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Productivity and economics of late sown rapeseed (*Brassica campestris* var. Toria) after winter rice under varying irrigation and nutrient levels

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Abstract

A field experiment was conducted during *Rabi* season, 2014-15 to 2016-17 at Assam Agricultural University, Jorhat, Assam to study the effect of irrigation and fertilizer on late sown rapeseed (*Brassica campestris* var. Toria) grown after rice with 4 irrigation regimes *viz*., rainfed, 6 cm irrigation at pre- flowering stage (25 DAS), 6 cm irrigation at siliqua formation stage (50 DAS) and 6 cm irrigation at pre- flowering (25 DAS) and siliqua formation stage (50 DAS) with three different fertilizer levels *viz*., 45-30-30, 60-40-40 and 75-50-50 N-P_2O_5-K_2O kg ha^{-1}. Two irrigations applied at pre-flowering- and siliqua formation stage recorded the highest chlorophyll stability index, growth *viz*., plant height, number of branches $plant^{-1}$ and leaf area index and yield attributes *viz*., siliquae $plant^{-1}$ and number of seeds $siliqua^{-1}$. Two irrigations at pre-flowering- and siliqua formation stage also recorded higher seed- and stover yield than one irrigation at flowering, one irrigation at siliqua formation and rainfed crop. This treatment also recorded the highest mean net return (Rs. 15562/ha) and B:C ratio (1.76). However, among the fertilizer levels, application of 75-50-50 N-P_2O_5-K_2O kg ha^{-1} being at par with 60-40-40 N-P_2O_5-K_2O kg ha^{-1} recorded the highest growth, yield attributes and seed- and stover yield. The highest water use efficiency (WUE) was observed under rainfed condition.

Key words: *Benefit-cost ratio, chlorophyll stability index, fertilizer, irrigation, rapeseed, water use efficiency*

Introduction

Edible oil, a high-energy food component, plays an important role in meeting the calorie requirements of human nutrition. Rapeseed-mustard is the second most important crop among the edible oilseeds crops in India. India contributes 28.3% and 19.8% in world area and production, respectively (Shekhawat *et al.*, 2012). The area under the crop has been either static or declining during last few years, against an increasing deficit for edible oils. The state of Assam offers promising scope for expansion of cultivated area under rapeseed as a succeeding crop to winter rice. About one third of the total winter rice cultivated area is medium land that mostly remains mono-cropped. The rice-rapeseed (Toria) is a popular cropping system in such situations. But, owing to climatic aberrations or floods, the harvesting of rice is delayed to end November, or early December. This leads to yield decline in rapeseed and mustard due to water stress under late sowing condition. The crop responds well to irrigation and it is a vital factor for proper growth and development of this crop in dry season. Rapeseed-mustard crops are highly responsive to fertilizers, particularly to nitrogen, phosphorus, and potassium (Allen and Morgan, 1972, Mondal and Gaffer, 1993). Thus, the feasibility of a successful late sown toria crop would depend on efficient nutrient and water supplementation. Accordingly, the present research was undertaken to determine the suitable schedule of irrigation for late sown toria grown after winter rice, and to find out effective fertilizer dose under irrigated condition.

Materials and Methods

A field experiment was conducted for three years (2014-2015 to 2016-2017) in two different sites in the *Rabi* season at Instructional Cum Research Farm of Assam Agricultural University, Jorhat, Assam, India. The climate of the area is sub-tropical, with an average annual rainfall of 1864.8 mm. 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% are recorded. The soil of the experimental plots were sandy loam in texture, acidic in reaction (pH 5.8, 5.1and 5.1 during 2014-15,2015-16 and 2016-17 respectively), medium in organic carbon

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(0.68, 0.64 and 0.64 %), low in alkaline $KMnO_4$ extractable N (259.5, 265.4 and 265.4 kg/ha), medium in Brays 1 P (25.70, 23.6 and 23.6 kg/ha) and low in 1 N ammonium acetate extractable K (137.6, 127.7 and 133.7 kg/ha). Experimental plots, 12 m² (4 m x 3 m) in size, where treatment were arranged in factorial randomized block design with three replications. The treatments consisted of four irrigation levels viz., I_0 - rainfed, I_1 - 6 cm irrigation at pre flowering stage [25 days after sowing (DAS)], I_2 - 6 cm irrigation at siliqua formation stage (50 DAS), I_3 - 6 cm Irrigation at 25 DAS and 50 DAS, and three fertilizer levels viz F_1 - 45-30-30, F_2 - 60-40-40 and F_3 - 75-50-50 N-P_2O_5-K_2O kg ha^{-1}, respectively. 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 harvest of the winter rice, Toria (JT-90-1) was sown on 15th, 16th and 15th December and harvested on 11, 12 and 11 March during 2014-15, 2015-16 and 2016-17 respectively. Toria seed was sown in rows at 30 cm spacing. For maintaining the plant population thinning of excess seedlings was done at two weeks after emergence of seedling, maintaining an intra-row spacing of 10 cm. Intercultural operations and plant protection measures were taken as and when required. The crop was irrigated as per treatment. Yields were recorded on a whole-plot basis after discarding border plants. For calculation of Chlorophyll Stability Index (CSI), two sets of leaf slices weighing 50 mg were transferred to test tubes containing 5 ml of dimathyl sulfoxide (DMSO). One set (control) was stored in room temperature. Another set of test tube was incubated at 65° C for 2 hours and treated as heated sample. The total chlorophyll content of the two sets was estimated by non-maceration method using dimethyl sulphoxide (DMSO) (Hiscox and Israelstam, 1979) and light absorption at 663 and 645 nm was read in a spectrophotometer. CSI was calculated using the following formula:

$$CSI(\%) = \frac{\text{Total chlorophyll content (heated)}}{\text{Total chlorophyll content (control)}} \times 100$$

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

Growth Characters

The data pertaining to growth characters as influenced by irrigation and fertilizer levels are given in Table 1. The treatment I_3 being at par with I_1 and I_2 recorded the highest plant height during all the three years. The treatment I_3 also recorded the highest dry matter m^{-2} and number of branches plant^{-1}. However, dry matter m^{-2} during 2015-16 and number of branches plant^{-1} during 2014-15 under I_1 and I_2 were at par with I_3. Similarly, during 2016-17, I_1

Table 1: Effect of irrigation regimes and fertilizer levels on plant height, dry matter and number of branches/plant of rapeseed at harvest

Treatment	Plant height (cm)			Dry matter/m²			No.of Branches/plant		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
Irrigation regimes									
I_0	104.5	99.1	100.6	225.9	193.6	225.9	7.7	7.0	7.1
I_1	115.1	105.1	117.5	251.3	205.9	276.4	8.2	7.3	8.3
I_2	111.8	108.5	115.5	255.6	215.6	262.9	8.3	8.1	7.5
I_3	118.9	112.2	120.6	288.6	220.6	294.6	8.6	8.3	8.7
SEm±	2.8	3.2	3.9	8.9	7.1	9.5	0.2	0.2	0.2
CD(P=0.05)	8.2	9.3	11.5	26.2	20.7	27.6	0.6	0.6	0.7
Fertilizer levels									
F_1	105.6	101.1	106.9	233.6	191.9	250.6	7.8	7.2	7.4
F_2	113.6	106.1	115.6	263.9	215.7	262.8	8.3	7.7	7.9
F_3	118.6	111.5	118.3	268.6	219.1	281.5	8.5	8.1	8.3
SEm±	2.4	2.8	3.4	7.8	6.1	8.1	0.2	0.2	0.2
CD(P=0.05)	7.1	8.1	10.0	22.7	18.0	23.9	0.5	0.5	0.6
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of different treatments on LAI and Chlorophyll Stability of rapeseed

Treatment	LAI						Chlorophyll Stability					
	40 DAS			60 DAS			40 DAS			60 DAS		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
Irrigation regimes												
I_0	1.17	1.15	1.23	0.66	0.63	0.75	88.0	86.1	88.3	64.3	63.3	65.7
I_1	1.42	1.40	1.64	0.76	0.75	0.89	94.4	92.3	95.9	69.1	70.1	71.0
I_2	1.17	1.14	1.25	0.74	0.69	0.85	88.1	86.0	88.2	70.1	70.0	70.5
I_3	1.51	1.46	1.71	0.82	0.79	0.99	95.0	92.4	96.3	76.0	76.5	66.1
SEm±	0.03	0.05	0.06	0.02	0.03	0.05	1.9	1.7	2.2	1.6	1.8	1.7
CD(P=0.05)	0.09	0.13	0.16	0.06	0.09	0.13	5.6	5.1	6.5	4.7	5.2	4.9
Fertilizer levels												
F_1	1.21	1.19	1.33	0.60	0.58	0.76	87.4	84.2	88.3	67.5	66.3	68.1
F_2	1.33	1.29	1.48	0.79	0.77	0.89	92.6	90.9	93.2	69.6	70.7	71.1
F_3	1.41	1.38	1.57	0.85	0.81	0.97	94.1	92.5	95.1	72.5	72.9	73.3
SEm±	0.03	0.04	0.05	0.02	0.03	0.04	1.6	1.5	1.9	1.4	1.5	1.4
CD(P=0.05)	0.08	0.11	0.14	0.05	0.08	0.11	4.8	4.4	5.7	4.1	4.5	4.2
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

recorded at par dry matter m^{-2} and number of branches $plant^{-1}$ with I_3. Adequate and timely supply of irrigation water in I_3 (irrigation at 25 and 50 DAS) treatment ensures higher moisture availability for cell turgidity and consequently higher meristematic activity leading to improved morphological parameters like higher plant height, more branches, more foliage development, greater photosynthetic rate, higher nutrient uptake, higher dry biomass production and better growth of plants (Tyagi and Upadhyay, 2017). Two irrigations at pre-flowering and post flowering stages under I_3 increased the biomass production due to increased plant height and number of branches $plant^{-1}$ as compared with less moisture availability to plants under single irrigation (I_1 and I_2) and without irrigation (I_0). Al-Barak (2006) and Tahir *el al.* (2007) also observed improvement in overall growth of rapeseed with application of irrigation. On the other hand, moisture deficit under I_0 (raifed) resulted in dehydration of protoplasm which decreased the turgor potential and turgor derived physiological processes viz. cell division and cell elongation which affected the plant growth and ultimately total dry matter accumulation (Tyagi and Upadhyay, 2016; Tyagi and Upadhyay, 2017). The treatment I_3 also recorded the highest LAI and chlorophyll stability at 40 and 60 DAS (Table 2). However, LAI during both the stages and Chlorophyll stability at 40 DAS under I_3 was at par with I_1. The high chlorophyll Stability Index indicates better chlorophyll availability in the plants (Kar *et al.*, 2004). Decreased chlorophyll under water stress generally occurs due to damage of chloroplasts caused by oxidative bursts or due to changed ratios of lipid protein complexes or elevated chlorophyllase activity which degrades the chlorophyll and damages the light harvesting machinery (Kaya et al., 2006).

Among the fertilizer levels, F_3 being at par with F_2 recorded the highest plant dry matter accumulation and number of branches $plant^{-1}$, LAI and CSI during all the three years. Fertilizer application provided more quantities of nutrients in readily available form which might have played a vital role in photosynthesis, translocation of phosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use, stimulation of root growth, activation of plant enzymes and many other processes. Similar results were reported by Khatkar *et al.* (2009) and Kumar and Kumar (2011).

Yield attributes and Yield

The results revealed that all the yield attributing characters of rapeseed *viz.* number of siliquae $plant^{-1}$ and number of seeds $siliqua^{-1}$ were influenced due to irrigation regimes and fertilizer levels (Table 3). In the present study, application of two irrigations *i.e.* 6 cm irrigation each at 25 and 50 DAS (I_3) produced the highest number of siliquae $plant^{-1}$ and number of seeds $siliqua^{-1}$. However, number of siliquae $plant^{-1}$ under I_2 during 2015-16 and under I_1 and I_2 during 2016-17 were at par with I_3. Similarly, number of seeds $siliqua^{-1}$ under I_1 and I_2 were at par with I_3 during all the three years. Two irrigations of 6 cm depth each at 25 and 50 DAS (I_3) maintained favourable soil moisture condition for better growth and development, partitioning of photosynthates and dry matter to seed.

Table 3: Effect of irrigation regimes and fertilizer levels on yield attributes and seed and stover yield of rapeseed

Treatment	No.of siliqua/plant			No.of seeds/siliqua			Test weight (g)			Seed yield (kg/ha)			Stover yield (kg/ha)		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
Irrigation regimes															
I0	94.6	94.1	92.6	12.4	10.0	9.0	2.0	2.0	2.0	6.95	6.17	6.85	16.28	13.39	16.53
I1	104.8	98.3	112.6	12.5	10.2	10.8	2.02	2.1	2.1	7.70	6.54	9.11	17.70	14.89	19.30
I2	105.3	100.1	103.6	12.8	10.5	10.9	2.08	2.1	2.1	8.19	6.96	8.78	17.87	14.96	18.67
I3	115.5	107.3	113.3	13.2	10.8	11.0	2.19	2.1	2.1	9.55	7.38	9.51	20.59	15.34	20.39
SEm±	1.5	2.7	3.8	0.3	0.20	0.50	0.08	0.08	0.1	0.20	0.20	0.24	0.37	0.31	0.35
CD(P=0.05)	4.4	7.9	11.2	0.7	0.60	1.4	NS	NS	NS	0.59	0.58	0.70	1.08	0.93	1.02
Fertilizer levels															
F_1	98.5	92.4	99.6	12.1	9.9	9.9	2.02	2.1	2.1	7.10	6.11	7.81	16.86	13.68	17.45
F_2	107.4	99.1	106.6	12.9	10.4	10.5	2.07	2.1	2.1	8.48	6.95	8.67	18.41	14.75	18.96
F_3	109.2	101.6	110.3	13.1	10.7	10.9	2.13	2.2	2.1	8.72	7.22	9.20	19.06	15.52	19.75
SEm±	1.3	2.3	3.3	0.2	0.20	0.4	0.07	0.1	0.1	0.7	0.17	0.21	0.32	0.28	0.30
CD(P=0.05)	3.8	6.9	9.7	0.6	0.50	NS	NS	NS	NS	0.51	0.50	0.61	0.94	0.81	0.88
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS			

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; Sarma and Das, 2017). Seeds siliqua^{-1} 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^{-1}. The first irrigation at pre flowering stage helped in formation of seeds in siliqua. 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 the treatment with two irrigations. Yadav *et al.*, 2010; Ray *et al.*, 2015 also observed that irrigation increased number of seeds siliqua^{-1}. The treatment I_1 also recorded the highest seed and stover yield during all the years of observation (Table 3). Rainfed crop recorded the lowest seed and stover yield. Two irrigations of 6 cm each at 25 and 50 DAS (I_3) produced 9.0, 6.3 and 27.4 per cent higher seed yield than 6 cm irrigation at 50 DAS (I_2), 6 cm irrigation at 25 DAS (I_1) and Rainfed (I_0), respectively. Higher seed yield and stover yield under two irrigations *i.e.* 6 cm each at 25 and 50 DAS (I_3) might be assigned to the higher values of various yield components under this treatment. Beneficial effects of irrigation on yield attributes and seed yield of rapeseed were also reported by Piri and Sharma (2006); Sultana *et al.* (2009); Yadav *et al.* (2010); Piri *et al.* (2011) and Sarma and Das, 2017.

Different fertilizer levels brought about significant differences in yield attributing characters of rapeseed (Table.3). Application of 75-50-50 N-P_2O_5-K_2O kg ha^{-1} (F_3) produced the higher yield attributes of rapeseed which was statistically *at par* with application of 60-40-40 kg ha^{-1} of N- P_2O_5 -K_2O (F_2). This might be due to increased availability of N, P and K resulting better utilization of nutrients from the soil rhizosphere leading to proper growth of all biometrical parameters of toria plants. Similar results were also reported by Patel and Thakur (1998) and Kumar and Singh (2006). In the present study, seed and stover yield of rapeseed increased significantly with increasing levels of fertilizers during all the years of observation. Application of 75-50-50 N-P_2O_5-K_2O kg ha^{-1} (F_3) produced the highest seed- and stover yield which was statistically *at par* with application of 60-40-40 N-P_2O_5-K_2O kg ha^{-1} (F_2) (Table 3). This might be attributed to higher values of various yield attributing characters under these treatments. Increase in yield attributes of Yellow Sarson with increase in levels of fertilizer was also reported by Sarma and Das (2017).

Table 4: Effect of different treatments on water use efficiency and benefit:cost ratio of toria

Treatment	Water use efficiency (kg/ha-cm)			Net Return (₹/ha))			Benefit: cost ratio		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
Irrigation regimes									
I_0	50.3	53.5	43.9	10021	6689	9473	1.54	1.36	1.50
I_1	43.1	41.0	43.5	12079	7197	17757	1.61	1.37	1.89
I_2	43.4	41.5	42	14060	8920	16404	1.71	1.45	1.84
I_3	42.8	38.2	40.9	18623	9686	18377	1.90	1.47	1.91
Fertilizer levels (N-P_2O_5-K_2O kg/ha)									
F_1	42.5	42.6	40.1	10911	6741	13707	1.59	1.37	1.74
F_2	48.1	44.7	44.6	15234	8907	15958	1.77	1.45	1.81
F_3	47.2	43.6	43.1	14943	8720	16842	1.71	1.42	1.80

Water use efficiency (WUE)

The highest water use efficiency (WUE) was observed under rainfed condition (I_0) (Table 4). Two irrigations one each at pre-flowering- and siliqua formation stage (I_3) recorded the lowest WUE indicating 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 and Das (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 the seed yield (Sarma *et al.*, 2007; Fanaei *et al.*, 2009 Sarma and Das 2013; Sarma and Das, 2017).

Economics

Net return and benefit: cost ratio realised from I_3 were higher than the I_0, I_1 and I_2 (Table 4). 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 also observed in F_2. Similar results were obtained by Piri *et al.* (2011) and Sarma and Das (2017).

Conclusion

Thus, it can be concluded that with the application of two irrigations at pre-flowering- and siliqua formation stage with 60-40-40 N-P_2O_5-K_2O kg/ha, productivity and monetary return of rapseed can be increased under late sown condition grown after rice.

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