other treatments except 1.2 IW:CPE ratio.

Table 2. Effect of irrigation level, planting methods and mulching on yield, economics, water-use efficiency and nitrogen uptake (mean data of 2 years)

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Net returns (×10^3 ₹/ha)	B: C ratio	WUE (kg/ha-cm)	N-uptake (kg/ha)		
						Seed	Stover	Total
Irrigation level (IW: CPE ratio)								
0.3 IW: CPE	0.96	1.37	8.33	0.37	49.79	28.5	11.7	40.2
0.6 IW: CPE	1.15	1.72	14.19	0.61	56.53	36.1	15.2	51.3
0.9 IW: CPE	1.39	2.46	21.41	0.88	59.27	48.8	23.8	72.6
1.2 IW: CPE	1.51	2.85	24.40	0.98	58.88	53.4	29.3	82.7
SEm±	0.03	0.05	0.801	0.04	1.25	0.75	0.53	0.83
CD (P=0.05)	0.09	0.18	2.764	0.12	2.24	2.59	1.84	2.98
Planting method								
Flat bed	1.20	1.99	15.75	0.67	54.52	38.70	18.30	57.0
Raised bed	1.31	2.20	18.41	0.75	57.71	44.60	21.70	66.3
SEm±	0.02	0.05	0.03	0.17	0.82	0.71	0.58	0.75
CD (P=0.05)	0.055	0.16	1.07	0.08	2.40	2.05	1.69	2.18
Mulching								
No Mulch	1.18	1.99	15.56	0.67	50.72	37.95	18.5	56.5
Mulch	1.33	2.20	18.59	0.75	61.52	45.4	21.4	66.8
SEm±	0.02	0.05	0.122	0.03	0.82	0.71	0.58	0.75
CD (P=0.05)	0.05	0.16	1.187	0.07	2.40	2.05	1.69	2.18

Mulch, Rice straw @ 5 tonnes/ha; IW: CPE ratio; irrigation water/cumulative pan evaporation

Higher water-use efficiency with increasing irrigation frequency was due to higher seed yield. WUE was influenced significantly owing to planting methods. Raised bed planting method increased WUE by 5.9% over flat bed planting method. Effect of mulching was significant on WUE. Application of mulch recorded 21.3% higher WUE as compared to no mulch. Awasthi *et al.* (2007) and Choudhary *et al.* (2008) also found maximum water-use efficiency with mulching.

Thus, the results of the present investigation clearly demonstrate that yellow *sarson* should be irrigated at 1.2 IW/CPE ratio to achieve higher yield and economic returns. Raised bed planting method and rice straw mulch @ 5 tonnes/ha also found more productive and economic over flat bed and no mulch.

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