# Crude protein, economics and water use efficiency of ryegrass under different irrigation regimes and nitrogen levels


**ABSTRACT**

A field experiment was undertaken at the Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat during 2017-2018 and 2018-2019 in order to study the effect of irrigation regimes and nitrogen levels on crude protein, economics and water use efficiency of ryegrass. The experiment was laid out in split-plot design with three replications. The treatments consisted of five levels of irrigation in main plot viz., $I_0$: Rainfed, $I_1$: Irrigation at critical growth stages, $I_2$: Irrigation at IW: CPE ratio of 1.0, $I_3$: Irrigation at IW:CPE ratio of 1.2 and $I_4$: Irrigation at IW:CPE ratio of 1.4 along with four levels of N - $N_0$: 0 kg N/ha, $N_1$: 30 kg N/ha, $N_2$: 60kg N/ha and $N_3$: 90 kg N/ha in sub- plots. The soil of the experimental site was sandy loam in texture, acidic in reaction, medium in organic carbon, medium in available N, available $P_2O_5$ and low in available $K_2O$. The study revealed that application of irrigation at IW:CPE ratio of 1.4 recorded the highest crude protein yield, highest value in terms of evapotranspiration, total water use, crop water use efficiency, field water use efficiency, gross return, net return and B:Cratio. Application of 90 kg N/ha recorded the highest crude protein yield. The highest values in terms of evapotranspiration, total water use, crop water use efficiency, field water use efficiency, gross return, net return and B:C ratio were observed under 90 kg N/ha.



**Key words:**Irrigation;nitrogen;crop water use efficiency; field water use efficiency; economics.


## 1.INTRODUCTION

Since the times of immemorial, livestock plays an important role in agriculture and it contributed to the growth of national economy through providing milk, meat, wool, various milk products and farm yard manure.Moreover,animal has been considered as the major source of energy for draught power in performing various agricultural operations among farmers in rural India. The success of livestock industry mainly depended upon the availability and supply of nutritious and adequate quantity of good quality green fodder to meet the nutritional requirement for the growth, maintenance and production of live stocks.Annual ryegrass(*Lolium multiflorum*) is an important and promising cereal fodder which grow well under agro-climatic conditions of Assam. The grasses are leafy and produced high quality and digestible fodder. It responds considerably to applied fertilizer and soil water. Jat et al.[1] found that Five irrigations produced significantly higher crude protein, crude fat, mineral matter and total digestible nutrients of fodder oats but there was no significantly differences in crude fibre, nitrogen free extract and total digestible nutrients at first cutting whereas minimum were noted with two irrigations in all the above parameters productions.Tahir et al.[2] found maximum crude fibre (37.35%), crude protein (9.13%) and total ash (14.4%) of oats with six irrigations at 21, 35, 42, 56, 70 and 84 DAS than other treatments. Scheduling irrigation at IW/CPE ratio 0.5 recorded higher WUE in summer (20.7 kg/ha-cm) and *kharif* (17.4 kg/ha-cm) over 0.75 and 1.0 IW/CPE ratio in sandy clay loam soil [3].Irrigation scheduling at IW/CPE ratio 0.6 recorded higher WUE (6.96 kg/ha-mm) of maize over ratios of 0.8 (6.37 kg/ha-mm) and 1.0 (6.33 kg/ha-mm) in sandy soil during rabi season [4]. Irrigations scheduled as per critical growth stages recorded higher WUE (5.86 kg/ha-mm) of maize over 40 mm (3.29 kg/ha-mm), 60 mm (3.86 kg/ha-mm) and 80 mm (4.19 kg/ha-mm) CPE [5]. Irrigation level at 1.1 IW:CPE recorded maximum gross return (Rs. 27100 $ha^{-1}$), net return (Rs. 15014 $ha^{-1}$) and B:C of 1.24 while, minimum gross return (Rs. 19950 $ha^{-1}$), net return (Rs. 8599 $ha^{-1}$) and B:C of 0.79 average of two years data recorded irrigation level at 0.7 IW: CPE [6]. The fertility levels up to 110 kg N $ha^{-1}$ produced significantly higher crude protein, crude fibre, crude fat, mineral matter, nitrogen free extract and total digestible nutrient production of fodder oat over 70 and 90 kg N $ha^{-1}$ whereas crude fibre production did not influence by nitrogen levels at first cutting [1]. Increase in nitrogen level from 0 to 160 kg $ha^{-1}$ decreased the dry matter content, digestibility and cell content whereas the reverse trend was noticed for crude protein content, acid-detergent fibre, neutral detergent fibre and hemicelluloses content of oat [7].Increase in nitrogen levels increased crude protein content but reduced crude fibre content of maize forage [8].With regard to the effect of nitrogen on the percentage of crude protein of teff grass, it was found that increasing the level of nitrogen increased the percentage of crude protein [9]. Application of nitrogen up to 120 kg N $ha^{-1}$ produced significantly higher crude protein yield of fodder oat (9.38 kg $ha^{-1}$) [10]. Jehangir et al. [11] found that increase in fertility level upto 150 kg N $ha^{-1}$ increased crude protein content and crude fibre content of oats. Mahdi et al. [12] reported that increase in N level from 60 to 120 kg/ha significant increase in protein content of maize. Shehzad et al. [13] found that significant increase in crude protein (10.52%), crude fat (2.82%), crude fibre (31.77%) and ash content (10.54%) in maize with application of 180 kg N/ha over other nitrogen levels. Dadarwalet al. [14] reported that increasing dose of fertilizer application increase the net returns and B:C ratio. They found higher net return (Rs. 18,910) and B:C ratio (2.47) with application of 180:60:45 kg NPK/ha.Application of 80 kg N $ha^{-1}$ recorded maximum gross return (Rs. 56232.00 $ha^{-1}$) and net return (Rs. 42853.74 $ha^{-1}$) and B:C of 1:3.20[15].Binadhaniet al. [16] reported application of nitrogen upto 120 kg $ha^{-1}$ significantly give higher net return and B:C ratio.

## 2. MATERIALS AND METHODS

Experiment was conducted during 2017-2018 and 2018-2019 at the Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat. The experiment was laid out in a split-plot design with three replications. The treatments consisted of five levels of irrigation in main plot viz., Rainfed, Irrigation at critical growth stages, Irrigation at IW: CPE ratio of 1.0, Irrigation at IW:CPE ratio of 1.2 and Irrigation at IW:CPE ratio of 1.4 along with four levels of N- 0 kg N/ha, 30 kg N/ha, 60kg N/ha and 90 kg N/ha in sub-plots. Ryegrass variety Makhan grass at the seed rate of 20 kg/ha were dry seeded in the research plots. The nutrients were applied in the form urea, single super phosphate (SSP) and muriate of potash (MOP) as per requirement in the treatment. Nitrogen was applied in three split doses i.e. ½ of N is applied in final ploughing, ¼ at $1^{st}$ cut and remaining ¼ at $2^{nd}$ cut as per the treatment. All the phosphatic and potassic fertilizers were applied at the rate of 188 kg/ha of SSP and 50 kg/ha of MOP, respectively one day ahead of sowing ryegrass. Each sub-plot was provided with a uniform depth of 6 cm irrigation for ryegrass crop according to different IW:CPE ratios.

### Evapotranspiration by crop

The evapotranspiration by crop was computed from the soil moisture data by using the following formula:

$$ET = \sum_{i=1}^{n}(E_0 \times K_c K_p) + \sum_{i=1}^{n}\frac{(M_{1i} - M_{2i})}{100} \times ASG_i \times D_i + ER + GWC$$

Where,

ET= Evapotranspiration (cm)

E0 = Pan evaporation value (cm) from USWB class A pan evaporimeter from the day of irrigation to the day when sampling in wet soil is possible

N = Time interval (days)

M1i = Per cent soil moisture of the ith layer on the date of sampling after irrigation

M2i = Per cent soil moisture of the ith layer on the date of sampling before irrigation

ASGi = Apparent Specific Gravity of ith soil layer

Di = Depth (cm) of the ith layer of the soil

ER= Effective Rainfall during the period under consideration

n= Number of soil layers

Kc= Crop coefficient

GWC= Ground water contribution

**Water use efficiency**

Water use efficiency (WUE) of the crop for different treatments was calculated as follows:

$$\text{Crop WUE (kg/ha-cm)} = \frac{\text{Dry matter yield (kg/ ha)}}{\text{ET of crop (cm)}}$$

$$\text{Field WUE (kg/ha-cm)} = \frac{\text{Dry matter yield (kg/ ha)}}{\text{Total water used (cm)}}$$

## 3. RESULTS AND DISCUSSION

### Crude protein content

The effect of irrigation regimes on crude protein content of ryegrass was found to be non-significant at all three cuts, during both the years(Table 1). The highest crude protein content was found irrigation at IW:CPE ratio of 1.4 and lowest was recorded in rainfed treatment.The effect of nitrogen levels on crude protein content of ryegrass was found to be significant at all three cuts, during both the years (Table 1). The highest crude protein content was recorded with the application of 90 kg N/ha followed by 60 kg N/ha. The lowest crude protein content observed under 0 kg N/ha. Higher application of N resulted in an increased in the crude protein content because there was better assimilation of N resulting on increased protein synthesis.

**Interaction effect**

The interaction effect between irrigation regimes and nitrogen levels was found to be non-significant on crude protein content at different growth stages of ryegrass during both the years.

**Table 1. Effect of irrigation regimes (I) and nitrogen levels (N) on crude protein content of ryegrass**

| Treatments | Crude protein (%) | | | | | |
|---|---|---|---|---|---|---|
| | 1st Year | | | 2nd Year | | |
| | 1st cut | 2nd cut | 3rd cut | 1st cut | 2nd cut | 3rd cut |
| **Irrigation regimes (I)** | | | | | | |
| $I_0$ | 7.61 | 8.24 | 8.13 | 7.60 | 8.27 | 8.14 |
| $I_1$ | 7.82 | 8.38 | 8.27 | 7.84 | 8.43 | 8.32 |
| $I_2$ | 8.12 | 8.87 | 8.78 | 8.10 | 8.89 | 8.86 |
| $I_3$ | 8.38 | 9.12 | 8.98 | 8.35 | 9.17 | 9.10 |
| $I_4$ | 8.54 | 9.23 | 9.16 | 8.62 | 9.25 | 9.17 |
| S.Ed (±) | 0.41 | 0.34 | 0.36 | 0.31 | 0.33 | 0.41 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| **Nitrogen levels (N)** | | | | | | |
| $N_0$ | 7.74 | 8.45 | 8.23 | 7.65 | 8.37 | 8.06 |
| $N_1$ | 7.96 | 8.56 | 8.47 | 7.96 | 8.59 | 8.55 |
| $N_2$ | 8.15 | 8.89 | 8.75 | 8.20 | 8.94 | 8.89 |
| $N_3$ | 8.52 | 9.17 | 9.20 | 8.59 | 9.30 | 9.37 |
| S. Ed (±) | 0.24 | 0.21 | 0.22 | 0.17 | 0.27 | 0.25 |
| CD (P=0.05) | 0.56 | 0.47 | 0.52 | 0.40 | 0.63 | 0.59 |
| **Interaction (I×N)** | | | | | | |
| S.Ed (±) | 0.54 | 0.46 | 0.50 | 0.38 | 0.61 | 0.57 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

N.S: Non-significant



**Crude protein yield**

The effect of irrigation regimes on crude protein yield was found to be significant in ryegrass at 1st cut, 2nd cut and 3rd cut, during both years (Table 2). The application irrigation at IW:CPE ratio of 1.4 recorded the highest crude protein yield (7.69 q/ha and 7.31 q/ha, respectively in both the years) which was significantly higher than other irrigation regimes. The lowest crude protein yield was found under rainfed treatment. The crude protein yield is the function of crude protein content and dry matter yield. The higher dry matter yield was found with application of irrigation at IW:CPE ratio of 1.4. So, the highest crude protein yield were recorded under this treatment. Similar findings were reported by Agrawal et al. [17] and Jat et al. [1] in case of fodder oat.The crude protein yield as influenced by different nitrogen levels was found to be significant in ryegrass at 1st cut, 2nd cut and 3rd cut, during both the years are presented in Table 2. Application of 90 kg N/ha recorded the highest crude protein yield (6.54 q/ha and 6.64 q/ha, respectively in both the years) followed by 60 kg N/ha and lowest was recorded in 0 kg N/ha. Highest dry matter yield was found with application of 90 kg N/ha which ultimately resulted in higher crude protein yield. These results are in conformity with the findings of Gasim [8] and Sarkar et al. [18].

**Table 2. Effect of irrigation regimes (I) and nitrogen levels (N)on crude protein yield (q/ha) of ryegrass**

| Treatments | Crude protein yield (q/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st Year | | | | 2nd Year | | | |
| | 1st cut | 2nd cut | 3rd cut | Total | 1st cut | 2nd cut | 3rd cut | Total |
| **Irrigation regimes (I)** | | | | | | | | |
| $I_0$ | 0.70 | 1.03 | 0.89 | 2.62 | 0.79 | 1.06 | 0.91 | 2.75 |
| $I_1$ | 1.13 | 1.43 | 1.25 | 3.96 | 1.17 | 1.46 | 1.32 | 3.95 |
| $I_2$ | 1.29 | 1.70 | 1.51 | 4.50 | 1.29 | 1.72 | 1.53 | 4.54 |
| $I_3$ | 1.58 | 2.07 | 1.88 | 5.52 | 1.68 | 2.12 | 1.91 | 5.72 |
| $I_4$ | 2.19 | 2.83 | 2.66 | 7.69 | 2.14 | 2.67 | 2.51 | 7.31 |
| S.Ed (±) | 0.17 | 0.094 | 0.18 | 0.62 | 0.095 | 0.16 | 0.15 | 0.35 |
| CD (P=0.05) | 0.39 | 0.22 | 0.42 | 1.44 | 0.22 | 0.37 | 0.35 | 0.81 |
| **Nitrogen levels (N)** | | | | | | | | |
| $N_0$ | 0.68 | 1.09 | 0.95 | 2.83 | 0.79 | 1.05 | 0.92 | 2.76 |
| $N_1$ | 1.35 | 1.74 | 1.53 | 4.62 | 1.34 | 1.74 | 1.51 | 4.59 |
| $N_2$ | 1.56 | 2.02 | 1.86 | 5.44 | 1.58 | 2.00 | 1.84 | 5.43 |
| $N_3$ | 1.92 | 2.41 | 2.22 | 6.54 | 1.94 | 2.43 | 2.27 | 6.64 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| S. Ed (±) | 0.099 | 0.091 | 0.094 | 0.26 | 0.076 | 0.087 | 0.091 | 0.24 |
| CD (P=0.05) | 0.23 | 0.21 | 0.22 | 0.60 | 0.18 | 0.20 | 0.21 | 0.55 |
| **Interaction (I×N)** | | | | | | | | |
| S.Ed (±) | 0.22 | 0.20 | 0.21 | 0.58 | 0.17 | 0.19 | 0.20 | 0.53 |
| CD (P=0.05) | 0.45 | 0.41 | 0.43 | 1.18 | 0.35 | 0.39 | 0.42 | 1.08 |
| CV (%) | 19.61 | 13.67 | 15.69 | 14.58 | 14.80 | 13.13 | 15.30 | 13.36 |

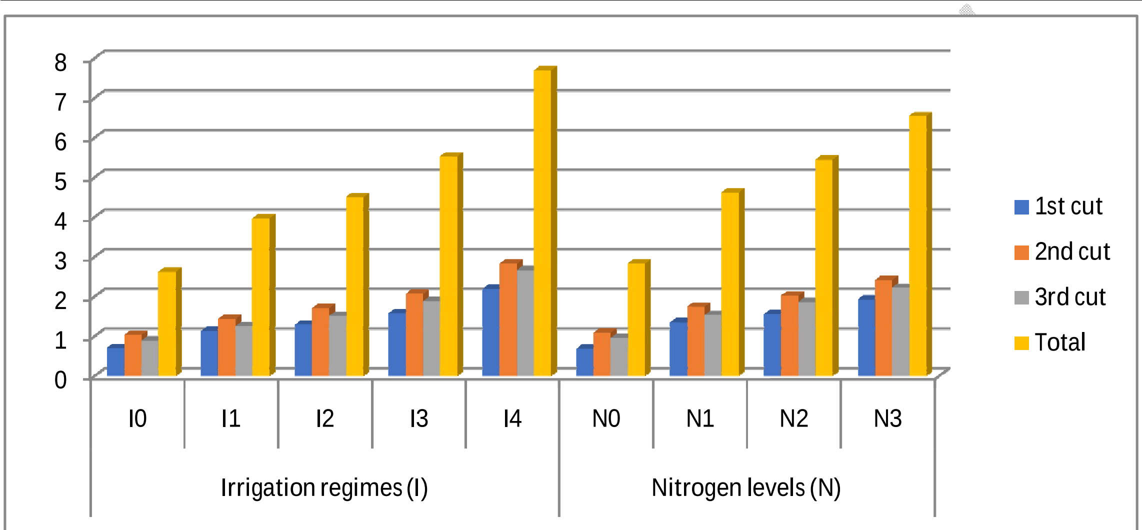


**Fig. 1: Indicating the effect of irrigation regimes and nitrogen levels on crude protein yield (q/ha) of ryegrass (1st year)**

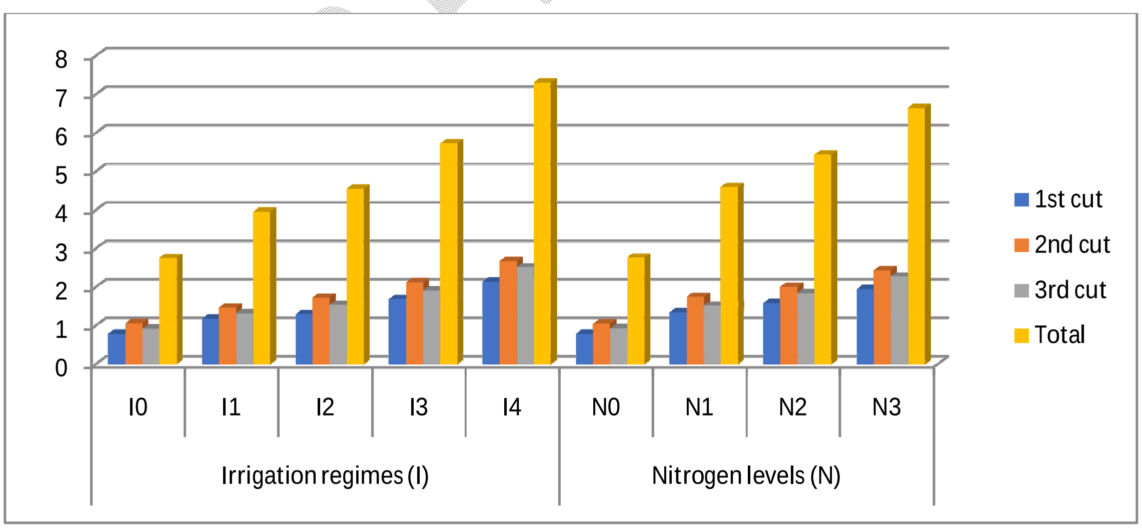


**Fig. 2: Indicating the effect of irrigation regimes and nitrogen levels on crude protein yield (q/ha) of ryegrass (2nd year)**

**Interaction effect**

The interaction effect between irrigation regimes and nitrogen levels was found to be significant in respect of crude protein yield of ryegrass at 1st cut, 2nd cut and 3rd cut during both the years are presented in Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9 and Table 10. The higher crude protein yield was recorded with the application of irrigation at IW:CPE ratio of 1.4 in combination with 90 kg N/ha at 1st cut, 2nd cut and 3rd cut during both the years followed by irrigation at IW:CPE ratio of 1.2 in combination with 60 kg N/ha. Rainfed treatment in combination with 0 kg N/ha recorded the lowest crude protein yield in all three cuts during both the years due to lowest dry matter accumulation in the respective treatments.

**Table 3. Interaction effect of irrigation regimes (I) × nitrogen levels (N) on crude protein yield (q/ha) of ryegrass at 1st cut (1st year)**

| Nitrogen levels (N) | Irrigation regimes (I) | | | | | Mean |
|---|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | |
| $N_O$ | 0.39 | 0.54 | 0.61 | 0.64 | 1.21 | 0.68 |
| $N_1$ | 0.68 | 1.05 | 1.25 | 1.50 | 2.27 | 1.35 |
| $N_2$ | 0.93 | 1.22 | 1.37 | 1.83 | 2.44 | 1.56 |
| $N_3$ | 0.78 | 1.69 | 1.94 | 2.33 | 2.83 | 1.92 |
| **Mean** | 0.70 | 1.13 | 1.29 | 1.58 | 2.19 | 1.38 |
| | | **I** | | **N** | | **I×N** |
| S.Ed (±) | | 0.17 | | 0.099 | | 0.22 |
| CD (P=0.05) | | 0.39 | | 0.23 | | 0.45 |

**Table 4. Interaction effect of irrigation regimes (I) × nitrogen levels (N) on crude protein yield (q/ha) of ryegrass at 2nd cut (1st year)**

| Nitrogen levels (N) | Irrigation regimes (I) | | | | | Mean |
|---|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | |
| $N_O$ | 0.66 | 0.83 | 1.03 | 1.06 | 1.86 | 1.09 |
| $N_1$ | 0.91 | 1.36 | 1.74 | 2.05 | 2.63 | 1.74 |
| $N_2$ | 1.21 | 1.59 | 1.74 | 2.36 | 3.21 | 2.02 |
| $N_3$ | 1.36 | 1.95 | 2.27 | 2.81 | 3.63 | 2.41 |
| **Mean** | 1.03 | 1.43 | 1.70 | 2.07 | 2.83 | 1.81 |
| | | **I** | | **N** | | **I×N** |
| S.Ed (±) | | 0.094 | | 0.091 | | 0.20 |
| CD | | 0.22 | | 0.21 | | 0.41 |

| (P=0.05) | | | | | | |
|---|---|---|---|---|---|---|

**Table 5. Interaction effect of irrigation regimes (I) × nitrogen levels (N) on crude protein yield (q/ha) of ryegrass at 3rd cut (1st year)**

| Nitrogen levels (N) | Irrigation regimes (I) | | | | | Mean |
|---|---|---|---|---|---|---|
| | **$I_0$** | **$I_1$** | **$I_2$** | **$I_3$** | **$I_4$** | |
| **$N_O$** | 0.51 | 0.70 | 0.92 | 0.91 | 1.72 | 0.95 |
| **$N_1$** | 0.78 | 1.25 | 1.39 | 1.82 | 2.40 | 1.53 |
| **$N_2$** | 1.11 | 1.41 | 1.60 | 2.12 | 3.06 | 1.86 |
| **$N_3$** | 1.16 | 1.66 | 2.12 | 2.66 | 3.48 | 2.22 |
| **Mean** | 0.89 | 1.25 | 1.51 | 1.88 | 2.66 | 1.64 |
| | | **I** | | **N** | | **I×N** |
| S.Ed (±) | | 0.18 | | 0.094 | | 0.21 |
| CD (P=0.05) | | 0.42 | | 0.22 | | 0.43 |

**Table 6. Interaction effect of irrigation regimes (I) × nitrogen levels (N) on total crude protein yield (q/ha) of ryegrass (1st year)**

| Nitrogen levels (N) | Irrigation regimes (I) | | | | | Mean |
|---|---|---|---|---|---|---|
| | **$I_0$** | **$I_1$** | **$I_2$** | **$I_3$** | **$I_4$** | |
| **$N_O$** | 1.56 | 2.64 | 2.56 | 2.61 | 4.79 | 2.83 |
| **$N_1$** | 2.37 | 3.65 | 4.38 | 5.38 | 7.30 | 4.62 |
| **$N_2$** | 3.25 | 4.22 | 4.71 | 6.31 | 8.71 | 5.44 |
| **$N_3$** | 3.30 | 5.30 | 6.33 | 7.80 | 9.95 | 6.54 |
| **Mean** | 2.62 | 3.96 | 4.50 | 5.52 | 7.69 | 4.86 |
| | | **I** | | **N** | | **I×N** |
| S.Ed (±) | | 0.62 | | 0.26 | | 0.58 |
| CD (P=0.05) | | 1.44 | | 0.60 | | 1.18 |

**Table 7. Interaction effect of irrigation regimes (I) × nitrogen levels (N) on crude protein yield (q/ha) of ryegrass at 1st cut (2nd year)**

| Nitrogen levels (N) | Irrigation regimes (I) | | | | | Mean |
|---|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | |
| $N_O$ | 0.46 | 0.66 | 0.75 | 0.80 | 1.30 | 0.79 |
| $N_1$ | 0.69 | 1.07 | 1.29 | 1.58 | 2.10 | 1.34 |
| $N_2$ | 0.94 | 1.32 | 1.38 | 1.97 | 2.31 | 1.58 |
| $N_3$ | 1.06 | 1.64 | 1.74 | 2.38 | 2.85 | 1.94 |
| **Mean** | 0.79 | 1.17 | 1.29 | 1.68 | 2.14 | 1.41 |
| | | **I** | | **N** | | **I×N** |
| S.Ed (±) | | 0.095 | | 0.076 | | 0.17 |
| CD (P=0.05) | | 0.22 | | 0.18 | | 0.35 |

**Table 8. Interaction effect of irrigation regimes (I) × nitrogen levels (N) on crude protein yield (q/ha) of ryegrass at 2nd cut (2nd year)**

| Nitrogen levels (N) | Irrigation regimes (I) | | | | | Mean |
|---|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | |
| $N_O$ | 0.68 | 0.85 | 0.99 | 1.08 | 1.63 | 1.05 |
| $N_1$ | 0.95 | 1.43 | 1.71 | 2.08 | 2.53 | 1.74 |
| $N_2$ | 1.23 | 1.60 | 1.82 | 2.39 | 2.99 | 2.00 |
| $N_3$ | 1.36 | 1.96 | 2.38 | 2.94 | 3.51 | 2.43 |
| **Mean** | 1.06 | 1.46 | 1.72 | 2.12 | 2.67 | 1.81 |
| | | **I** | | **N** | | **I×N** |
| S.Ed (±) | | 0.16 | | 0.087 | | 0.19 |
| CD (P=0.05) | | 0.37 | | 0.20 | | 0.39 |

**Table 9. Interaction effect of irrigation regimes (I) × nitrogen levels (N) on crude protein yield (q/ha) of ryegrass at 3rd cut (2nd year)**

| Nitrogen levels (N) | Irrigation regimes (I) | | | | | Mean |
|---|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | |
| $N_O$ | 0.51 | 0.73 | 0.95 | 0.95 | 1.47 | 0.92 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **$N_1$** | 0.78 | 1.30 | 1.39 | 1.83 | 2.23 | 1.51 |
| **$N_2$** | 1.12 | 1.45 | 1.64 | 2.17 | 2.84 | 1.84 |
| **$N_3$** | 1.21 | 1.81 | 2.14 | 2.70 | 3.49 | 2.27 |
| **Mean** | 0.91 | 1.32 | 1.53 | 1.91 | 2.51 | 1.64 |
| | | **I** | | **N** | | **I×N** |
| S.Ed (±) | | 0.15 | | 0.091 | | 0.20 |
| CD (P=0.05) | | 0.35 | | 0.21 | | 0.42 |

**Table 10. Interaction effect of irrigation regimes (I) × nitrogen levels (N) on total crude protein yield (q/ha) of ryegrass (2nd year)**

| **Nitrogen levels (N)** | **Irrigation regimes (I)** | | | | | **Mean** |
|---|---|---|---|---|---|---|
| | **$I_0$** | **$I_1$** | **$I_2$** | **$I_3$** | **$I_4$** | |
| **$N_O$** | 1.65 | 2.23 | 2.69 | 2.83 | 4.40 | 2.76 |
| **$N_1$** | 2.42 | 3.81 | 4.38 | 5.49 | 6.85 | 4.59 |
| **$N_2$** | 3.29 | 4.37 | 4.83 | 6.53 | 8.14 | 5.43 |
| **$N_3$** | 3.64 | 5.41 | 6.26 | 8.02 | 9.86 | 6.64 |
| **Mean** | 2.75 | 3.95 | 4.54 | 5.72 | 7.31 | 4.86 |
| | | **I** | | **N** | | **I×N** |
| S.Ed (±) | | 0.35 | | 0.24 | | 0.53 |
| CD (P=0.05) | | 0.81 | | 0.55 | | 1.08 |

**Evapotranspiration, Water use and water use efficiency**

Data on evapotranspiration, total water use, crop water use efficiency and field water use efficiency as influenced by different irrigation regimes are presented in Table 11. Increasing levels of irrigation regime increased the evapotranspiration and total water use. Application of irrigation at IW:CPE ratio of 1.4 recorded the highest value in terms of evapotranspiration (26.33 cm and 24.74 cm, respectively in both the years), total water use (26.65 cm and 25.16 cm, respectively in both the years), crop water use efficiency (324.49 kg/ha-cm and 324.12 kg/ha-cm, respectively in both the years) and field water use efficiency (322.69 kg/ha-cm and 318.84 kg/ha-cm, respectively in both the years) followed by irrigation at IW:CPE ratio of

1.2 and lowest values were recorded in rainfed treatment. The evapotranspiration and total water use increased with increasing level of irrigation regimes due to more numbers of irrigation applied which facilitated higher availability water in the soil profile leading to more loss of water through evapotranspiration. The crop and field water use efficiency also increased under IW:CPE ratio of 1.4 because of higher yield. Data pertaining to the evapotranspiration, total water use, crop water use efficiency and field water use efficiency as influenced by different nitrogen levels are presented in Table 11. The highest values in terms of evapotranspiration (21.16 cm and 18.89 cm, respectively in both the years), total water use (21.16 cm and 19.05 cm, respectively in both the years), crop water use efficiency (343.19 kg/ha-cm and 376.87 kg/ha-cm, respectively in both the years) and field water use efficiency (344.33 kg/ha-cm and 372.88 kg/ha-cm, respectively in both the years) were observed under 90 kg N/ha. The higher evapotranspiration and total water use observed due to higher crop growth rate and yield of the crop which exhibited more extraction of soil moisture. Higher crop and field water use efficiency recorded because higher yield in the respective treatments in both the years.

**Table 11. Effect of irrigation regimes (I) and nitrogen levels (N) on water use and water use efficiency of ryegrass**

| Treatments | 1st year | | | | 2nd year | | | |
|---|---|---|---|---|---|---|---|---|
| | Evapotranspiratin (cm) | Total water use (cm) | Crop water use efficiency(kg/ha-cm) | Field water use efficiency (kg/ha-cm) | Evapotranspiratin (cm) | Total water use (cm) | Crop water use efficiency(kg/ha-cm) | Field water use efficiency (kg/ha-cm) |
| **Irrigation levels (I)** | | | | | | | | |
| $I_0$ | 14.12 | 14.12 | 234.69 | 234.69 | 12.32 | 12.32 | 277.18 | 277.18 |
| $I_1$ | 17.15 | 17.24 | 271.03 | 270.84 | 15.46 | 16.12 | 309.76 | 299.40 |
| $I_2$ | 21.13 | 22.31 | 245.90 | 234.54 | 18.61 | 18.72 | 278.96 | 277.79 |
| $I_3$ | 23.43 | 24.81 | 260.40 | 253.08 | 20.17 | 20.64 | 317.33 | 310.64 |
| $I_4$ | 26.33 | 26.65 | 324.49 | 322.69 | 24.74 | 25.16 | 324.12 | 318.84 |
| **Nitrogen levels (N)** | | | | | | | | |
| $N_0$ | 18.96 | 20.54 | 173.68 | 160.37 | 18.12 | 18.42 | 189.65 | 186.02 |
| $N_1$ | 20.21 | 21.08 | 266.03 | 258.72 | 17.65 | 18.15 | 302.55 | 294.82 |
| $N_2$ | 21.40 | 21.33 | 286.31 | 289.24 | 18.37 | 18.76 | 336.79 | 333.35 |
| $N_3$ | 21.16 | 21.16 | 343.19 | 344.33 | 18.89 | 19.05 | 376.87 | 372.88 |

**Economics of cultivation of ryegrass**

Data presented in Table 12 indicated that in spite of increase in cost of cultivation, the gross return, net return and B:C ratio increased with the increasing irrigation regime from IW:CPE ratio of 1.0 to IW:CPE ratio of 1.4. The highest gross return (Rs. 78073.00 and Rs. 78254.00, respectively in both the years), net return (Rs. 51252.00 and Rs. 52433.00, respectively in both the years) and B:Cratio (1.87 and 1.99 respectively, in both the years) was obtained in Irrigation at IW:CPE ratio of 1.4 and followed by Irrigation at IW:CPE ratio of 1.2 in terms of gross return, net return and B:C ratio. The lowest gross return, net return and B:C ratio was observed under rainfed treatment in both the years. The highest cost of cultivation in irrigation at IW:CPE ratio of 1.4 due to higher cost of irrigation but increase yield led to higher gross return, net return and B: C ratio in both the years. Data presented in Table 12 showed that the higher gross return, net return and B:C ratio was obtained in 90 kg N/ha treatment over the other nitrogen levels. The cost of cultivation of ryegrass was observed to be comparatively higher with application of 90 kg N/ha. Yet, the higher gross return (Rs. 72376.00 and Rs. 70383.00, respectively in both the years), net return (Rs. 45038.00 and Rs. 43645.00, respectively in both the years) and B:C ratio (1.63 and 1.62 respectively in both the years) was obtained in 90 kg N/ha treatment followed by 60 kg N/ha. The highest cost of cultivation recorded with application of 90 kg N/ha because higher amount of fertilizer used compared to other nitrogen levels but higher gross return, net return and B:C ratio were obtained due to higher yield.

**Table 12. Economics of ryegrass as affected by irrigation regimes (I) and nitrogen levels (N)**

| Treatments | 2017-18 | | | | 2018-19 | | | |
|---|---|---|---|---|---|---|---|---|
| | **Cost (Rs.)** | **Gross return (Rs.)** | **Net return (Rs.)** | **B:C ratio** | **Cost (Rs.)** | **Gross return (Rs.)** | **Net return (Rs)** | **B:C ratio** |
| **Irrigation regimes (I)** | | | | | | | | |
| $I_0$ | 24321 | 36195 | 12275 | 0.48 | 24321 | 36267 | 12386 | 0.49 |
| $I_1$ | 25321 | 48022 | 23516 | 0.90 | 25071 | 49711 | 24640 | 0.96 |
| $I_2$ | 25821 | 53384 | 27146 | 1.02 | 25321 | 52224 | 26903 | 1.04 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $I_3$ | 25821 | 63244 | 37418 | 1.41 | 25321 | 63659 | 38338 | 1.48 |
| $I_4$ | 26821 | 78073 | 51252 | 1.87 | 25821 | 78254 | 52433 | 1.99 |
| **Nitrogen levels (N)** | | | | | | | | |
| $N_0$ | 22420 | 32505 | 11058 | 0.48 | 22020 | 34824 | 13156 | 0.59 |
| $N_1$ | 26038 | 55586 | 29215 | 1.11 | 25638 | 56023 | 30385 | 1.17 |
| $N_2$ | 26688 | 62667 | 35975 | 1.33 | 26288 | 62862 | 36574 | 1.38 |
| $N_3$ | 27338 | 72376 | 45038 | 1.63 | 26738 | 70383 | 43645 | 1.62 |

## 4. CONCLUSION

Itwas concluded thatapplication of irrigation at IW:CPE ratio of 1.4 recorded the significantly higher crude protein yield as compared to other irrigation treatments. The highest value in terms of evapotranspiration, total water use, crop water uses efficiency and field water use efficiency recorded under this treatment. The highest gross return, net return and B:C ratio obtained in irrigation at IW:CPE ratio of 1.4 over the rest of the treatments. The crude protein content of ryegrass was significantly influenced by different nitrogen levels. The highest values of crude protein content were observed under 90 kg N/ha. Application of 90 kg N/ha recorded significantly higher crude protein yield over rest of the treatments. The higher values in terms of evapotranspiration, total water use, crop water use efficiency and field water use efficiency observed with application of 90 kg N/ha. Economic analysis showed that the higher gross return, net return and B:C ratio were recorded in 90 kg N/ha. Among the different treatment combination of irrigation regimes and nitrogen levels, the highest crude protein yield was recorded with application of irrigation at IW:CPE ratio of 1.4 in combination with 90 kg N/ha.

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