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Irrigation and fertilizer effects on productivity, quality, water use and economics of Yellow *Sarson* [*Brassica rapa* (L.) var. *trilocularis*]

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Abstract

An experiment was conducted to study the effect of irrigation and fertilizer on Yellow *Sarson* (*Brassica rapa* L. var. *trilocularis* (Roxb.) Kitam.) with 4 irrigation regimes *viz*., irrigation at flowering, irrigation at pod formation, irrigation at flowering and pod formation and conventional practice (rainfed) and 3 levels of fertilizers *viz*., 60-40-40, 75-50-50 and 90-60-60 N-P_2O_5-K_2O kg/ha during 2012-13 to 2014-15. Two irrigations applied at flowering- and siliqua formation stage recorded higher yield attributes *viz*., siliqua/plant, siliqua length and number of seeds/siliqua. Two irrigations at flowering- and pod formation stage also recorded 6.8, 11.6 and 46.9 percent higher yield over single irrigation at flowering, single irrigation at pod formation and rainfed crop. Among the fertilizer levels, application of 90-60-60 N-P_2O_5-K_2O kg/ha being at par with 75-50-50 N-P_2O_5-K_2O kg/ha recorded the highest yield attributes, seed yield, net return and B : C ratio. The highest water use efficiency (WUE) was observed with two irrigations at flowering- and pod formation stage.

Key words: *Benefit-cost ratio, crude seed protein yield, water use efficiency, Yellow Sarson*

Introduction

The rapeseed-mustard group broadly includes *Brassica juncea* and *B. rapa*. The *B. rapa* is divided into three ecotypes, *viz.,* Toria, Brown *Sarson* and Yellow *Sarson* which are grown in India. Of these three ecotypes, Yellow *Sarson* is self compatible in breeding behavior and is one of the most important members among them. Yellow *Sarson* is mainly grown in Assam, Bihar, Uttar Pradesh, Sikkim, Meghalaya and West Bengal (Misra, 2008). As a high-energy component of food, edible oils are important for meeting the calorie requirements. Each gram of oil/fat supplies 9 kilocalories of energy, whereas each gram of carbohydrate/protein furnishes about 4 kilocalories of energy (Alam *et al*., 2014). Fats and oils are also the sources of essential fatty acids. Fats and oils are used to synthesize phospholipid, which are important components of active tissues *viz*., brain, nerve, and liver of human beings and other animals.

Present dietary pattern of the people of Assam is highly imbalanced due to excess consumption of carbohydrates in the form of rice which is more than the body requirement. Internal production of oilseed is only 2.0 lakh ton as against its requirement of 6.0 lakh ton (considering 30 g/person/ day, 33% oil from other sources and 40% oil recovery). The area and productivity of rape and mustard is much lower than the agriculturally advanced states. It is mainly due to non adoption of improved method of cultivation, low use of chemical fertilizers and irrigations. To meet the annual requirement of edible oil, it is necessary to give immediate attention to increase its domestic production. Increased production of edible oil can come from expansion of cultivated area or increase in productivity or from both. Rice-based cropping systems are the most common in Assam because rice is the staple food crop. During the *Kharif* (commencing June to September) season, there is no scope to replace rice in the state due to soil and climatic compulsion. However, a series of crops can profitably be grown during the winter and summer months with proper management (Baishya *et al*., 2015). At present, the rice areas of the state are mostly monocropped and the land remains fallow after harvest of the *Kharif* crops. The oilseed crops like Yellow *Sarson* may enhance land use efficiency as well as productivity. After harvesting the winter paddy, cultivation of Yellow *Sarson* can be practiced. It occupies an important position due to the presence of high oil content (up to 45%), high seed yield and early maturity as compared to Indian mustard. Moreover, its yellow seed coat colour has preference over brown seed colour. The oil is mainly used for edible purposes and in addition to this; the yellow *sarson* is most preferred choice as leafy vegetables among the entire cultivated oilseed brassicas in India (Chatterjee, 1992). It is also used as spice in West Bengal, Bihar and Assam. At present no recommended package of practices has been developed for the state of Assam. With these ideas in mind, this investigation was planned to find out the influence of irrigation and various levels of fertilization on growth and yield of Yellow *Sarson* grown after winter rice.

Materials and Methods

A field experiment was conducted for three years (2012–2013 to 2014–2015) in three different sites with Yellow *Sarson* (*Brassica rapa* L. var. *trilocularis* (Roxb.) Kitam.) in the *Rabi* season on a paddy growing inceptisol at Instructional Cum Research Farm of Assam Agricultural University, Jorhat, India. The climate of the area is sub-tropical, with an average annual rainfall of 1864.8 mm. Out of this, 1194.8 mm, 467.1 mm, 151.4 mm and 51.5 mm are received during monsoon, pre-monsoon, post monsoon and winter, respectively. Minimum monthly temperature of 9.7 ^{0}C and maximum monthly temperature of 32.4 ^{0}C are observed in January and August, respectively. During January and March, maximum (morning) and minimum (evening) monthly relative humidity of 94.8% and 61.1%, respectively are observed. The soil of the experimental plots were sandy loam in texture, acidic in reaction (pH 5.1, 4.9 and 5.1 during 2012-13, 2013-14 and 2014-15, respectively), medium in organic carbon (7.0, 6.4 and 7.1 g/kg), low in alkaline $KMnO_4$ extractable N (220, 248 and 263 kg/ha), medium in Brays I P (11.2, 12.6 and 12.8 kg/ha) and low in 1 N ammonium acetate extractable K (106.3, 133.6 and 160.2 kg/ha). It contained soil moisture 24.1, 24.3 and 24.4 percent at 0.03 MPa and 11.7, 11.8 and 11.8 % at 1.5 MPa with bulk density of 1.37, 1.36 and 1.35 g/cc. Experimental plots, 12 m^2 (4 m × 3 m) in size, were arranged in a split plot design and each treatment was carried out in triplicate. The main plot treatment included I_1 : Irrigation at flowering, I_2 : Irrigation at siliqua formation, I_3 : Irrigation at flowering and siliqua formation and I_4 : rainfed. The subplot treatment included different levels of fertilizers namely F_1 : 60-40-40 kg N-P_2O_5-K_2O/ha, F_2 : 75-50-50 kg N-P_2O_5-K_2O/ha and F_3 : 90-60-60 kg N-P_2O_5-K_2O/ha. Borax @ 10 kg/ha was applied uniformly to all the treatments. The nutrients N, P and K were applied in the form of urea, single super phosphate and muriate of potash, respectively. Half of the N and full dose of P_2O_5, K_2O and Borax were applied to all the treatments at the time of sowing. Remaining N was applied at 20 days after sowing. After rice harvest, yellow *sarson* (var. B-9) was sown on 6 and 5 December and 21 November and harvested on 16, 13 and 1 March during 2011-12, 2012-13 and 2013-14. During first and second year, the crop was grown after long duration (160 days) rice variety Ranjit and in third year, the crop was sown after rice variety Mahsuri (145 days). Yellow *Sarson* seed was sown in rows at 30 cm spacing. A uniform plant population was maintained by thinning of excess seedlings at two week after emergence, maintaining an intra-row spacing of 10 cm. Intercultural operations. and plant protection measures were taken as and when necessary. The crop was irrigated as per treatment. Yields were recorded on a whole-plot basis after discarding border plants. For chemical analysis, plant samples were oven dried at 65°C for 72 hours to a constant weight and grounded to reduce the material to a fineness suitable size by using a mechanical grinder. The samples were stored in airtight plastic containers. Samples were digested in diacid mixture of H_2SO_4 and $HClO_4$ in the ratio of 9 : 1 for nutrient N estimation. Nitrogen content in digested plant material was determined by Nessler's reagent method (Lindner, 1944). The seed from the seed lot was taken for estimation of seed quality like oil with the help of Soxhlet's extraction method (AOAC, 1960). Oil yield was estimated by multiplying seed yield with oil content and crude seed-protein content (CSPC) of rapeseed was calculated by multiplying nitrogen content (%) of seeds by a factor 6.25 (De and Sinha, 2012).

The data were analyzed statistically and the mean differences among the treatment means were evaluated by the least significance difference (LSD) at 5% level of probability (Sarma, 2016). For economic analysis, all input costs including the cost for lease of land and interest on running capital were considered for computing the cost of production.

Results and Discussions

Yield attributes

The yield components *viz*. siliqua/plant, siliqua length, number of seeds/siliqua and test weight were significantly influenced by different irrigation regimes (Table 1). The treatment I_3 recorded the highest siliqua/plant and number of seeds/siliqua during 2014-15. However, seeds/siliqua during 2012-13 and siliqua/plant during 2012-13 and 2013-14 under I_1 were at par with I_3. Adequate supply of water under irrigation might have increased the turgidity of cells, opening of stomata, more photosynthesis and their translocation to yield components (Sarma and Das, 2013). Hasanuzzaman *et al*. (2008) also reported positive effect of irrigation water towards siliqua development and siliqua length. Seeds/siliqua increased with increasing levels of irrigation due to supply of adequate soil moisture which helped siliquae to be longer and have more number of seeds/siliqua. The first irrigation at flowering stage helped in formation of seeds in siliqua. Plants receiving single irrigation at siliqua formation stage might have witnessed a greater water stress up to 60 days thereby resul-ting in lower siliqua length, siliqua/plant and seeds/siliqua than that of two irrigations at flowering (40 DAS) and siliqua formation stage (60 DAS). Deka (2016) also found a significant increase of seeds/siliqua with two irrigations. The production of higher amount of photosynthates in two irrigations due to sufficient soil moisture helped the plants to develop larger nutrient sink in order to accumulate synthesized photosynthates. This resulted in improvement of yield components in two irrigations. A number of researcher (Sultana *et al*., 2009; Kashved *et al*., 2010; Yadav *et al*., 2011; Ray *et al*., 2015) also observed that irrigation increased number of seeds/siliqua. The treatment I_3 recorded the highest test weight. However, during 2013-14 and 2014-15, treatment I_2 recorded at par test weight with I_3. Adequate soil moisture at seed formation stage might have helped the seeds to be larger and thereby increased test weight. Piri *et al*. (2011a) also reported higher test weight under two irrigations.

Table 1: Effect of different treatments on yield components of yellow *sarson*

Treatments	Siliqua/plant			Siliqua length (cm)			No. of seeds/siliqua			Test weight (g)		
	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
Irrigation Schedule												
I_1	65.0	63.7	94.5	4.89	4.8	5.1	8.6	8.4	8.5	2.82	2.82	2.86
I_2	61.9	60.7	91.0	4.80	4.7	5.1	7.7	8.2	8.2	2.83	2.99	2.98
I_3	66.2	65.6	100.7	5.12	5.1	5.3	8.9	8.7	9.1	2.99	3.01	3.02
I_4	44.9	42.6	68.8	4.77	4.7	4.7	7.0	6.2	7.9	2.78	2.74	2.84
SEm +	1.3	1.4	1.0	0.09	0.1	0.1	0.2	0.1	0.2	0.05	0.06	0.05
CD(P=0.05)	3.8	4.0	2.9	0.26	0.3	0.3	0.6	0.3	0.6	0.14	0.16	0.14
Level of Fertilizers												
F_1	56.5	55.2	83.3	4.84	4.8	4.9	7.3	7.5	7.6	2.86	2.85	2.92
F_2	60.1	58.7	90.3	4.91	4.8	5.0	8.2	8.1	8.4	2.89	2.89	2.94
F_3	61.8	60.4	92.6	4.93	4.9	5.1	8.7	8.3	8.6	2.93	2.94	2.95
SEm +	1.1	1.2	0.9	0.08	0.1	0.1	0.2	0.1	0.2	0.04	0.05	0.04
CD(P=0.05)	3.3	3.5	2.5	NS	NS	NS	0.6	0.3	0.6	NS	NS	NS
Interaction	NS	NS	S	NS	NS	NS	NS	S	S	NS	NS	NS

Different levels of fertilizers influenced the siliqua/plant and seeds/siliqua significantly. It was observed that treatment F_3 recorded the highest siliqua/plant and number of seeds/siliqua. However, it was at par with F_2. The enhancement in siliqua/plant and seeds/siliqua under these treatments might be owing to rapid conversion of synthesized photosynthates into protein in the form of more protoplasm resulting in expansion of photosynthetic surface and more branching. The information is corroborated with the findings of Patil and Acharya (2009), Singh *et al*. (2010), Jadav *et al*. (2012), Meena *et al*. (2013) and Kumar (2015).

Yield

The treatment I_3 recorded the highest seed and stover yield during all the years of observation (Table 2). Rainfed crop recorded the lowest seed and stover yield. The treatment I_3 recorded 6.8, 11.6 and 46.9 per cent higher mean seed yield than I_1, I_2 and I_4. In the present investigation, adequate moisture under two irrigations increased the seed yield by improving the setting pattern of siliquae on branches, number of siliquae/plant, and other yield attributes. Chitale and Bhambri (2001) also reported positive effect of irrigation water towards seed yield. In a similar study, Panda *et al*. (2004) observed 62.9% and 41.7% increase in seed yield with irrigation at the flowering- and pod development stage and irrigation at the flowering stage over the control in mustard. Yadav *et al.* (1994) reported that increase in the amount of water increased leaf water potential, stomatal conductance, light absorption, leaf area index and seed yield.

The harvest index varied from 22.7 to 26.3 in 2012-13, 24.0 to 25.6 in 2013-14 and 25.3 to 26.7 in 2014-15, but remained non significant among different irrigation schedule. However, the highest values were recorded at I_3 during all the years. Two irrigations at flowering- and pod formation stage improved the growth and development of the plants by improving the uptake of essential nutrients and translocation from source to sink, resulting in to higher harvest index**.** These results were in conformity with those of Piri *et al*. (2011b).

Seed and stover yield of *toria* were significantly increased with fertilizer levels. The highest yield of seed- and stover yield were recorded by treatment F_3 which was at par with F_2. Similar results were also reported by Ghimire and Bana (2011), Singh *et al*. (2010) and Sharma (2013). Harvest index was found to be non-significant.

Overall yield of rapeseed recorded in third year was higher than first two years. This might be due to enhanced sowing time of the crop in the third year. Earlier sowing helped the crop to utilize higher residual soil moisture. Delayed sowing also exposed the crop to low temperature at vegetative- and flowering stage and high temperature during siliqua formation stage. Rapeseed-mustard follows C_3 pathway for carbon assimilation. Therefore, it has efficient photosynthetic response at 15–20 ^{0}C temperature. At this temperature the plant achieve maximum CO_2 exchange range which declines thereafter (Yeganeh *et al*. 2012). This observation was further supported by positive correlation of seed yield with soil moisture at sowing ($r = 0.80^{**}$) and mean air temperature at flowering ($r = 0.77^{**}$) and negative correlation of seed yield with mean air temperature at siliqua formation ($r = -0.65^{**}$).

Quality

Oil- and seed protein content were not significantly influenced by irrigations (Table 3). However, oil- and crude protein yield increased significantly due to application of two irrigations at flowering- and pod formation stage (I_3). Decrease in rapeseed oil content was also assessed by Sinaki *et al.* (2007). The authors verified significant decrease in grain oil content in non-irrigated treatments. Similar results were found by Bilibio *et al.* (2011) and Raza *et al.* (2015).Oil and protein content in *toria* seed and their yield were influenced by different fertilizer levels (Tables 3). The highest oil content was observed in F_1 which was at par with F_2 and significantly higher than F_3. It is established fact that nitrogen has an adverse effect on oil content of rapeseed and mustard. The reduction in oil due to higher rate of nitrogen appears to be due to conversion of carbohydrates into protein. Thus, the amount of carbohydrates left to get converted into acetyl co-A for synthesis of fatty acids was too low as compared to other low nitrogen treated plants. Similar findings

Table 2: Effect of different treatments on seed- and stover yield, harvest index, net return and B:C ratio of yellow *sarson*

Treatments	Seed Yield			Stover yield			Harvest Index			Net Return (Rs)			B : C ratio		
	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
Irrigation Schedule (I)															
I_1	723	692	1027	2089	2099	2860	25.7	24.8	26.4	20420	18870	35620	1.30	1.20	2.26
I_2	684	665	988	2041	2025	2765	25.1	24.7	26.3	18470	17520	33670	1.17	1.11	2.14
I_3	778	737	1094	2183	2172	2998	26.3	25.3	26.7	22570	20520	38370	1.38	1.26	2.35
I_4	527	504	745	1798	1587	2200	22.7	24.1	25.3	10720	10070	22120	0.71	0.67	1.46
SEm +	16	7	11	45	48	71	0.8	0.8	0.7	-	-	-	-	-	-
CD(P=0.05)	47	21	32	132	141	208	NS	NS	NS	-	-	-	-	-	-
Level of Fertilizers (F)															
F_1	642	609	902	1827	1770	2426	25.9	25.6	27.1	17396	15746	30396	1.18	1.07	2.07
F_2	686	661	986	2004	1972	2749	25.4	25.1	26.4	18570	17320	33570	1.18	1.10	2.13
F_3	706	678	1003	2252	2170	2942	23.8	23.8	25.4	18544	17144	33394	1.11	1.02	1.99
SEm +	14	6	9	39	42	61	0.7	0.7	0.6	-	-	-	-	-	-
CD(P=0.05)	41	19	27	114	122	150	NS	NS	NS	-	-	-	-	-	-
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Effect of different treatments on oil content, oil yield, crude seed protein content and crude seed protein yield of yellow *sarson*

Treatments	Oil content (%)			Oil Yield (kg/ha)			Crude Seed Protein Content(%)			Crude Seed Protein Yield (kg/ha)		
	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
Irrigation Schedule												
I_1	41.0	40.7	41.1	296	282	422	22.9	22.4	23.4	166	155	240
I_2	40.5	40.3	41.6	277	268	411	23.2	22.6	23.0	159	150	227
I_3	41.4	40.9	42.3	322	301	463	23.5	22.9	23.6	183	169	258
I_4	39.2	39.1	39.5	207	197	294	22.2	21.9	22.4	117	110	167
SEm +	0.8	0.9	0.9	10	9	13	0.8	0.8	0.9	5	4	5
CD(P=0.05)	NS	NS	NS	29	26	38	NS	NS	NS	15	12	15
Level of Fertilizers												
F_1	41.7	41.3	42.4	268	252	382	22.0	21.6	22.0	141	132	198
F_2	41.0	40.7	41.5	281	269	409	23.1	22.6	23.4	159	149	230
F_3	38.9	38.8	39.5	274	263	396	23.7	23.2	24.0	168	158	241
SEm +	0.7	0.8	0.9	9	8	11	0.7	0.7	0.8	4	3	4
CD(P=0.05)	NS	NS	NS	25	23	33	NS	NS	NS	12	10	12
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

were reported by Singh *et al*. (2010) and Ghimire, and Bana (2011). Oil yield increased significantly due to fertilizer application up to 125% RDF at treatment F_2 because of increased seed yield of *toria* varieties. However, it was at par with F_3 (150% RDF). Unlike the oil content, the crude protein content and crude protein yield increased with increasing level of fertilizer, the highest being at F_3 which, however, was at pat with F_2 (Table 2). This might be due to the more accumulation of nitrogen in seed under higher supplies of nutrients. Since, nitrogen plays an important role in the synthesis of amino-acids which constitute building blocks of protein, it resulted in higher protein content in seeds with increasing level of fertilizers. These findings are in close conformity with those of Chauhan *et al.*, 2007; De and Sinha (2012).

Water use

Total water use was markedly higher with treatment I_3 than I_1, I_2 and I_4 (Table 4). This might be due to the fact that under two irrigations at flowering and

Table 4: Effect of different treatments on total water used and field water use efficiency of yellow sarson

Treatments	Total waterused (cm)			Field WUE(kg/ha-cm)		
	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
Irrigation Schedule (I)						
I_1	13.3	12.7	13.9	54.4	54.5	73.9
I_2	13.4	13.1	14.3	51.0	50.8	69.1
I_3	15.4	14.9	16.5	50.5	49.5	66.3
I_4	10.3	10.1	11.1	51.2	49.9	67.1
Level of Fertilizers (F)						
F_1	12.8	12.5	13.7	50.2	48.7	65.8
F_2	13.1	12.7	14.0	52.4	52.0	70.4
F_3	13.3	12.9	14.2	53.1	52.6	70.6

pod formation stage, evapotranspiration was higher due to more water (soil moisture) than the crop irrigated at wider interval (as was the case in I_1 and I_2). The highest field water use efficiency (WUE) was observed with one irrigation at flowering (I_1). Two irrigations at flowering- and pod formation stage (I_3) recorded the lowest WUE. This means that production of rapeseed per cm of water used decreased with increase in water supply and relative increase in rapeseed yield was not proportional to the increase in water application and use, thereby resulted in decrease in WUE. Sarma *et al.* (2007) and Sarma *et al*. 2013 also reported decrease in water use efficiency with increase in water use. Total water use and water use efficiency increased with increasing levels of fertilizers. This may be due to their favourable effect on yield attributing characters and ultimately seed yield (Sarma *et al.*, 2007; Sarma *et al*., 2013).

Economics

Net return and benefit: cost ratio realized from I_3 were higher than the other I_1, I_2 and I_4 (Table 2). Among the different fertilizer levels, F_2 recorded the highest net return followed by F_3 and F_1. The highest benefit cost ratio was observed under F_3. Similar results were obtained by Chauhan *et al.* (2002) and Piri *et al*. (2011b). Thus, it can be concluded that with the application of two irrigations at flowering- and siliqua formation stage with 75-50-50 N-P_2O_5-K_2O kg/ha, productivity and monetary return of yellow *sarson* can be increased.

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