



## Effect of irrigation and nitrogen on growth, yield and water-use efficiency of black cumin (*Nigella sativa*) in lower Indo-Gangetic plains

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### ABSTRACT

An experiment was conducted during winter (*rabi*) season of 2005–06 and 2006–07 to find out the differential irrigation and nitrogen management effects on black cumin (*Nigella sativa*) in alluvial plains of West Bengal. Irrigation based on soil moisture tension at  $\psi_m = -0.03$  at 20 cm soil depth recorded the maximum seed yield of 445 kg/ha wherein crop received four irrigations with an interval of 18–20 days. The highest seed yield (412 kg/ha) recorded with 80 kg N/ha was significantly superior to 20, 40, and 60 kg/ha, respectively. Actual evapotranspiration (AET) of black cumin was low (181 mm) under limited water supply situation but irrigation at  $\psi_m = -0.03$  MPa recorded the maximum AET of 272 mm. The high dose of 80 kg N/ha increased the AET value to the extent of 225 mm and increment in N level increased the AET. Water-use efficiency (WUE) was recorded maximum (1.81 kg/ha/mm) when crop was under moderately wet moisture regime ( $\psi_m = -0.05$  MPa), whereas WUE value decreased with increased water supply at  $\psi_m = -0.03$  MPa in black cumin. Irrigation and nitrogen management improved the benefit:cost ratio of the crop by 14.8–18.7%. In black cumin, irrigation at  $\psi_m = -0.03$  MPa, ie irrigation at an interval of 18–20 days with a nitrogen dose of 80 kg/ha was found equally productive and economic in the sandy loam soils of Indo-Gangetic plains.

**Key words:** Actual evapotranspiration, Black cumin, Irrigation, Nitrogen, Yield

Black cumin (*Nigella sativa* L.) is one of the minor spices cultivated on a small scale or occasionally found as a weed, in cultivation in Rajasthan, Gujarat, Punjab, Himachal Pradesh, Madhya Pradesh, Bihar and Assam (Purthi 2001). In India cumin is cultivated in 4.29 lakh ha producing 1.72 lakh tonnes with an average productivity of 402 kg/ha. In West Bengal, black cumin is grown in an area of 840 ha utilizing post monsoon residual soil moisture in lowland rice ecosystem and marginal medium uplands of lower Gangetic plains of West Bengal. Crop is generally sown by broadcasting under zero tillage situations in lowland but with tillage for medium land situation. Farmers are reluctant about water and nutrient management in black cumin. One or two irrigations depending upon winter rain are given to the crop following a nitrogenous fertilizer top-dressing in low and medium land situation, respectively. Water and nutrient are most often the limiting factors for black cumin production in sandy loam soils, especially in upland situations. Irrigation promoted the growth and greater number of shoots, seed yield and seed weight of black cumin (Akbarinia *et al.* 2005).

Nitrogen is essential for vegetative growth of plant and seed yield (Das *et al.* 1991). Application of excess amount of fertilizers in stress condition had a detrimental effect on the growth and yield of crop (Purthi 2001). Seed yield of spice crops was much affected by the level of applied N and water management (Jangir and Singh, and Yadav and Dahama 2003). The site-specific N recommendations were noted in black cumin as 30 kg for Assam (Luchon and Sarat 2003), 60 kg for Kanpur (Singh *et al.* 1999) and 100 kg for South India (Nataraja *et al.* 2003). So, adequate nitrogen is needed for black cumin in sandy loam soil at appropriate soil moisture level. Therefore, the investigation was carried out to study the effect of different levels of nitrogen at varying soil moisture regimes on the crop growth and water-use efficiency of black cumin in sandy loam soils of West Bengal.

### MATERIALS AND METHODS

The field experiment was conducted under All India Coordinated Project of Water Management, Bidhan Chandra Krishi Viswavidyalaya at Nadia, West Bengal (88° 3' N, 22° 58' E and 9.75 m altitude), to study the effect of irrigation and nitrogen management on black cumin during winter (*rabi*) season of 2005–06 and 2006–07. The soil of the experimental field was sandy loam in texture having soil bulk

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density 1.48 g/cc, soil moisture content at FC and PWP were 24.6 and 11.4%, respectively. The experimental soil was neutral in reaction ( $pH$  6.8) having soil organic carbon 0.64%, available N 246.4, P 9.2 and K 152.1 kg/ha. The treatments consisted of three levels of moisture regime: (i) farmers practice, ie irrigation at branching + flowering, (ii)  $\psi_m = -0.05$  MPa at 20 cm soil depth, and (iii)  $\psi_m = -0.03$  MPa at 20 cm soil depth and four levels of nitrogen (20, 40, 60 and 80 kg N/ha). Depth of each irrigation water was 50 mm. Experiment was laid out in split-plot design, keeping the irrigation in main plot and nitrogen in subplots with three replications. Black cumin cultivar 'Krishnagar' was sown in second week of November following land preparation with two passes of tractor and one pass of power tiller. Full dose of 21.7 P, 32.8 K kg/ha and half dose of N as per treatment was applied as basal and rest half N was applied at 30 days. During the experimental period the maximum monthly average temperature was 30.9°C in November and minimum monthly average temperature was 9.6°C in January. A pre-sowing irrigation and a common irrigation adopting check basin method at 30 days, ie just after nitrogen topdressing were given for good germination and plant establishment in sandy loam soil. Crop received no rainfall during the crop growing period in 2005–06 but crop received 36 and 24 mm rainfall on 8 and 12 February of 2006–07, respectively. Desired soil water potential ( $\psi_m$ ) was estimated as per the treatments ( $-0.03$  and  $-0.05$  MPa) on the basis of mercury column reading of tensiometer placed in the field at 20 cm soil depth. Profile soil water depletion was measured gravimetrically (oven dry basis) at 15 cm depth interval from soil surface to maximum root zone depth (0 - 60 cm). Seasonal crop demand in terms of reference crop evapotranspiration ( $ET_c$ ) was measured from daily pan evaporation ( $E_{pan}$ ) multiplying with pan factor ( $K_p$ ) and crop factor ( $K_c$ ). Actual evapotranspiration (AET) was estimated following field water balance method. Water-use efficiency (WUE, kg/ha/mm) was calculated in terms of yield per unit water lost. Crop was harvest on third week of March. The observations on crop growth, yield attributes and yield were statistically tested at 5% level of significance following standard statistical methods. The cost of irrigation water was @30/hr and the other input-costs were calculated on the basis of prevailing market price. The total cost of cultivation varied

from ₹ 9 940 to 11 740 and ₹ 10 510 to 11 170 in irrigation and nitrogen treatments, respectively. Gross returns were calculated on the basis seed wholesale price @ ₹ 50/kg of the produce.

## RESULTS AND DISCUSSION

### *Crop water demand and supply*

Crop water demand in terms of reference crop evapotranspiration ( $ET_c$ ) was computed for black cumin in sub-humid lower Indo-Gangetic plains to the tune of 195 mm for a period of 120 days from 15 November to 15 March (Table 1). Under wet soil moisture regime, ie irrigation at  $\psi_m = -0.03$  MPa, crop received 200 mm water in four irrigations with 18–20 days interval and at moderate moisture regime ie irrigation at  $\psi_m = -0.05$  MPa, crop received 150 mm water in three irrigations at 25–26 days interval. In farmers' practice, the drier regime crop received only 100 mm irrigation water applied at branching and flowering stage. The average rainfall received during the cropping period to the extent of 30 mm. In sandy loam soil, profile contribution was maximum in farmers' practice ranging from 57 to 66 mm, whereas, contribution was low ranging from 41 to 50 mm at  $\psi_m = -0.03$  MPa. Application of N fertilizers at different levels influenced the profile soil water uptake that was increased with increase in N supply.

### *Crop growth and yield*

Differential water supply to black cumin had significant effect on plant growth in terms of plant height, branches/plant and total dry matter production (Table 2). Maintenance of wet soil moisture regime at  $y_m = -0.03$  MPa increased the plant height by 35%, number of branches by 98% and the dry matter production to the extent of 129% over farmers practice. Nitrogen application with 80 kg/ha recorded the maximum plant height that was 34.8% more over 20 kg N/ha application. Dry matter production increased up to 14.5% with increasing dose of nitrogen from 20 to 80 kg/ha. Photosynthetic rate and radiation-use efficiency increased with higher concentration of nitrogen (Hasegawa and Horie 1996).

Water supply and nitrogen management (Table 2) significantly influenced yield attributes of black cumin. Irrigation at  $y_m = -0.03$  MPa increased the number of umbels/

Table 1 Crop water demand ( $ET_c$ ) and field water supply as influenced by irrigation scheduling in black cumin (mean data of two years)

Treatment	$ET_c$ (mm)	Irrigation details			Rainfall (mm)	Profile contribution (mm)			
		No.	Days interval	Amount (mm)		N <sub>20</sub>	N <sub>40</sub>	N <sub>60</sub>	N <sub>80</sub>
Farmers' practice*	195	2		100	30	57	64	66	66
$\psi_m = -0.05$ MPa	195	3	25–26	150	30	44	47	49	50
$\psi_m = -0.03$ MPa	195	4	18–20	200	30	41	42	47	50

\*Irrigation at branching and flowering

Table 2 Growth, yield attributes (mean) and yield of black cumin as influenced by irrigation and nitrogen levels in sandy loam soils

Treatment	Plant height (cm)	Branches/plant	Total DM (g/m <sup>2</sup> )	Umbels/plant	Seeds/umbel	Test weight (g)	Seed yield (kg/ha)		
							2005-06	2006-07	Pooled
<i>Irrigation levels</i>									
Farmers' practice	42.2	4.9	77.2	8.5	59	1.84	164	385	274
$\Psi_m = -0.05$ MPa	53.1	8.9	160.0	12.3	88	2.01	347	443	394
$\Psi_m = -0.03$ MPa	57.1	9.7	177.0	15.3	104	2.31	380	510	445
CD ( $P=0.05$ )	0.78	0.30	2.41	1.11	2.75	0.17	16.31	29.8	23.4
<i>Nitrogen (kg/ha)</i>									
20	48.3	6.6	129.9	10.4	74	1.89	256	399	327
40	49.7	7.2	138.5	11.8	78	2.04	284	446	364
60	51.3	7.8	140.5	12.3	89	2.05	312	450	381
80	53.9	8.9	144.4	13.7	94	2.17	336	488	412
CD ( $P = 0.05$ )	1.40	0.33	2.55	1.04	4.32	0.22	37.29	36.10	36.7

plant by 80.1%, seeds/umbel by 76.3% and test weight by 25.5% over farmers' practice. Yield attributes were also progressively increased with increasing dose of N. The highest number of umbels/plant recorded with 80 kg N/ha which was 31.7, 16.1 and 11.4% more than 20, 40 and 60 kg N/ha, respectively. Nitrogen nutrition also increased the number of seeds/umbel. One thousand seed weight was significantly influenced by N-application and with increased dose of nitrogen seed weight increased up to 14.8%. The application of N fertilizer had a great effect on filling of caryopsis. Dry matter of caryopsis were delivered from photosynthates from leaves, branches and tillers (Juan *et al.* 2006)

Irrigation at  $\Psi_m = -0.03$  and  $-0.05$  MPa significantly increased the seed yield of black cumin by 43.8 and 62.4%, respectively over farmers' practice. Crop irrigated at  $\Psi_m = -0.03$  MPa recorded the maximum seed yield of 445 kg/ha when four irrigations were applied with an interval of 18-20

days. Yield increase was also noticeable in moderately wet regime wherein crop received three irrigations with an interval of 25-26 days. Beneficial effects of irrigation on black cumin have been reported by Lakepale *et al.* (2003). Seed yield of black cumin was increased significantly with the increasing dose of nitrogen wherein the highest seed yield of 4.12 q/ha was recorded with 80 kg/ha which was 26.0, 13.2 and 8.1% higher than 20, 40, 60 kg N/ha, respectively.

The interaction effect of irrigation and nitrogen on seed yield was significant during 2005-06. Black cumin seed yield was the highest with 80 kg N/ha under wet moisture regime  $\Psi_m = -0.03$  MPa (Fig 1). In farmers' practice seed yield increased significantly up to 40 kg N/ha and then declined steadily with 60 and 80 kg N/ha nitrogen application. This is due to deleterious effect of high dose nitrogen on growth and yield of the crop in drier soil moisture level. Interaction effect on seed yield in 2006-07 was not significant due to

Table 3 Water and nitrogen-use efficiency and production economics of black cumin as influenced by irrigation and nitrogen levels in sandy loam soils (mean data)

Treatment	Water supply (mm)	Actual evapotranspiration (mm)	Water-use efficiency (kg/ha-mm)	Moisture extraction pattern (%)				Nitrogen-use efficiency (kg seeds/kg N)	Net returns* (₹/ha)	B:C ratio
				0-15 cm	15-30 cm	30-45 cm	45-60 cm			
<i>Irrigation levels</i>										
Farmers' practice	193	181	1.51	29.1	26.4	23.2	21.3	5.5	1 020	1.35
$\Psi_m = -0.05$ MPa	227	217	1.81	30.5	26.2	22.5	20.8	7.9	4 925	1.81
$\Psi_m = -0.03$ MPa	275	272	1.63	29.9	25.9	23.2	20.9	8.9	6 060	1.89
CD ( $P=0.05$ )	27.3	36.9	0.142	0.56	0.20	0.31	0.17	1.22	1 254	0.23
<i>Nitrogen (kg/ha)</i>										
20	231	210	1.56	29.4	25.9	23.2	21.5	16.3	2 570	1.55
40	234	213	1.71	29.3	26.2	23.3	21.2	9.1	3 830	1.69
60	237	218	1.75	30.1	26.9	22.3	20.7	6.3	4 290	1.74
80	239	225	1.83	30.7	27.2	22.8	19.3	5.1	5 310	1.84
CD ( $P=0.05$ )	NS	5.68	0.09,8	0.55	0.50	0.39	0.65	4.34	984	0.10

\*Cost of irrigation water @ ₹ 30/hr, seed whole sale price @ ₹ 40/kg

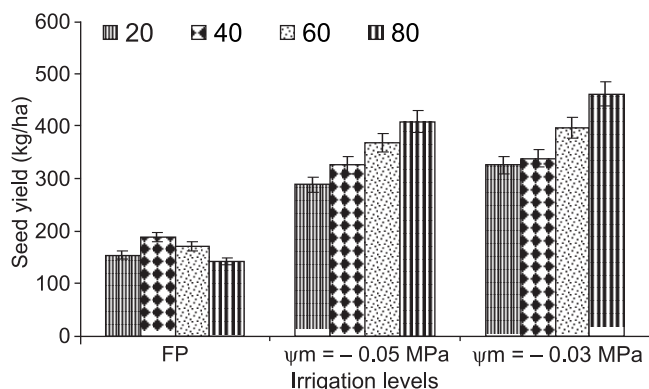


Fig 1 Interaction effect of irrigation and nitrogen levels on seed yield of black cumin during 2005–06

rainfall (36 and 24 mm) received in two successions on 8 and 12 February at umbel formation stage.

#### Water and nitrogen-use efficiency

Actual evapotranspiration (AET) of black cumin was low (181 mm) under limited water supply situation, ie in farmers' practice but irrigation at  $\psi_m = -0.03$  MPa recorded the maximum AET of 272 mm (Table 3). The application of nitrogen at 80 kg/ha recorded the maximum AET value of 225 mm over 20 kg N/ha and the increment was 7.1%. Water-use efficiency (WUE) was recorded maximum (18.1 kg/ha/mm) when crop was under moderately wet moisture regime ( $\psi_m = -0.05$  MPa), whereas, WUE value decreased with increased water supply in black cumin. Nitrogen application increased the WUE progressively. Higher value of WUE (18.3 kg/ha/mm) was recorded when crop was fertilized with 80 kg N/ha. Soil water extraction was significantly more (27 to 4.8%) from surface layer (0–15 cm) at  $\psi_m = -0.03$  MPa and  $\psi_m = -0.05$  MPa than farmers' practice. Similarly, high dose of nitrogen application significantly increased the extraction from surface layers. Relative contribution of lower layer (45–60 cm) was at higher scale (2.5 to 9.1%) when crop was grown under farmers' practice and at lower N-supply (20 and 40 kg/ha) which might be attributed to higher root activity in the lower layers under soil water and nutrient stress situation. Irrigation at  $\psi_m = -0.03$  and  $-0.05$  MPa significantly increased the nitrogen-use efficiency by 61.8 and 43.6%, respectively over farmers' practice (Table 3). On the other hand, nitrogen-use efficiency declined 2–3 times with increasing in N application levels at 20, 40, 60 and 80 kg/ha. Studies on N utilization showed the highest nitrogen-use efficiency (16.3 kg seed/kg N applied) with 20 kg N/ha, application beyond which it decreased progressively which might be ascribed with N-losses in sandy loam soil texture.

#### Economics

Net returns were 3–5 times more with irrigations at  $\psi_m = -0.03$  and  $-0.05$  MPa than farmers' practice in

black cumin cultivation (Table 3). Crops grown with irrigation at  $\psi_m = -0.03$  MPa recorded the higher benefit: cost ratio than other irrigation treatments due to higher productivity of black cumin with increased level of soil moisture supply in sandy loam soils. Similarly, increment in nitrogen application improved the ratio under irrigated condition and the crop recorded the highest benefit : cost ratio with 80 kg N/ha.

Thus, present study indicated that black cumin could be grown successfully maintaining wet soil moisture regime ( $\psi_m = -0.03$  MPa), ie irrigation at an interval of 18–20 days for sustaining higher productivity in the sandy loam soils of Indo-Gangetic plains. Similarly, 80 kg N/ha was found equally productive and economic for irrigated condition.

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