PLANT SCIENCE TODAY
Vol 13(sp1): 01–10
https://doi.org/10.14719/pst.12263

eISSN 2348-1900

RESEARCH ARTICLE

Effect of irrigation and nutrient management in Indian mustard (*Brassica juncea*) direct-seeded autumn rice (*Oryza sativa*) cropping system in Assam

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Received: 14 October 2025; Accepted: 27 January 2026; Available online: Version 1.0: 13 March 2026

Cite this article: Bollaveni SK, Das JC, Sharma A, Sri BSSN. Effect of irrigation and nutrient management in Indian mustard (*Brassica juncea*) direct-seeded autumn rice (*Oryza sativa*) cropping system in Assam. Plant Science Today. 2026;13(sp1):01–10. https:/doi.org/10.14719/pst.12263

Abstract

Irrigation and nutrient management play a crucial role in the productivity and economics of agricultural crops, including mustard, an important oilseed and paddy, a staple food crop in many countries worldwide. Irrigation and nutrients are 2 major inputs change the scenario of crop growth, yield and economics in all the crops. The study titled "Effect of irrigation and nutrient management in Indian mustard (*Brassica juncea)* direct-seeded autumn rice (*Oryza sativa*) cropping system in Assam" was conducted over 2 consecutive years (2016–2017 and 2017–2018) at Assam Agricultural University, Jorhat, Assam. The experiment was conducted during the rabi season (October–February), followed by the summer season (February–June). The irrigation regime with irrigation water (IW): cumulative pan evaporation (CPE) = 1.60 yielded the highest gross and net returns, as well as the highest benefit-cost ratio, followed by IW:CPE = 1.40, for both crops application of 50 % recommended dose of fertilizers (RDF) (N) + 50 % N through farmyard manure (FYM) + biofertilizers resulted in higher values of gross and net return and B:C ratio in both the mustard and rice crops.

Keywords: Assam; cropping system; direct seeded rice; economics; irrigation water/cumulative pan evaporation and integrated nutrient management

Introduction

Rice-growing regions adopt diverse cropping systems influenced by climatic conditions, agro-ecological settings, domestic needs, market opportunities and the resources available to farmers. Rapeseed-Indian mustard (*Brassica juncea* (L.) Czern.), one of the most important edible oilseed crops, has recently emerged as a potential crop in rice-growing regions of the country. In recent years oil seeds have received more importance owing to higher prices due to increased domestic requirement. Inclusion of oil crops in different cropping systems is a fruitful way to fulfil the demand for oilseeds (1). Rapeseed-Indian mustard ranks third among oilseed crops in India, after soybean and groundnut, with a cultivated area of 6.646 million hectares and a production of 7.877 million tonnes. The average national productivity is 1185 kg per hectare (2). In Assam, under rainfed conditions, rapeseed covers about 279 thousand hectares but records a much lower productivity of 605 kg per hectare compared to the national average (3). Recently, Indian mustard has been gaining popularity among farmers in Assam as an alternative to rabi rapeseed in rice-based cropping systems. However, the adoption of mustard remains limited due to insufficient technological awareness and lack of access to improved cultivation practices.

India and China are the largest producers of paddy and rice is a staple food in many countries worldwide (4–6). To face the water shortages, labour scarcity and rising wages in paddy farming, farmers can shift from transplanting to aerobic rice systems, where rice is grown by direct seeding in non-puddled fields saving both water and labour (7, 8).

Aerobic rice systems are well known for water productivity and less destruction of soil structure. The requirements for a successful crop under direct-seeded method: Effective crop establishment, weed management, water management and nutrient management (9). The practice is more fruitful when such upland rice growing areas are brought to produce an additional quantity of oilseeds, to achieve food security and reduction of import pressure.

The rabi and early summer of Assam are characterized by prolonged drought with high evapotranspirational demand of the crops and its leads to moisture deficit of crops and may respond very well to availability of application of moisture. The seed and oil yields in Indian mustard will increase with adequate and timely nutrient supply (10) which leads to higher returns from these oil seeds. Several studies have shown that integrated nutrient management plays a key role in direct-seeded upland rice. It involves the judicious use of chemical fertilizers in combination with organic sources. This approach improves crop productivity and soil fertility. The slow release of nutrients from organic inputs ensures a sustained nutrient supply throughout the crop-growing season. Crop nutrient requirement, safe and long-term availability of nutrients, availability of all kinds of nutrients and sustainability fulfil by integrated nutrition management (INM) (11). The integrated use of organic and inorganic fertilizers well augments the efficiency of both substantially to luxurious production and productivity (12). Continuous utilization of pure chemical fertilizers under intensive cropping system leads to depletion of reserve pool of non-applied nutrients and deterioration of soil productivity and fertility (13). To achieve these objectives, it is essential to promote INM, combining organic and inorganic sources of plant nutrition. This approach ensures higher productivity, economic feasibility, social acceptance and ecological sustainability (14).

Materials and Methods

Experimental site

The present study was conducted during 2 consecutive rabi (October–February) followed by summer (February–June) seasons of 2016–2017 and 2017–2018 at Assam Agricultural University (Instructional-cum-Research Farm), Jorhat, Assam.

Treatments

The treatments consisted of four irrigation levels (I0- Rain-fed, I1- IW:CPE =1.20, I2– irrigation water (IW): cumulative pan evaporation (CPE) =1.40 and I3 - IW:CPE =1.60) as main plots, 5 nutrient management practices (N1- Recommended dose of fertilizers (RDF), N2 - RDF + farmyard manure (FYM) at 5t/ha, N3 -75 % RDF (N) + 25 % N through FYM, N4 - 50 % RDF (N) + 50 % N through FYM and N5- 50 RDF (N) + 50 % N through FYM + Biofertilizers (Consortium of *Azotobacter* and PSB) as sub-sub plots. Each subplot was irrigated with a uniform water depth of 6 cm for Indian mustard and 5 cm for direct-seeded rice, according to the assigned IW:CPE ratios. The details of dates of irrigation for each treatment along with number of irrigations and the total quantity of water applied are given in Table 1.

$$q = a \times d$$

Where,

q = Amount of water required for each irrigation (m^3)

a = area to be irrigated (12 m^2)

d = depth of water (6 cm) for Indian mustard and (5 cm) for direct seeded rice

Indian mustard

q = 12 m2 x 0.06 m

= 0.72 m3 plot^{-1}

= 720 litre plot^{-1} (Eqn.1)

Direct seeded rice

q = 12 m2 x 0.05 m

= 0.60 m3 plot^{-1}

= 600 litre plot^{-1} (Eqn.2)

The required quantity of well decomposed FYM for both the crops were weighed, broadcasted as per treatments and incorporated with the soil thoroughly before sowing. During both the years, at the time of Indian mustard sowing full dose of nitrogen (RDF (N) at 60 kg N/ha) as per treatments, phosphorus at 40 kg P_2O_5 ha^{-1} and potassium at 40 kg K_2O ha^{-1} were applied as basal in the form of urea, SSP and MOP fertilizers and broadcasted these fertilizers and uniformly incorporated in to the soil. In case of direct seeded rice, out of the RDF (40-20-20 kg N-P_2O_5-K_2O) half of the recommended nitrogen and potassium and full dose of P_2O_5 were applied in the form of Urea, SSP and MOP and incorporated

Table 1. Number and dates of irrigation in various treatments

Treatments	Date of application	No. of irrigations	The depth of each irrigation (cm)	Total depth of irrigation water (cm)
Indian Mustard, 2016-2017				
I_0	--	Nil	--	
I_1	27.11.2016 and 30.12.2016	2	6.00 and 3.20	9.20
I_2	24.11.2016, 20.12.2016 and 23.1.2017	3	6.00	18.00
I_3	20.11.2016, 12.12.2016 and 20.1.2017	3	6.00	18.00
Direct seeded rice, 2017				
I_0				
I_1	10.3.2017, and 18.4.2017	2	4.02 and 3.91	7.93
I_2	08.3.2017, 20.3.2017and 15.4.2017	3	4.02, 1.22 and 4.36	9.60
I_3	06.3.2017, 17.3.2017and 14.4.2017	3	5.00, 3.15 and 4.36	12.51
Indian Mustard, 2017-2018				
I_0				
I_1	17.11.2017 and 21.1.2018	2	5.30 and 5.95	11.25
I_2	13.11.2017, 9.12.2017 and 9.1.2018	3	5.30, 4.53 and 5.95	15.78
I_3	10.11.2017, 2.12.2017, 28.12.2017 and 21.1.2018	4	5.3, 4.53, 6.00 and 5.95	21.78
Direct seeded rice, 2018				
I_0				
I_1	1.3.2018, 22.3.2018 and 3.4.2018	3	2.33, 3.36 and 3.69	9.38
I_2	25.2.2018, 20.3.2018, 30.3.2018 and 15.4.2018	4	3.66, 3.36, 3.69 and 2.99	13.70
I_3	22.2.2018, 17.3.2018, 28.3.2018 and 6.4.2018	4	3.93, 3.52, 1.47 and 4.87	13.80

in to the soil along with the FYM. The rest half of N was divided into 2 equal parts and one part along with half of K_2O was applied at the tillering stage (30 DAS) and other part applied at panicle initiation stage (55 DAS) as a top dressing.

Crop varieties used

TM-2 (Indian mustard) is a tall variety recommended for both rain-fed and irrigated conditions. The variety was developed at the Bhabha Atomic Research Centre in Trombay, Mumbai, Maharashtra and released in 1993. It has a crop duration of about 95 days and an average productivity of 1.37 t ha^{-1}.

Inglongkiri (Paddy) was used in this experiment. It is an Assam famous tall paddy variety recommended for direct seeded, rain-fed upland/Jhum situations of Hill zones of Assam.

Rainfall information

During the 1st year of investigation (25th October 2016 to 2nd June 2017), out of the total amount of rainfall of 713.9 mm (Table 2 and 3) received in 46 rainy days, during the period of Indian mustard crop, 63.3 mm rainfall was received in 5 rainy days and during direct-seeded rice crop the amount of rainfall was 650.6 mm occurred in 41 rainy days. During the period of Indian mustard, the maximum weekly total rainfall was 43.5 mm, received in 52nd week (24th–31st December, 2016), while such value was 115.9 mm received in 13th week (26th March to 1st April 2017) during the period of direct seeded rice.

During the 2nd year of investigation (25th October 2017 to 1st June 2018), total rainfall was 482 mm (Tables 2 and 3) which was received in 30 rainy days. During the period of Indian mustard crop, rainfall was 25.4 mm, received in 3 rainy days and during direct-seeded rice crop, 456.6 mm rainfall was received in 27 spells.

Measurements

Seed yield of mustard

After the practices of threshing and winnowing, the clean seed produce obtained from each of the individual plots were weighed and weight was recorded as kg per plot and expressed as kg per hectare.

Grain yield of paddy

After the crop harvested bundled and recorded weight according to the net-plot. After threshing and winnowing, the weights of the grains per plot were recorded. The yields of grains (on sun-dry basis) are reported in quintal per hectare.

Cost of cultivation

Calculated the amount utilised for each treatment (Different inputs, labour and operational cost) per hectare.

Gross and net return

$$\text{Gross return (Rs ha}^{-1}\text{)} = \text{Yield per ha} * \text{Price per unit produce} \quad \text{(Eqn.3)}$$

$$\text{Net return} = \text{Gross return} - \text{Cost of cultivation} \quad \text{(Eqn.4)}$$

Benefit: Cost (B: C) ratio

The benefit: cost ratio was computed by dividing the net return by the total cost of cultivation.

Statistical analysis

The experiment was conducted using a split-plot design with 3 replications. The main plot irrigation factor consisted of four treatment levels, which were randomly assigned to the main plots within each replication. Each main plot was further divided into 5 nutrient management subplots, resulting in a total of 60

Table 2. Weekly meteorological data during the experimentation period of Indian mustard during 2 seasons

SMW	Date	Maximum T (°C)	Minimum T (°C)	Mean T (°C)	RH (%) Morning	RH (%) Evening	Rainfall (mm)	Evaporation (mm)	Bright sun shine hours (hr)	Ground water (cm)
Indian mustard (2016–2017)										
43	22nd October – 28th October	30.60	20.60	25.60	95.00	68.00	1.20	18.90	3.80	95.80
44	29th October – 4th November	31.30	19.50	25.40	96.00	62.00	0.00	19.60	5.90	95.90
45	5th November – 11th November	27.90	19.80	23.80	98.00	79.00	16.50	9.80	2.50	94.70
46	12th November – 18th November	30.20	18.00	24.10	96.00	66.00	0.00	12.60	3.30	95.70
47	19th November – 25th November	27.50	12.30	19.90	98.00	63.00	0.00	14.00	8.80	97.00
48	26th November – 2nd December	27.70	13.80	20.70	95.00	62.00	0.00	12.60	8.20	99.50
49	3rd December – 9th December	27.60	11.80	19.70	99.00	61.00	0.00	11.20	8.00	106.40
50	10th December –16th December	26.50	9.70	18.10	100.00	58.00	0.00	11.20	8.80	111.50
51	17th December – 23rd December	26.00	12.60	19.30	99.00	62.00	0.00	9.10	5.80	115.80
52	24th December– 31st December	25.00	12.60	18.80	99.00	66.00	43.50	10.50	5.80	111.50
1	1st January – 7th January	25.90	10.70	18.30	99.00	56.00	0.10	11.20	8.20	118.30
2	8th January – 14th January	24.00	9.30	16.60	98.00	61.00	0.00	9.80	6.60	123.30
3	15th January–21st January	24.30	8.00	16.10	99.00	57.00	0.00	11.20	8.10	129.20
4	22nd January – 28th January	26.80	9.10	17.90	96.00	51.00	0.00	11.90	7.60	130.10
5	29th January – 4th February	25.50	11.30	18.40	97.00	59.00	2.00	11.90	7.30	129.20
Indian mustard (2017–2018)										
43	22nd October – 28th October	27.60	20.30	23.95	97.00	79.00	57.00	12.60	4.90	81.90
44	29th October – 4th November	28.10	18.50	23.30	93.00	74.00	7.00	14.00	7.10	76.20
45	5th November – 11th November	30.10	16.20	23.10	93.00	65.00	0.00	16.80	9.20	81.40
46	12th November – 18th November	28.20	16.30	22.20	96.00	67.00	0.30	11.90	5.80	90.40
47	19th November – 25th November	28.70	17.10	22.90	97.00	68.00	7.00	12.60	7.40	86.60
48	26th November – 2nd December	26.00	13.60	19.80	99.00	70.00	7.40	10.50	6.60	77.90
49	3rd December – 9th December	26.50	11.20	18.80	99.00	66.00	0.00	12.60	6.30	82.60
50	10th December –16th December	25.70	16.50	21.10	98.00	77.00	0.00	9.10	1.30	90.60
51	17th December – 23rd December	25.20	12.50	18.80	100.00	68.00	0.00	7.00	5.50	99.50
52	24th December–31st December	25.80	11.10	18.40	100.00	65.00	0.00	10.50	7.30	110.10
1	1st January – 7th January	23.70	11.80	17.70	98.00	73.00	0.50	9.80	4.60	120.80
2	8th January– 14th January	23.20	8.90	16.00	98.00	65.00	0.00	12.60	6.90	131.40
3	15th January–21st January	23.20	11.80	17.50	99.00	67.00	0.00	10.50	4.80	138.90
4	22nd January – 28th January	24.10	12.50	18.30	98.00	73.00	2.20	11.90	3.20	137.00
5	29th January–4th February	22.60	12.20	17.40	98.00	72.00	1.00	9.10	7.30	135.10

Table 3. Weekly meteorological data during the experimentation period of direct seeded rice during 2 seasons

SMW	Date	Max T (°C)	Min T (°C)	Mean T (°C)	RH (%) Mor.	RH (%) Eve.	RF (mm)	EVP (mm)	BSSH (hr)	GWT (cm)
Direct seeded rice (2017)										
8	19th February –25th February	25.6	15.0	20.3	96	66	37.4	16.1	4.5	128.4
9	26th February – 4th March	25.9	15.0	20.4	94	60	0.0	18.2	3.2	131.0
10	5th March – 11th March	26.3	14.6	20.4	91	62	19.2	22.4	5.0	129.1
11	12th March – 18th March	26.8	14.3	20.5	91	53	10.6	23.1	6.7	119.9
12	19th March –25th March	26.3	15.2	20.7	95	61	26.0	20.3	4.9	112.6
13	26th March–1st April	26.6	19.3	22.9	97	77	115.9	14.7	1.9	100.8
14	2nd April –8th April	25.9	19.4	22.6	96	79	99.9	14.7	2.6	87.4
15	9th April – 15th April	31.1	19.7	25.4	90	59	4.3	29.4	7.4	84.3
16	16th April – 22nd April	28.1	20.3	24.2	94	75	36.8	18.2	3.0	76.1
17	23rd April – 29th April	28.8	21.2	25.0	97	77	33.6	20.3	4.6	65.4
18	30th April – 6th May	28.6	20.4	24.5	96	73	46.3	22.4	4.3	57.8
19	7th May – 13th May	31.4	22.5	26.9	94	70	39.2	25.9	5.8	50.4
20	14th May – 20th May	31.7	23.4	27.5	93	74	35.9	23.8	4.7	43.1
21	21st May – 27th May	29.4	23.2	26.3	96	82	95.7	17.5	2.1	36.8
22	28th May–3rd June	30.6	24.2	27.4	94	79	49.8	20.3	1.8	31.9
Direct seeded rice (2018)										
6	5th February–11th February	22.5	13.2	17.8	99	73	1.4	9.1	2.1	128.2
7	12th February–18th February	26.7	11.6	19.1	95	55	10.7	15.4	7.3	124.8
8	19th February–25th February	26.4	14.5	20.4	96	63	4.3	16.1	3.2	120.8
9	26th February–4th March	23.7	15.6	19.6	97	79	56.3	12.6	1.5	111.2
10	5th March–11th March	27.4	15.2	21.3	94	60	3.2	17.5	2.5	106.1
11	12th March–18th March	26.9	15.8	21.3	95	66	13.8	15.4	2.4	99.7
12	19th March–25th March	28	15.5	21.7	95	60	11.3	22.4	4.7	93.2
13	26th March–1st April	28.7	17.5	23.1	93	57	3.1	25.2	5.5	86.9
14	2nd April–8th April	31.5	18.4	24.9	92	56	20.1	28.0	4.5	80.3
15	9th April–15th April	28.2	19.2	23.7	96	69	37.6	21.7	3.8	72.7
16	16th April –22 April	29.1	19.9	24.5	93	69	43	23.8	3.7	65.9
17	23rd April–29th April	30.4	20	25.2	85	66	11.1	25.9	5.9	59.6
18	30th April–6th May	28.6	20.5	24.5	93	72	39.7	20.3	3.1	53.0
19	7th May–13th May	25.1	21.2	23.1	96	77	25.5	21.7	2.8	45.7
20	14th May–20th May	32	22.1	27.0	90	64	73.4	23.8	7.1	38.5
21	21st May–27th May	33.2	24.6	28.9	91	72	86.3	25.9	3.7	33.5
22	28th May–3rd June	31.1	24.1	27.6	94	73	17.2	21.0	4.1	30.0

experimental units (4 × 5 × 3). Data were analysed using Analysis of Variance (ANOVA) appropriate for a split-plot structure. In this model, replication effects and main plot treatments were tested against the main plot error (variation among main plots within replications), while subplot treatments and the interaction between main plot and subplot factors were tested against the subplot error (variation among subplots within main plots). The general linear model included the overall mean, replication effect, main plot effect, subplot effect, their interaction and corresponding error terms.

$$Y_{ijk} = \mu + R_i + A_j + (RA)_{ij} + B_k + (AB)_{jk} + \varepsilon_{ijk}$$

Where:

- Y_{ijk} = observed response
- μ = overall mean
- R_i = replication (block) effect
- A_j = j^{th} level of irrigation effect (Factor irrigation)
- $(RA)_{ij}$ = main plot error term
- B_k = k^{th} level of nutrient management effect (Factor nutrient management)
- $(AB)_{jk}$ = interaction effect between factors A and B
- ε_{ijk} = subplot error term

Statistical analyses were performed using standard software packages such as R (Library doe bioresearch 4.5.2. R version) and treatment means were compared using LSD at a 5 % level of significance.

Results

Effect of irrigation regime

Results of Indian mustard (Tables 4 and 5) revealed that in spite of increase in yield (Fig. 1), cultivation cost, the gross and net returns and B:C ratio also increased with the increasing irrigation regime from IW: CPE 1.20 to IW: CPE 1.60 and the poor values in these aspects were observed under rainfed in both the year. The highest yield, gross return (Rs. 67933 and 69333), net return (Rs. 49569 and 50249) and B:C ratio (2.69 and 2.62) was observed under irrigation practice IW: CPE=1.60 which was followed by IW:CPE ratio 1.40 and IW: CPE ratio 1.20, respectively.

The data on economics of cultivation of direct seeded rice (Table 6, Fig. 2) revealed that the cost of cultivation was same under IW:CPE ratio 1.40 and IW: CPE ratio 1.60 with same number of irrigations. Even though, the gross and net return and B:C ratio increased with the increasing intensity of irrigations from IW:CPE ratio 1.20 (2 and 3 irrigations in 2016 and 2017, respectively) to IW:CPE ratio 1.60 (3 and 4 irrigations in 2016 and 2017, respectively) and the lowest values in these aspects were observed underrun irrigated rainfed conditions. As such, among the different irrigation schedules the highest values in gross (Rs. 56779 and 58044) and net return (Rs. 35063 and 36268) and B:C ratio (1.62 and 1.67) was observed under irrigation at IW: CPE= 1.60 which was followed by irrigation regimes IW: CPE ratio 1.40 and IW: CPE ratio 1.20, respectively.

Effect of nutrient management

The cost of cultivation of Indian mustard (Table 6, Fig. 3) was observed to be comparatively higher with RDF + FYM at 5 t/ha followed by the treatment 50 % (N) through RDF + 50 % N through

Table 4. Effect of irrigation and nutrient management on yield of Indian mustard

Treatments	Seed yield (kg/ha)			Stover yield (kg/ha)		Biological yield (kg/ha)		Harvest index (%)	
	2016–17	2017–18	Pooled	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18
Irrigation (I)									
Rainfed	681.47	699.47	690.48	1579.91	1666.57	2261.37	2366.04	30.61	29.86
IW:CPE = 1.20	1029.00	1204.33	1117.00	2877.01	2977.01	3906.01	4181.34	26.46	29.30
IW:CPE = 1.40	1328.73	1248.73	1288.70	3896.23	4026.23	5224.96	5277.63	25.56	23.82
IW:CPE = 1.60	1358.66	1389.33	1372.67	4426.50	4586.51	5785.17	5973.17	23.60	23.27
S.Ed±	51.01	55.61	69.24	195.94	126.60	213.63	182.10	1.29	0.95
CD: (P=0.05)	124.83	136.07	220.34	479.47	309.79	522.75	445.61	3.16	2.32
Nutrient Management (N)									
Recommended dose of fertilizer (RDF)	906.00	915.17	910.58	2750.33	2858.66	3656.33	3773.83	25.82	25.41
RDF + FYM at 5t/ha	1204.00	1255.67	1229.83	3440.21	3573.54	4644.21	4829.21	26.92	27.17
75 % RDF(N) + 25 %N through FYM	985.83	1039.17	1012.50	2987.48	3112.48	3973.32	4151.65	25.49	25.92
50 % RDF(N) + 50 % N through FYM	1156.58	1184.92	1170.75	3165.31	3277.82	4321.90	4462.73	27.82	27.72
50 % RDF(N) + 50 % N through FYM + Bio-fertilizers	1244.91	1282.42	1264.08	3631.22	3747.89	4876.14	5030.30	26.73	26.58
S.Ed±	40.04	46.89	14.73	201.66	204.36	209.98	199.27	1.77	1.86
CD: (P=0.05)	81.57	95.52	40.91	410.79	416.29	427.73	405.91	N.S	N.S
Interaction (I x N)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

N.S: Non-significant.

Table 5. Economics of Indian mustard under various treatments

Treatments	Cost (Rs.)		Gross return (Rs.)		Net return (Rs.)		B:C ratio	
	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18
Irrigation (I)								
Rainfed	16865	17085	34074	34973	17209	17888	1.02	1.05
IW:CPE = 1.20	17865	18085	51450	60217	33585	42132	1.87	2.32
IW:CPE = 1.40	18365	18585	66437	62570	48072	43985	2.61	2.36
IW:CPE = 1.60	18365	19085	67933	69333	49569	50249	2.69	2.62
Nutrient Management								
Recommended dose of fertilizers (RDF)	15900	16245	45300	45758	29400	29514	1.83	1.80
RDF + FYM at 5t/ha	19780	20125	60200	62783	40421	42659	2.02	2.09
75 % RDF(N) + 25 % N through FYM	16511	16856	49292	51958	32781	35103	1.96	2.05
50 % RDF(N) + 50 % N through FYM	18562	18907	57829	59246	39268	40339	2.09	2.11
50 % RDF(N) + 50 % N through FYM + Bio-fertilizers	18612	18957	62246	64121	43634	45164	2.34	2.38

Table 6. Economics of direct seeded autumn rice under various treatments

Treatments	Cost (Rs.)		Gross return (Rs.)		Net return (Rs.)		B:C ratio	
	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation (I)								
Rainfed	20216	19776	43467	42051	23251	22275	1.16	1.13
IW:CPE = 1.20	21216	21276	46205	48760	24989	27484	1.18	1.30
IW:CPE = 1.40	21716	21776	55543	56862	33827	35086	1.56	1.61
IW:CPE = 1.60	21716	21776	56779	58044	35063	36268	1.62	1.67
Nutrient Management (N)								
Recommended dose of fertilizers (RDF)	19070	19005	46820	48043	27750	29038	1.45	1.52
RDF + FYM at 5t/ha	22950	22885	53176	54214	30226	31329	1.31	1.36
75 % RDF(N) + 25 %N through FYM	20400	20335	48474	48933	28074	28598	1.37	1.40
50 % RDF(N) + 50 % N through FYM	21730	21665	49863	50854	28133	29189	1.29	1.34
50 % RDF(N) + 50 % N through FYM + Bio-fertilizers	21930	21865	54160	55104	32230	33239	1.46	1.52

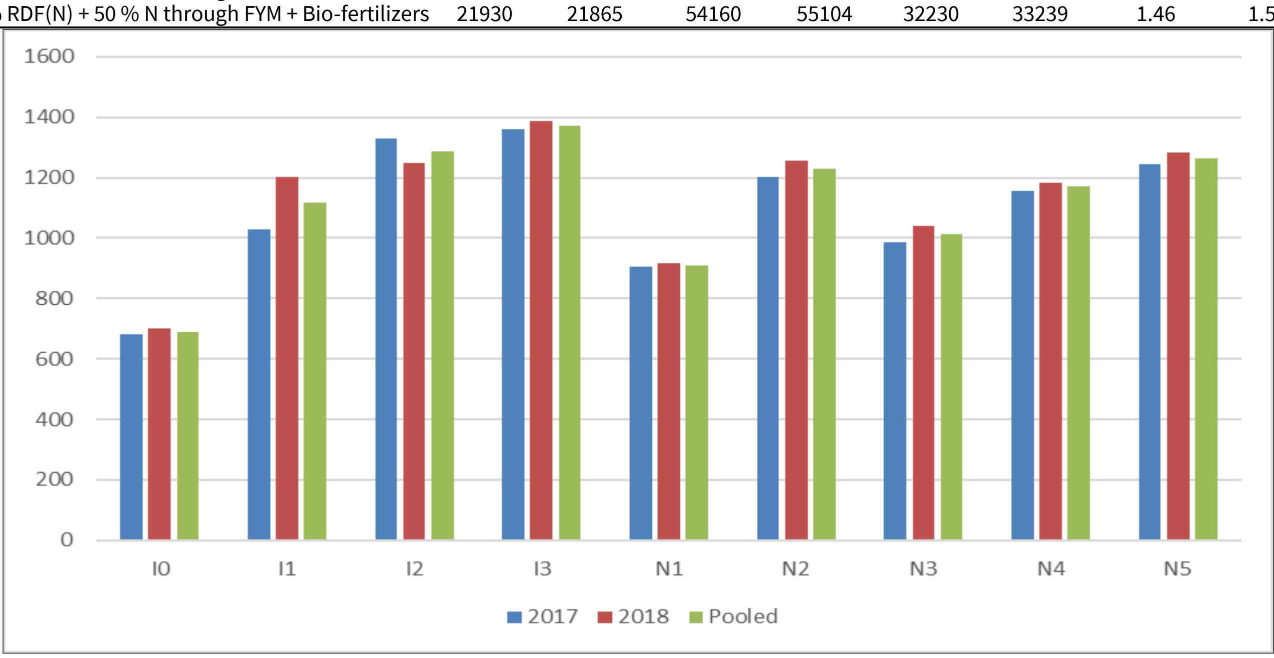

Fig.1. Effect of irrigation and nutrient management on yield of Indian mustard (kg/ha).

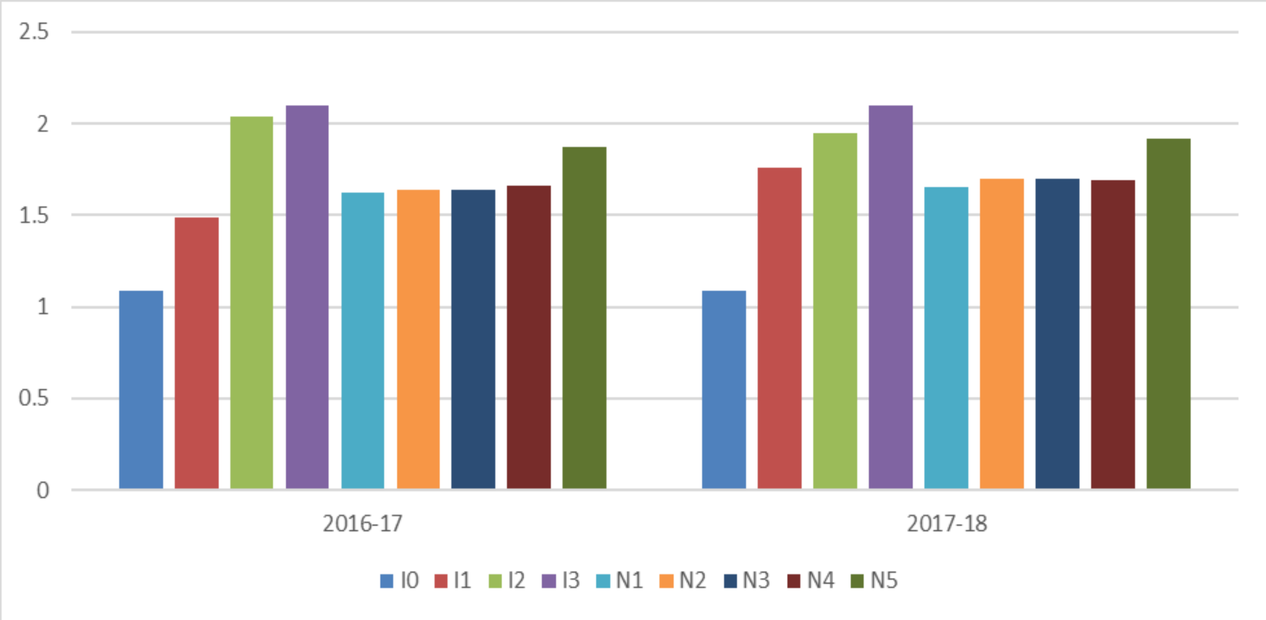

Fig. 2. Effect of irrigation and nutrient management on benefit cost ratio of direct seeded autumn rice.

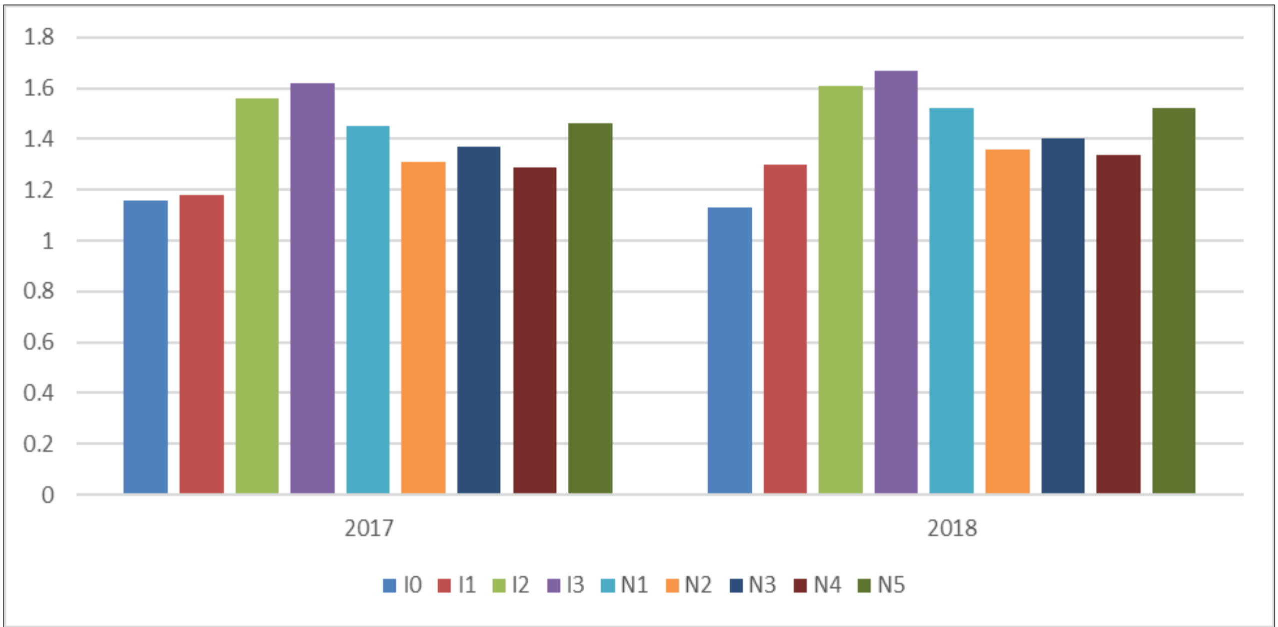

Fig. 3. Effect of irrigation and nutrient management on benefit cost ratio of Indian mustard.

FYM + Biofertilizers over other treatments. Yet application of 50 % (N) through RDF + 50 % N through FYM + Biofertilizers resulted in higher values of gross return (Rs. 62246 and 64121), net return (Rs. 43634 and 45164) and B:C ratio. This was followed by application of RDF + FYM at 5 t/ha in respect to gross and net returns in both the year. However, with respect to the benefit–cost (B:C) ratio, the treatments 50 % RDF (N) + 50 % N through FYM and RDF + FYM at 5 t ha^{-1} produced similar values. The lowest values in all these aspects were observed under RDF alone in both the year.

Application of 50 % (N) through RDF + 50 % N through FYM + Biofertilizers produced the highest paddy grain yield (24.15 and 24.36 q/ha) in both the year (Table 5, Fig. 4). The cost of cultivation was higher with the treatment RDF + FYM at 5 t/ha which was followed by 50 % (N) through RDF + 50 % N through FYM + Biofertilizers (Table 7, Fig. 2). 50 % (N) through RDF + 50 % N through FYM + Biofertilizers resulted in higher values of gross return (Rs. 54160 and 55104), net return (Rs. 32230 and 33239) and B:C ratio (1.46 and 1.52) compared to other treatments in both the year. This was followed by application of RDF + FYM at 5 t/ha in resulting higher values of gross and net returns. The lowest values of cost of cultivation, gross return and net return were observed under RDF, but this showed almost similar or nearer values of B:C ratio with that of 50 % (N) through RDF + 50 % N through FYM + Biofertilizers. Cropping system economics given in Table 8.

Discussion

Irrigation regime

Irrigation has a positive influence on crop development of Indian mustard through increasing in the nutrient availability to the crop and fulfil the crop physiological demands also confirmed by (15, 16). The rabi season in Assam receives very little rainfall. Under such conditions, adequate and timely irrigation positively influences crop growth and development by improving root development, reducing moisture stress, maintaining favourable canopy temperature, minimising flower drop and enhancing photosynthate assimilation. Mustard experienced only 63.3 mm and 25.4 mm of rainfall in both the years and the irrigation amount was IW: CPE 1.60 (180 mm and 217 mm) and IW: CPE 1.40 (180 mm and 157 mm). Due to better amount and high frequent irrigation IW: CPE 1.60 showed superiority

Table 7. Effect of irrigation and nutrient management on yield of direct seeded autumn rice

Treatments	Grain yield (q/ha)			Straw yield (q/ha)		Harvest index (%)	
	2017	2018	Pooled	2017	2018	2017	2018
Irrigation (I)							
Rainfed	18.66	18.20	18.43	30.98	29.57	37.58	38.09
IW:CPE = 1.20	20.32	21.29	20.81	31.59	33.32	39.14	39.02
IW:CPE = 1.40	25.34	25.65	25.49	35.11	36.77	41.95	41.10
IW:CPE = 1.60	26.01	26.25	26.13	35.59	37.33	42.28	41.34
S.Ed±	0.43	0.52	0.40	1.18	0.69	0.99	0.53
CD: (P=0.05)	1.05	1.27	1.28	2.89	1.68	2.43	1.29
Nutrient Management (N)							
Recommended dose of fertilizer (RDF)	20.73	21.03	20.88	31.49	32.14	39.55	39.42
RDF + FYM at 5t/ha	23.73	24.09	23.87	35.16	36.41	40.09	39.58
75 % RDF(N) + 25 %N through FYM	21.73	21.89	21.85	31.78	32.44	40.54	40.26
50 % RDF(N) + 50 % N through FYM	22.56	22.86	22.72	32.20	33.12	41.02	40.68
50 % RDF(N) + 50 % N through FYM + Bio-fertilizers	24.15	24.36	24.26	35.95	37.12	39.98	39.50
S.Ed±	0.68	0.71	0.04	0.99	0.99	0.97	1.00
CD: (P=0.05)	1.38	1.44	0.11	2.03	2.02	N.S	N.S
Interaction (I x N)	N.S	N.S	N.S	N.S	N.S	N.S	N.S

N.S: Non-significant.

Table 8. Economics of Indian mustard-direct seeded autumn rice cropping system under various treatments

Treatments	Cost (Rs.)		Gross return (Rs.)		Net return (Rs.)		B:C ratio	
	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18	2016–17	2017–18
Irrigation (I)								
Rainfed	37094	36874	77540	77023	40446	40149	1.09	1.09
IW:CPE = 1.20	39094	39374	97726	108978	58632	69604	1.49	1.76
IW:CPE = 1.40	40094	40374	121998	119434	81904	79060	2.04	1.95
IW:CPE = 1.60	40094	40874	124752	127378	84658	86504	2.10	2.10
Nutrient Management (N)								
Recommended dose of fertilizers (RDF)	34970	35250	92141	93800	57171	58550	1.62	1.65
RDF + FYM at 5t/ha	42730	43010	113379	116997	70649	73987	1.64	1.70
75 % RDF(N) + 25 % N through FYM	36911	37191	97763	100896	60852	63705	1.64	1.70
50 % RDF(N) + 50 % N through FYM	40292	40572	107783	110098	67491	69526	1.66	1.69
50 % RDF(N) + 50 % N through FYM + Bio-fertilizers	40542	40822	116455	119226	75913	78404	1.87	1.92

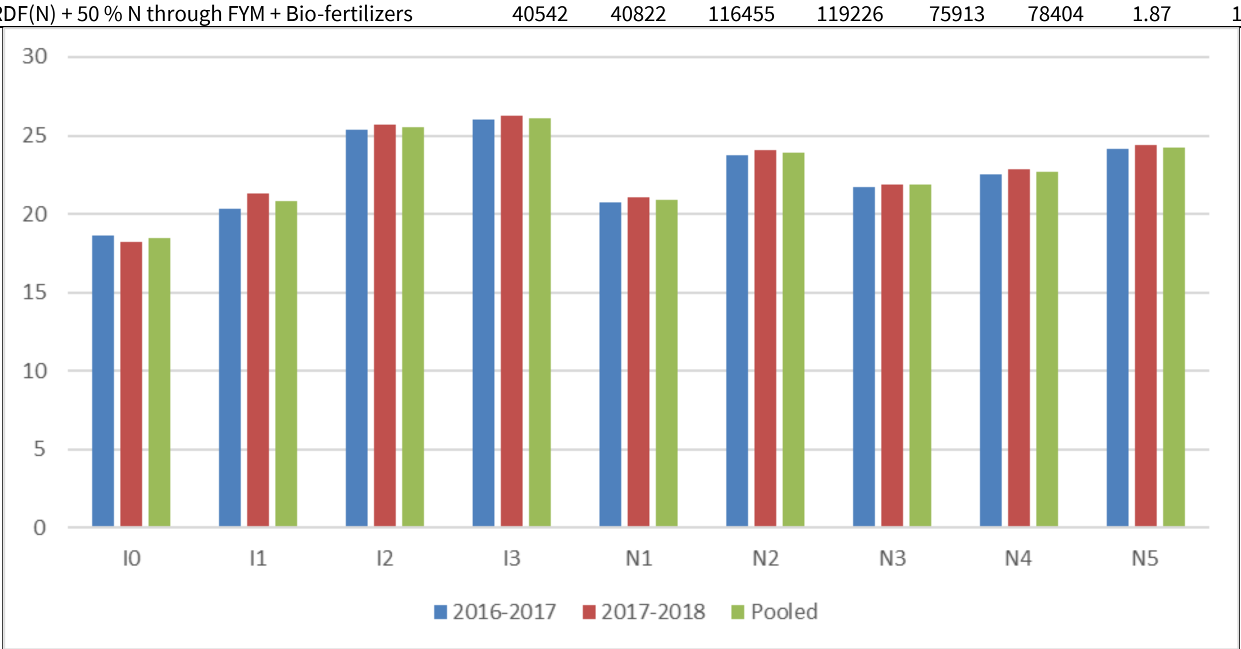

Fig. 4. Effect of irrigation and nutrient management on yield of direct seeded autumn rice (Q/ha).

in growth, yield and economics also. These kind of superior economic returns by adequate irrigation practices in different crops also observed by (17–19).

Paddy is a water loving crop. Adequate and timely irrigations show significant influence on growth, yield and returns of the crop. The positive responses of irrigations in increasing grain and straw yield and economic returns of direct seeded rice have been reported by different workers (20–25). The higher cost of irrigation due to a greater number of irrigations applied under the treatments IW:CPE ratio 1.60 and IW: CPE ratio 1.40 (3 and 4 irrigations in 2017 and 2018, respectively) led to result higher cost of cultivation. On the other hand, increased gross and net return and B:C ratio with the increasing levels of irrigation from unirrigated rainfed to IW:CPE ratio 1.60 directly attributed from the corresponding increase in grain and straw yield of rice. Irrigation applied according to the treatments increased soil moisture availability, maintained favourable soil temperature, enhanced assimilation, reduced weed infestations and promoted photosynthesis under an IW:CPE ratio of 1.60 compared with lower irrigation frequencies. Similar results of higher economic returns trough increased grain and straw yield of rice with intensive irrigation regime have also been reported by different workers (26–29). Sufficient irrigation increases the microbial activity in soil which leads to good decomposition of organic manures (30).

Nutrient management

Nutrient availability is an important factor to influencing performance of the mustard crop. Adequate and timely application of nutrients through different resources increase the shoot and root growth, cell division, photosynthesis process, sink development and harvest index (31–33). 50 % (N) through RDF + 50 % N through FYM + Biofertilizers showed better growth and yield (Fig. 1) and economic returns maybe due to slow releasing organic fertilizers are showed better results in integration with ready to use chemical fertilizers and biofertilizers. Biofertilizers are cost effective and ecofriendly, they benefit the crop through nitrogen fixation, nutrient solubilising and boost in yield upto 15 to 20 %. The superiority of organic and biofertilizers in enhancing growth, yield and economic returns of mustard and other crops has been reported by several researchers (34, 35).

50 % (N) through RDF + 50 % N through FYM + Biofertilizers showed better yield and economics in direct seeded rice maybe due to application of organic fertilizers improves the soil productivity through increasing soil organic matter, improving soil structure, aeration and water retention capacity (36–40). Superior organic matter supports the beneficial microbes, enhancing soil biodiversity and resilience against degradation of soil (41–43). These slow releasing fertilizers and nitrogen fixation biofertilizers provide the adequate amount of nutrients to the crop throughout the life cycle for luxurious yields (44, 45).

Thus, higher cost under the treatment RDF + FYM at 5 t/ha followed by 50 % (N) through RDF + 50 % N through FYM + Biofertilizers were attributed from the additional cost of the farmyard manure and biofertilizers respectively, along with the chemical fertilizers. It is worth mentioning that the grain and straw yield were significantly higher under these treatments which attributed towards the higher gross and net return. The lower cost of cultivation under rainfed conditions, along with marginally higher inputs in the 50 % N through RDF + 50 % N through FYM + biofertilizer treatment, produced a comparable (or) even higher B:C ratio. The higher gross and net returns under this treatment may be due to better grain and straw yields and returns obtained for the produce (46–51).

Conclusion

The study revealed that IW:CPE ratios of 1.40 and 1.60 are optimum for Indian mustard and direct-seeded autumn rice under Assam's upland conditions. Mustard performed well at both ratios, while rice benefited from 1.40 for stability and 1.60 for higher economic returns. Integrating RDF with FYM and biofertilizers significantly enhanced yield and profitability. Overall, the mustard-rice cropping system proved a feasible, sustainable and economically beneficial option for farmers in irrigated uplands of Assam.

Acknowledgements

Authors are thankful to all the teaching and non-teaching staff of the Department of Agronomy, Assam Agricultural university, Jorhat for providing necessary technical guidance and support for the successful research work.

Authors' contributions

BSK carried out the field trial, performed data analysis and drafted the manuscript. JCD advised and critically supervised the entire research work. AS assisted with manuscript drafting and data analysis, while BSSSN contributed to drafting and editing the research article. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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