

## EFFECT OF SOIL MOISTURE LEVEL AND NUTRIENT MANAGEMENT ON YIELD, BIO-CHEMICAL PROPERTIES AND WATER PRODUCTIVITY OF BLACK CUMIN

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### Abstract

A field experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur farm during *rabi* season of 2017-2018 to evaluate the effects of soil moisture levels and nutrient management on yield, bio-chemical properties and water productivity of black cumin (cv. BARI Kalozira-1) in the Shallow Red-Brown Terrace Soil of Salna series under AEZ-28 (Madhupur Tract). The experiment was set up in a Randomized Complete Block Design (factorial) with three replications comprising 9 treatment combinations having 3 soil moisture levels (Irrigation at 10%, 20% and 30% depletion of soil available water at field capacity) and 3 nutrient management packages: 100% RDF (80-45-50-20-5-2 kg ha<sup>-1</sup> of N-P-K-S-Zn-B), 75% RDF + 25% N from cowdung and 50% RDF + 50% N from cowdung. The highest seed yield (1027 kg ha<sup>-1</sup>), biomass yield (2303 kg ha<sup>-1</sup>), thymoquinone (3286 mg kg<sup>-1</sup> seed), thymol (149 mg kg<sup>-1</sup> seed), fixed oil (28.7%), essential oil (0.85%), total consumptive use of water (112 mm) and water productivity (20.5 & 9.14 kg ha<sup>-1</sup> mm<sup>-1</sup>, on the basis of biomass & seed yield, respectively) were obtained from irrigation at 10% depletion of available water along with 75% RDF + 1.98 t ha<sup>-1</sup> cowdung. The application of irrigation water at 10% depletion of available water (112.22 mm) with N, P, K, S, Zn and B @ 60, 45, 50, 20, 5 and 2 kg ha<sup>-1</sup>, respectively + 1.98 t ha<sup>-1</sup> cowdung (for supplementing 25% N requirement) appeared to be the best suited treatment package for black cumin cultivation in the study area.

Keywords: Cowdung, Seed yield, Spice crop, Black cumin, Oil content, Water productivity

### Introduction

Black cumin (*Nazilla sativa* L.) of the family Ranunculaceae originated in Mediterranean region, is a short-lived annual herb, and is cultivated commercially in many Sub-tropical countries. Its seeds, whole plant and oils are used as medicine, spices, condiments and many culinary purposes since ancient times (Ali *et al.*, 2015 and Herlina *et al.*, 2017). In Bangladesh, it covers 1007 ha area with

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annual production of 1068 tons showing  $1.06 \text{ t ha}^{-1}$  (BBS, 2022). The utilization of black cumin is increasing with advancement of time, but the production is constrained due to lack of high yield potential varieties (only one variety BARI has so far developed *i.e.*, BARI Kalozira-1) and efficient soil and crop management (Bhutia *et al.*, 2015; Kara *et al.*, 2015). Both water and nutrient management among others are the major factors for normal growth and development of plants, economical yield and soil health. The plant can be grown under water stress condition, but higher yields are obviously associated with an appropriate irrigation frequency from growth to seed formation stage (Bhanwaria *et al.*, 2022). Soil fertility is a function of nutrient availability indices and its management should follow 4R concept (right source, right rate, right time and right method of fertilizer application).

Black cumin due to its shallow root system often responds to added fertilizers. Thus, black cumin crops when soil moisture and nutrient availability are limited, might suffer from water stress and nutrient deficiencies and consequently produce reduced yields (Ghamarnia *et al.*, 2014; Ali *et al.*, 2015; Kara *et al.*, 2015; Bayati *et al.*, 2022). Hence, the objective of the present study was to assess yield, oil content, medicinal value and water productivity of black cumin under varying levels of soil moisture and integrated nutrient management approaches.

### Materials and Methods

The field experiment was carried out at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during *rabi* season of 2017-18. The geographic coordinates of the experimental location are  $24^{\circ}09'$  North Latitude and  $90^{\circ}26'$  East Longitude with an elevation of 8.2 m from mean sea level. A brief description of basic soil properties and irrigation of the experimental field is presented in Table 1. The experiment was set up in a factorial randomized complete block design with three replications having Factor A: three soil moisture levels ( $I_1$  = Irrigation at 10% depletion of available water,  $I_2$  = Irrigation at 20% depletion of available water and  $I_3$  = Irrigation at 30% depletion of available water) and Factor B: three nutrient management packages ( $T_1$  = 100% Recommended dose of fertilizers (RDF),  $T_2$  = 75% RDF + 25% N from cowdung ( $1.98 \text{ t ha}^{-1}$ ) and  $T_3$  = 50% RDF + 50% N from cowdung at  $3.96 \text{ t ha}^{-1}$ ). The 100% rates of N, P, K, S, Zn and B @ 80, 45, 50, 20, 5 and  $2 \text{ kg ha}^{-1}$ , respectively was selected on soil the basis. The whole amount (as per treatment) of cowdung, TSP, MoP, gypsum, zinc sulphate and boric acid was applied as basal and the urea was applied in three equal splits at 5<sup>th</sup>, 9<sup>th</sup> and 11<sup>th</sup> week after sowing. The cowdung contained 0.99% N, 0.19% P, 0.49% K, 0.11% S, 0.39% Ca and 0.20% Mg on dry weight basis. The seeds of black cumin cv. BARI Kalozira-1 were sown on 12 November 2017 in  $3.0 \text{ m} \times 3.0 \text{ m}$  plot at a row-to-row distance of 15 cm. Before sowing, the seeds were soaked in water for 24 hours to facilitate germination, and then the seeds were dried under shade. Subsequently, the seeds were treated with

Autostin (carbendazim) @ 2g kg<sup>-1</sup> seeds to get rid of primary seed-borne diseases. The treated seeds were mixed with some loose soil to allow uniform sowing in rows @ 10 kg ha<sup>-1</sup> at a depth of about 1 cm. Seeds thus sown were covered immediately with loose soil followed by light irrigation to facilitate normal germination. Thinning was done at 25 DAS and also at 40 DAS, maintaining plant to plant distance at 10 cm. Light irrigation (6 mm) was done immediate after every thinning. Three times hand weeding were done for the control of weed infestation while Autostin @ 2 g l<sup>-1</sup> of water was sprayed thrice to control damping off disease during the entire cropping period. The crops were harvested on 15 March 2018 early morning to avoid shattering of seeds, when 50 - 60% of the capsules turned into straw color from green. Ten plants were selected randomly from each plot to estimate yield and yield contributing parameters of black cumin. The seed yield per plot was recorded from 1m<sup>2</sup> area and then converted to yield per hectare. The harvested plants were sun dried for four days and threshing was done by beating with a stick. The seeds were winnowed and cleaned for recording yield and yield related data.

### **Determination of irrigation water requirement**

#### **Field capacity**

Soil moisture at field capacity (FC) was determined by selecting a representative plot of 2 m x 2 m surrounded by dikes of 15 cm height. Weeds were removed to avoid transpiration loss of water from the plot. Water was applied into the plot to keep it ponded to a height of 10-12 cm above the soil surface for more than 24 hours to ensure soil saturation up to at least 30 cm depth of the soil profile. After complete depletion of ponded water, the plot was covered by polyethylene sheet to restrict evaporation loss of water and soil samples were collected by sampling auger at different depths of 0-10, 10-20 and 20-30 cm to determine gravimetric soil moisture for a period of 3 days after depletion of ponded surface water in the macro-pores through downward movement by gravitational force, which was allowed to continue for 3 days. The soil moisture at this period decreases every day. When the gravitational water is percolate completely, the soil moisture values remained more or less constant for few days signifying the maximum moisture the soil can hold against the gravitational force which is considered as the soil moisture at FC.

**Available water** was determined by using the following equation:

$$AW = FC - WP$$

Where,

AW = Available soil moisture percentage (by weight basis)

FC = Soil moisture percentage at field capacity (by weight basis)

WP = Soil moisture percentage at wilting point (by weight basis)

(It is assumed that soil moisture at wilting point might be soil moisture at half of field capacity level)

**Irrigation requirement** was determined by using the following equation (Michael, 1978):

$$IR = \{(M_{FC} - M_{PI}) / 100\} \times \rho_b \times D$$

Where,

IR = Irrigation requirement (cm)

$M_{FC}$  = Soil moisture percentage at field capacity (weight basis)

$M_{PI}$  = Soil moisture percentage in field prior to irrigation (weight basis)

$\rho_b$  = Bulk density ( $\text{g cm}^{-3}$ )

D = Rooting depth (cm)

**Total consumptive use of water** (Michael, 1978) was calculated by using the following equation:

$$W_c = I_w + S_w + P_e$$

Where,

$W_c$  = Total consumptive use of water (mm)

$I_w$  = Total amount of irrigation water applied (mm)

$S_w$  = Soil moisture contribution (mm)

$P_e$  = Effective rainfall (mm)

**Soil moisture contribution** (Michael, 1978) was determined by using the following equation:

$$S_w = (M_S - M_H) / 100 \times \rho_b \times D$$

Where,

$M_S$  = Soil moisture percentage at sowing (weight basis)

$M_H$  = Soil moisture percentage at harvest (weight basis)

$\rho_b$  = Bulk density ( $\text{g cm}^{-3}$ )

D = Rooting depth (cm)

**Effective rainfall ( $P_e$ )** was calculated by the using equation:

$$P_e = 0.8P - 25 \text{ if } P > 75 \text{ mm month}^{-1}$$

$$P_e = 0.6P - 10 \text{ if } P < 75 \text{ mm month}^{-1}$$

Where,

$P_e$  = Effective rainfall (mm)

P = Rainfall (mm)

**Water productivity (WP)** was estimated by following formula:

$$\text{WP} = \frac{\text{Total dry biomass or seed yield (kg ha}^{-1}\text{)}}{\text{total consumptive use of water (mm)}}$$

**Table 1. Physical and chemical properties of initial soil of the experimental field**

| Soil characteristics                          | Analytical value        | Analytical method                              | Reference                   |
|---|-------------------------|--|-----------------------------|
| Textual class                                 | Silty clay loam         | Hydrometer method                              | Bouyoucos, 1962             |
| Bulk density                                  | 1.40 g cm <sup>-3</sup> | Core sampling method                           | Blake, 1965a                |
| Particle density                              | 2.68 g cm <sup>-3</sup> | Pycnometer method                              | Blake, 1965b                |
| Field capacity (% by weight)                  | 29.5                    | Gravimetric method                             | Grewal <i>et al.</i> , 1990 |
| Soil pH                                       | 5.91                    | Soil: water=1:2.5                              | Jackson, 1962               |
| Organic C (%)                                 | 0.89                    | Wet oxidation method                           | Walkley and Black, 1934     |
| Total N (%)                                   | 0.09                    | Micro Kjeldhal method                          | Black, 1965                 |
| Available P (ppm)                             | 7.31                    | Bray and Kurtz method                          | Bray and Kurtz, 1945        |
| Exchangeable K (meq 100g <sup>-1</sup> soil)  | 0.08                    | N NH <sub>4</sub> OAc extraction method        | Jackson, 1962               |
| Available B (ppm)                             | 0.21                    | Calcium chloride extraction method             | Christian and Feldman, 1970 |
| Exchangeable Ca (meq 100g <sup>-1</sup> soil) | 2.60                    | N NH <sub>4</sub> OAc extraction method        | Thomas, 1982                |
| Exchangeable Mg (meq 100g <sup>-1</sup> soil) | 2.69                    | N NH <sub>4</sub> OAc extraction method        | Thomas, 1982                |
| CEC (meq 100g <sup>-1</sup> soil)             | 8.44                    | N NH <sub>4</sub> OAc extraction method        | Schollenberger, 1980        |
| Available Zn (ppm)                            | 0.61                    | DTPA Extraction method                         | Christian and Feldman, 1970 |
| Available Cu (ppm)                            | 0.13                    | DTPA Extraction method                         | Christian and Feldman, 1970 |
| Available Mn (ppm)                            | 0.73                    | DTPA Extraction method                         | Christian and Feldman, 1970 |
| Available S (ppm)                             | 8.1                     | Calcium dihydrogen phosphate extraction method | Hesse, 1971                 |

## **Extraction and analysis of essential & fixed oils**

### **Essential oil**

Essential oils are basically composed of C, H, O and occasionally N, S and other minerals and vitamins. In order to determine the seed essential oil content, 100 g powdered seed samples in 0.5 L water from each population were extracted by hydro-distillation for 3 hours using Clevenger apparatus following a standard procedure described in European Pharmacopoeia for determining the oil content (v/w, %) (Stainier, 1975).

### **Fixed oil**

Fixed oil characterized by that it is not evaporated and volatile, also not distilled without its hydrolysis, not dissolved in water but dissolved in organic solvents and it does not have strong volatile odor. For determination of fixed oil content (%), about 4 g dry and powdered seed samples from each treatment were extracted with n-hexan for 6 hours by Soxhlet apparatus (Buchi Universal Extraction System B-811, Germany) (Allen *et al.*, 1974).

### **Measurement of thymoquinone and thymol content**

Thymoquinone and thymol in black cummin fixed oil sample of black cummin was estimated following the method as outlined by Al-Saleh *et al.* (2006). An amount of 0.1g ground seed sample was extracted with 1 ml methanol, vortexed for 1 minute and sonicated for 20 minutes. After that it was left over night in constant Rota mix, vortexed for 1 minute and centrifuged for 25 minutes at 1400 rpm. The supernatant was aspirated and aliquot of 20  $\mu\text{L}$  was injected into high-performance liquid chromatography (HPLC) with UV detector at a wavelength of 275 nm. The mobile phase used was methanol: water (75: 25) at 1.0 ml  $\text{ml}^{-1}$  flow rate. Calibration curves of peak area versus the concentration 20, 40, 80 and 160  $\mu\text{g ml}^{-1}$  for thymoquinone and 2, 4, 8 and 16  $\mu\text{g ml}^{-1}$  for thymol were constructed.

### **Statistical Analysis**

The recorded data on different parameters were statistically analyzed by using *R* version 3.5.0 software to find out the significance of variation resulting from the experimental treatments. The difference between treatment means were judged by Least Significant Difference (LSD) test at 5% level of significance.

### **Results and Discussion**

The combined effects of soil moisture levels and nutrient management on some selected plant parameters of black cummin were significant (Table 2) showing that treatment  $I_1T_2$  (irrigation at 10% depletion of available water with application of 75% RDF + 25% N from cowdung) recorded the maximum plant height (63.7 cm), period of flower initiation (65.0 days), period of capsule setting (76.3 days), and number of capsules per plant (42.3) (Table 5). Such values were minimum with

treatment I<sub>3</sub>T<sub>3</sub> (allowing 30% depletion of available water along with 50% RDF + 50% N from cowdung). The slow decomposition of cowdung and subsequent release of nutrients during winter could be a reason for lesser effect of cowdung on the crop growth in terms of leaf primordial, plant growth and capsule formation. The results are in agreement with the results of Ali and Hasan (2014) and Karim *et al.* (2017).

**Table 2. Combined effects of soil moisture levels and nutrient management on growth components of black cumin**

| Treatment                     | Plant height (cm) | Days to flower initiation | Days to capsule setting | No. of branch per plant | No. of capsules per plant |
|-------------------------------|-------------------|---------------------------|-------------------------|-------------------------|---------------------------|
| I <sub>1</sub> T <sub>1</sub> | 60.0ab            | 63.7b                     | 74.7ab                  | 6.7b                    | 34.3c                     |
| I <sub>1</sub> T <sub>2</sub> | 63.7a             | 65.0a                     | 76.3a                   | 8.0a                    | 42.3a                     |
| I <sub>1</sub> T <sub>3</sub> | 58.0b             | 63.0b                     | 71.3c                   | 5.7c                    | 29.7d                     |
| I <sub>2</sub> T <sub>1</sub> | 56.7b             | 60.3cd                    | 70.7c                   | 6.7b                    | 39.0b                     |
| I <sub>2</sub> T <sub>2</sub> | 60.0ab            | 61.3c                     | 72.3bc                  | 7.6a                    | 41.0ab                    |
| I <sub>2</sub> T <sub>3</sub> | 55.0b             | 59.3de                    | 71.7c                   | 5.0cd                   | 25.0e                     |
| I <sub>3</sub> T <sub>1</sub> | 45.0c             | 59.3de                    | 71.0c                   | 4.3d                    | 13.7g                     |
| I <sub>3</sub> T <sub>2</sub> | 42.7c             | 59.0de                    | 72.0c                   | 4.3d                    | 17.0f                     |
| I <sub>3</sub> T <sub>3</sub> | 35.7d             | 57.3f                     | 70.3c                   | 2.7e                    | 13.7g                     |
| CV (%)                        | 5.68              | 1.12                      | 1.93                    | 9.30                    | 6.62                      |
| LSD (0.05)                    | 5.21              | 1.18                      | 2.41                    | 0.91                    | 3.26                      |

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD test.

**Legend:**

I<sub>1</sub> = Irrigation at 10% depletion of available water

I<sub>2</sub> = Irrigation at 20% depletion of available water and

I<sub>3</sub> = Irrigation at 30% depletion of available water

T<sub>1</sub> = 100% Recommended dose of fertilizers, RDF (80-45-50-20-5-2 kg ha<sup>-1</sup> of N-P-K-S-Zn-B)

T<sub>2</sub> = 75% RDF + 25% N from cowdung (1.98 t ha<sup>-1</sup>) and

T<sub>3</sub> = 50% RDF + 50% N from cowdung at 3.96 t ha<sup>-1</sup>

Nutrients used for plant growth, development and yield generally come from the internal cycling of reserve and supplied nutrient materials which require water for their solubilization and translocation. Decreasing in soil moisture availability affects the rate of diffusion of many plants nutrients and finally the composition and then total crop morphology. Capsule size (indicted by the length and diameter), number of seed per capsule, 1000-seed weight, seed yield and biomass yield of black cumin were significantly influenced due to interaction effect of soil moisture

levels and nutrient management treatments (Table 3). Similar to the results of above stated parameters the maximum capsule size (length 0.88 cm and diameter 0.64 cm), number of seeds per capsule (130.7), 1000-seed weight (2.82 g), seed yield (1026.7 kg ha<sup>-1</sup>) and biomass yield (2303 kg ha<sup>-1</sup>) were recorded with the same treatment I<sub>1</sub>T<sub>2</sub> and the minimum capsule size (length 0.38 cm and diameter 0.21 cm), number of seeds per capsule (52.0), 1000-seed weight (1.30 g), seed yield (391.7 kg ha<sup>-1</sup>) and biomass yield (1195 kg ha<sup>-1</sup>) were recorded in treatment I<sub>3</sub>T<sub>3</sub>. In case of seed yield, no significant difference was observed with the highest soil moisture regime along with application of recommended dose fertilizers of which 25% of N being replaced by cowdung I<sub>1</sub>T<sub>1</sub> (956.7 kg ha<sup>-1</sup>) (Table 3). So, it may be recommended that I<sub>1</sub>T<sub>2</sub> treatment for black cumin cultivation due to subsidized urea use is reduced on one hand and possible beneficial effect of cowdung on soil and future crop. Supplemental irrigation along with presence of optimum nutrients might have resulted in retention of soil moisture and availability of nutrients to a desired level which leads to higher transpiration and translocation of nutrients that ultimately favored the growth and development of the crops. The research findings of Karim *et al.* (2017), Shahattary & Mansourifar (2017) and Bayati *et al.* (2022) are in agreement with the results of present study.

**Table 3. Combined effects of soil moisture levels and nutrient management on yield and yield components of black cumin**

| Treatment                     | Capsule length (cm) | Capsule diameter (cm) | No. of seeds per capsule | 1000-seed weight (g) | Seed yield (kg ha <sup>-1</sup> ) | Biomass yield (kg ha <sup>-1</sup> ) |
|-------------------------------|---------------------|-----------------------|--------------------------|----------------------|-----------------------------------|--------------------------------------|
| I <sub>1</sub> T <sub>1</sub> | 0.82a               | 0.55ab                | 118.0b                   | 2.64b                | 956.7a                            | 2175b                                |
| I <sub>1</sub> T <sub>2</sub> | 0.88a               | 0.64a                 | 130.7a                   | 2.82a                | 1026.7a                           | 2303a                                |
| I <sub>1</sub> T <sub>3</sub> | 0.66b               | 0.49ab                | 90.0c                    | 2.10e                | 790.0b                            | 2001c                                |
| I <sub>2</sub> T <sub>1</sub> | 0.68b               | 0.47ab                | 96.7c                    | 2.18d                | 603.3c                            | 1710d                                |
| I <sub>2</sub> T <sub>2</sub> | 0.71b               | 0.54ab                | 122.7ab                  | 2.50c                | 773.3b                            | 1993c                                |
| I <sub>2</sub> T <sub>3</sub> | 0.59c               | 0.40bc                | 80.7d                    | 1.84f                | 586.7c                            | 1598e                                |
| I <sub>3</sub> T <sub>1</sub> | 0.47d               | 0.24c                 | 56.3f                    | 1.36h                | 496.7d                            | 1455f                                |
| I <sub>3</sub> T <sub>2</sub> | 0.52d               | 0.50ab                | 70.0e                    | 1.47g                | 443.3de                           | 1310g                                |
| I <sub>3</sub> T <sub>3</sub> | 0.38e               | 0.21c                 | 52.0f                    | 1.30i                | 391.7e                            | 1195h                                |
| CV (%)                        | 5.69                | 26.44                 | 5.6                      | 1.30                 | 6.35                              | 7.25                                 |
| LSD (0.05)                    | 0.06                | 0.21                  | 8.79                     | 0.05                 | 74.15                             | 0.12                                 |

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD test.

**Legend:**

- I<sub>1</sub> = Irrigation at 10% depletion of available water
- I<sub>2</sub> = Irrigation at 20% depletion of available water and
- I<sub>3</sub> = Irrigation at 30% depletion of available water



T<sub>1</sub> = 100% Recommended dose of fertilizers, RDF (80-45-50-20-5-2 kg ha<sup>-1</sup> of N-P-K-S-Zn-B)

T<sub>2</sub> = 75% RDF + 25% N from cowdung (1.98 t ha<sup>-1</sup>) and

T<sub>3</sub> = 50% RDF + 50% N from cowdung at 3.96 t ha<sup>-1</sup>

### Bio-chemical parameters

The combined effects of soil moisture levels and nutrient management on the thymoquinone, thymol, fixed oil and essential oil content of black cumin was significant (Table 4). Where the highest thymoquinone (3286 mg kg<sup>-1</sup> seed), thymol (149 mg kg<sup>-1</sup> seed), fixed oil (28.7%) and essential oil (0.85%) contents were recorded in treatment I<sub>1</sub>T<sub>2</sub> (Irrigation at 10% depletion of available water and nutrients applied at 75% RDCF + 25% N from cowdung), the lowest values were being noted in treatment I<sub>3</sub>T<sub>3</sub> (Table 4). Optimum soil moisture levels and nutrients availability might have influenced morpho-physiological features of plants and increased the seed yields and oil contents of black cumin. Similar results were documented by (Safaei *et al.*, 2014 and Ghamarnia *et al.*, 2014; Sen, 2016; Ariafar and Forouzadeh, 2017; Shnrwe and Ahamed, 2022).

**Table 4. Combined effects of soil moisture levels and nutrient management on thymoquinone, thymol, fixed oil and essential oil of black cumin**

| Treatment                     | Thymoquinone (mg kg <sup>-1</sup> seed) | Thymol (mg kg <sup>-1</sup> seed) | Fixed oil (%) | Essential oil (%) |
|-------------------------------|---|-----------------------------------|---------------|-------------------|
| I <sub>1</sub> T <sub>1</sub> | 3156b                                   | 134.63bc                          | 26.7          | 0.81a             |
| I <sub>1</sub> T <sub>2</sub> | 3286a                                   | 148.87a                           | 28.7          | 0.85a             |
| I <sub>1</sub> T <sub>3</sub> | 2840c                                   | 127.00cd                          | 23.3          | 0.67cd            |
| I <sub>2</sub> T <sub>1</sub> | 2740c                                   | 125.47cd                          | 22.0          | 0.71bc            |
| I <sub>2</sub> T <sub>2</sub> | 2831c                                   | 136.90b                           | 25.0          | 0.75b             |
| I <sub>2</sub> T <sub>3</sub> | 2606d                                   | 120.43d                           | 20.0          | 0.67cd            |
| I <sub>3</sub> T <sub>1</sub> | 2410e                                   | 78.53e                            | 16.7          | 0.59e             |
| I <sub>3</sub> T <sub>2</sub> | 2453e                                   | 84.13e                            | 17.7          | 0.65d             |
| I <sub>3</sub> T <sub>3</sub> | 2036f                                   | 58.67f                            | 13.7          | 0.54e             |
| CV (%)                        | 2.54                                    | 4.77                              | 3.16          | 4.66              |
| LSD (0.05)                    | 118.8                                   | 9.31                              | 1.71          | 0.06              |

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD test.

### Legend:

I<sub>1</sub> = Irrigation at 10% depletion of available water

I<sub>2</sub> = Irrigation at 20% depletion of available water and

I<sub>3</sub> = Irrigation at 30% depletion of available water

T<sub>1</sub> = 100% Recommended dose of fertilizers, RDF (80-45-50-20-5-2 kg ha<sup>-1</sup> of N-P-K-S-Zn-B)

T<sub>2</sub> = 75% RDF + 25% N from cowdung (1.98 t ha<sup>-1</sup>) and

T<sub>3</sub> = 50% RDF + 50% N from cowdung at 3.96 t ha<sup>-1</sup>

### Consumptive use of water and water productivity

Water productivity provides a quick and simple measure of how well available water can be converted into biological and economical parts and thereby is the basic indicator for measuring the effectiveness of water saving agriculture. The maximum consumptive use of water was noted in treatment I<sub>1</sub>T<sub>2</sub> (112 mm) followed by I<sub>1</sub>T<sub>1</sub> (109 mm), I<sub>1</sub>T<sub>3</sub> (106 mm) (Table 5). Hence, water productivity was found higher and proportionately higher seed yield with the judicious management of water. The minimum value was mentioned in treatment I<sub>3</sub>T<sub>3</sub> (86.02 mm). The maximum water productivity was found in treatment I<sub>1</sub>T<sub>2</sub> (20.52 kg ha<sup>-1</sup> mm<sup>-1</sup> for biomass yield and 9.14 kg ha<sup>-1</sup> mm<sup>-1</sup> for seed yield) followed by I<sub>1</sub>T<sub>1</sub> (19.98 kg ha<sup>-1</sup> mm<sup>-1</sup> and 8.79 kg ha<sup>-1</sup> mm<sup>-1</sup> for biomass seed yield, respectively). The minimum water productivity (13.89 kg ha<sup>-1</sup> mm<sup>-1</sup> for biomass and 4.55 kg ha<sup>-1</sup> mm<sup>-1</sup> for seed yield) was recorded in I<sub>3</sub>T<sub>3</sub>. As the crop was irrigated with required amount of water as per need and fertilized with integrated use of chemical fertilizers and cowdung judiciously, therefore, there was no stress, during the growing period which ultimately contributed to gaining the higher biological and economical yield of black cumin. Similar results were obtained by Ghamarnia *et al.* (2014) and Prajapat *et al.* (2020).

**Table 5. Total consumptive use of irrigation water, water productivity of black cumin as influenced by soil moisture levels and nutrient management**

| Treatment                     | Total amount of irrigation (mm) | Soil moisture contribution (mm) | Effective rainfall (mm) | Total consumptive use of water (mm) | Water productivity (kg ha <sup>-1</sup> mm <sup>-1</sup> ) |                            |
|-------------------------------|---------------------------------|---------------------------------|-------------------------|-------------------------------------|--|----------------------------|
|                               |                                 |                                 |                         |                                     | On the basis of biomass yield                              | On the basis of seed yield |
| I <sub>1</sub> T <sub>1</sub> | 101.3                           | 5.7                             | 1.82                    | 108.82                              | 19.98  | 8.79                       |
| I <sub>1</sub> T <sub>2</sub> | 104.9                           | 5.5                             | 1.82                    | 112.22                              | 20.52  | 9.14                       |
| I <sub>1</sub> T <sub>3</sub> | 98.2                            | 6.0                             | 1.82                    | 106.02                              | 18.87  | 7.45                       |
| I <sub>2</sub> T <sub>1</sub> | 92.2                            | 6.6                             | 1.82                    | 100.62                              | 16.99  | 5.99                       |
| I <sub>2</sub> T <sub>2</sub> | 96.7                            | 6.2                             | 1.82                    | 104.72                              | 19.33  | 7.38                       |
| I <sub>2</sub> T <sub>3</sub> | 90.1                            | 6.8                             | 1.82                    | 98.72                               | 16.18  | 5.94                       |
| I <sub>3</sub> T <sub>1</sub> | 78.2                            | 7.2                             | 1.82                    | 87.22                               | 16.68  | 5.69                       |
| I <sub>3</sub> T <sub>2</sub> | 81.1                            | 7.0                             | 1.82                    | 89.92                               | 14.57  | 4.93                       |
| I <sub>3</sub> T <sub>3</sub> | 76.7                            | 7.5                             | 1.82                    | 86.02                               | 13.89  | 4.55                       |

#### Legend:

I<sub>1</sub> = Irrigation at 10% depletion of available water

I<sub>2</sub> = Irrigation at 20% depletion of available water and

I<sub>3</sub> = Irrigation at 30% depletion of available water

T<sub>1</sub> = 100% Recommended dose of fertilizers, RDF (80-45-50-20-5-2 kg ha<sup>-1</sup> of N-P-K-S-Zn-B)

T<sub>2</sub> = 75% RDF + 25% N from cowdung (1.98 t ha<sup>-1</sup>) and

T<sub>3</sub> = 50% RDF + 50% N from cowdung at 3.96 t ha<sup>-1</sup>

## Conclusion

It is concluded that both water deficit and nutrient deficiency reduced the seed yield, biomass yield, fixed & essential oils and medicinal properties (Thymoquinone and Thymol) of black cumin. Application of irrigation at 10% depletion of available water along with a package of N, P, K, S, Zn and B @ 60, 45, 50, 20, 5 and 2 kg ha<sup>-1</sup>, respectively + 1.98 t ha<sup>-1</sup> cowdung was appeared to be the best suited combination for black cumin cultivation in the Shallow Red-Brown Terrace Soil of Salna series under AEZ-28 (Madhupur Tract) for maximizing the seed yield, oil content and medicinal properties.

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