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Yield-Water-Nitrogen Response Analysis in Coriander

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Abstract A field study on the response of coriander (*Coriandrum sativum* L.) to irrigation and nitrogen was made for two years at the Central Arid Zone Research Institute, Jodhpur. A 2- factor central composite rotatable design with water and N each at predetermined values -1.414, -1, 0, 1 and 1.414 was used. The actual values, in order of their predetermined levels, were 120, 180, 340, 490 and 550 mm of water and 0, 18, 60, 102 and 120 kg N ha^{-1}. However, interactive effects of water and N were examined at their equispaced levels. The higher water supplies imposed greater demand on applied N. The nitrogen optima were 36, 62, 88, 114 and 140 kg ha^{-1} for the 120, 240, 360, 480 and 600 mm of water supplies, respectively. Nitrogen at 140 kg ha^{-1} and water level at 600 mm were beyond the experimental range, and therefore the treatment combining 480 mm of irrigation water and 114 kg N ha^{-1} emerged as the optimal package to produce the seed yield of 2366 kg ha^{-1}. However, the combination of 490 mm of water and 93 kg. N ha^{-1} would cost least to the farmer for a yield goal set to 2300 kg ha^{-1}, which was identical to optimal yield.

Key words *Coriandrum sativum*, response surface, irrigation, nitrogen, water-use efficiency, yield

Coriander (*Coriandrum sativum* L.), important seed spice as it is for home consumption, preparation of Ayurvedic medicines and as export product, is cultivated in about 0.33 million hectares mainly in the states of Andhra Pradesh, Gujarat and Rajasthan. In spite of having such significance, it did not receive due attention until the inception of All India Co-ordinated Spices Improvement Project. Under this programme, substantial work has been carried out to develop location specific high-yielding genotypes (Sharma 1989). With regard to agronomic practices, field studies to develop location specific agronomic recommendations are imperative. As no such studies have been made earlier in this desertic region, the present study was undertaken to evaluate the interactive effects of easily controlled variables of water and nitrogen on seed yield of coriander.

Materials and Methods

A field study on response of coriander to water and N was made during 1978-79 and 1979-80 in the arid, northwest India at the Central Arid Zone Research Institute, Jodhpur. The treatments comprised five levels of water and N at predetermined values -1.414, -1, 0, 1 and 1.414. The actual values, in order of their predetermined values, were 120, 180, 340, 490 and 550 mm of water and 0, 18, 60, 102 and 120 kg N ha^{-1}. A central composite rotatable design in two x-variables as described by Cochran & Cox (1957) was used. It has been reported that this design, which "provides quantitative information in its simplest form, yet accounting for linear, quadratic and interactive response with a high efficiency relative to input" (Dougherty *et al.* 1978) "so that important interactions are not overlooked" (Herbert & Baggerman 1983).

The soil was a coarse loamy Typic Camborthid, low in nitrogen (0.02%) with a pH of 7.5 and 0.47 dSm^{-1}, bulk density 1.55 g x 10^{-6} m^{-3}, and moisture of 10.4% (wt/wt) at field capacity and 3.0% (wt/wt) at 15-atm tension.

The required amounts of nitrogen, supplied through urea, and a uniform application of single superphosphate to supply 26 kg ha^{-1} of P (elemen-

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tal) were mixed well with dry soil in each 5 m long and 3 m wide plot. As a conventional practice in the area, seeds of coriander cultivar RCr-41 were sown in dry soil on 29 November in both the seasons, at a seeding rate of 12 kg ha^{-1} in lines 20 cm apart. In all treatments 50 mm of water was applied immediately after sowing, followed by 70 mm within a week for enhancing germination. The depths, number, average intervals and the amounts of water applied in each irrigation are given in Table 1. The crop was harvested on 22 March in each year.

Table 1 *Irrigation (I) schedules for the coriander crop*

Water applied (mm)	Post-emergence I		
	Number	Interval (days)	Avg. amt. per I (mm)
120	No post–emergence		
180	2	32	31.5
310	6	10	35.8
490	8	9	45.9
550	11	7	39.1

Regression coefficients were computed from the values of individual years and from the two-year mean values 1978-79 and 1979-80 for the linear, quadratic and interaction terms; standard error for each term and coefficients of determination that would show the extent of variation explained by the two variables. The levels in equations are the predetermined values -1.414, -1, 0, 1 and 1.414 and not the actual treatment level as shown in the graphics.

Predicted Y was calculated from the fitted equation for each of a grid of values of equally spaced X_1 (water) and X_2 (nitrogen) that cover the experimental region. The contours of equal response were then drawn in smooth curve.

Results and Discussion

Seed yield : In 1978-79 only the linear terms were significant. The R^2 value was close to unity (0.99), typical of a very close relationship between seed yield and water and that between yield and applied N. When the water level was set to the central value (340 mm), seed yield peaked (1639 kg ha^{-1}) at 60 kg N ha^{-1} (Fig. 1). Further increases in N produced similar yields. In the same way if the N level was set to the central value (60 kg ha^{-1}), seed yield continued to increase with increase in water supply, peaking (2118 kg ha^{-1}) at the 550 mm of water (Fig.1). Thus under one set of conditions, the optimum recommen-

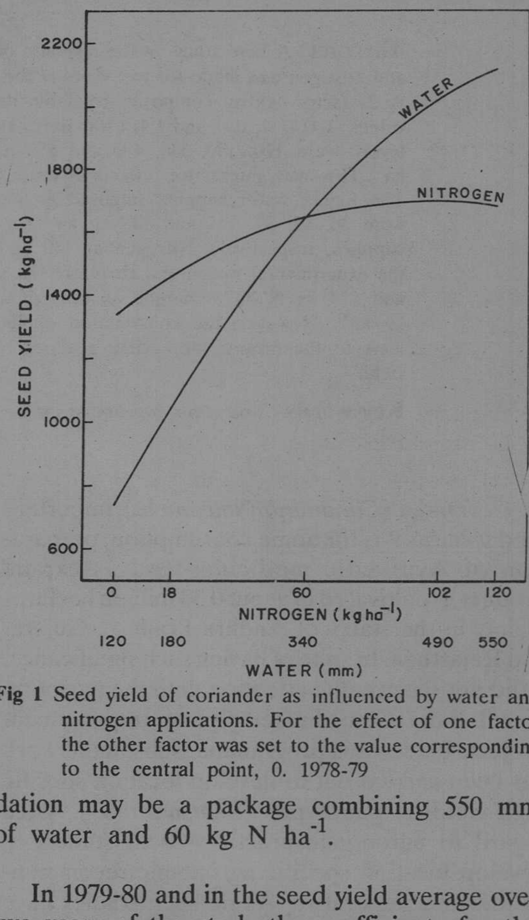

Fig 1 Seed yield of coriander as influenced by water and nitrogen applications. For the effect of one factor the other factor was set to the value corresponding to the central point, 0. 1978-79

dation may be a package combining 550 mm of water and 60 kg N ha^{-1}.

In 1979-80 and in the seed yield average over two years of the study the coefficients for the linear, quadratic and interaction terms were highly significant (Table 2). The water and N as predictors explained 98% of the variability in the response variable (seed yield, Y). As seen from the magnitudes of the linear terms, the average crop response to water in this arid zone was 68% higher than the response to applied N.

Shown in Fig. 2 is the seed yield response to applied N at various levels of seasonal irrigation. The crop revealed three kinds of response to N depending upon the water supplies (Fig. 2).

Table 2 *Constants and coefficients of response surface for seed yield of coriander grown during 1978-79 and 1979-80 at Jodhpur*

Term	Yield in kg ha^{-1}		
	1978-79	1979-80	Mean
Constant	1639.36	2063.38	1851.57
X_1 (Water)	484.35**	372.37**	428.39**
X_2 (Nitrogen)	119.86**	388.97**	254.44**
X_{11}	–103.22	–345.04**	–224.08**
X_{22}	–63.24	–250.07**	–156.60**
X_{12}	52.25	436.50**	244.25**
SE : Linear terms	39.20	30.61	30.12
SE : Quadratic terms	41.97	32.78	32.25
SE : Interaction term	55.37	43.24	42.55
R^2	0.99	0.98	0.98

** Significant at the 1% level of probability by the t-test.

With limited water supplies (120 and 240 mm), there was a linear yield response to N up to 60 kg ha^{-1}. When the water supply was moderate (360 mm), seed yield tended to increase linearly up to 90 kg N ha^{-1}. At the higher water supplies (480 and 600 mm), peak yields of 2375 to 2498 kg ha^{-1} were found at 120 kg N ha^{-1}. Higher irrigation thus imposed greater demand on fertilizer N.

The physical N optimum, determined from partial derivative of Y (seed yield) with respect to N and equating the same to zero (i.e., dy/dN = 0), varied with variations in the seasonal water supplies (Table 3). The N optima were found to increase steadily with increase in the water supply from 120 mm to 600 mm, and therefore, the highest optimum yield was found to be 2575 kg ha^{-1} from the treatment combining 600 mm

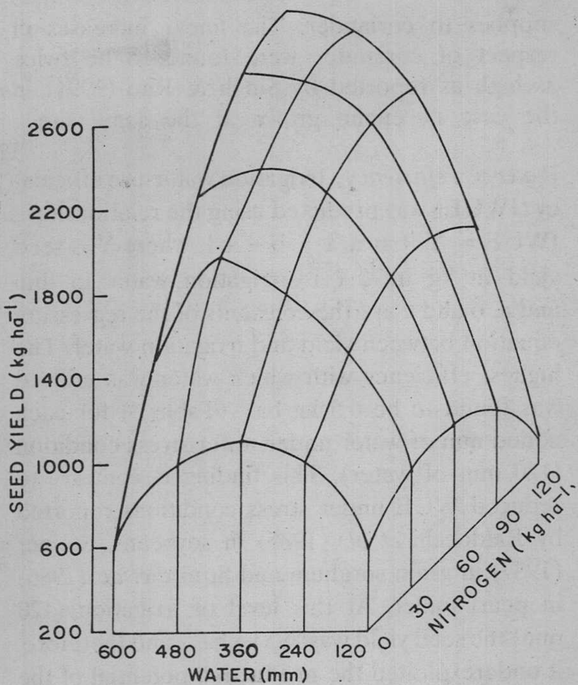

Fig 2 Interactive effects of water and nitrogen on mean seed yield of coriander grown at Jodhpur

of water and 140 kg N ha^{-1} (Table 3). Nitrogen at 140 kg ha^{-1} and water at 600 mm were beyond the experimental range, and therefore, can be used with caution. Bearing this limitation in mind it may be economical to use 480 mm of water and 120 kg N ha^{-1} and obtain a yield of 2375 kg ha^{-1} (Fig. 2).

As seen from Table 3, the linear increases in seed yield per unit increase in N application were 8.21, 12.75, 17.30, 21.83 and 26.36 kg ha^{-1} for 120, 240, 360, 480 and 600 mm of water

Table 3 *Mean yield (Y, kg ha^{-1}) to nitrogen (N) relationship, R^2 and optimum N (Nopt), optimal yield (Yopt) and IWUE at each level of water supply to the coriander crop*

Water (mm)	Y–N relation	R^2	Nopt (kg ha^{-1})	Yopt (kg ha^{-1})	IWUE
120	$Y = 602.0 + 8.21N - 0.087N^2$	0.999	36	785	6.5
240	$Y = 1015.9 + 12.75N - 0.087N^2$	1.000	62	1472	6.1
360	$Y = 1151.1 + 17.30N - 0.087N^2$	0.999	88	2000	5.6
480	$Y = 1007.8 + 21.83N - 0.087N^2$	0.999	114	2366	4.9
600	$Y = 585.1 + 26.36N - 0.087N^2$	1.000	140	2575	4.3

supplies to coriander. The linear increases in respect of coriander were found to be twice as high as reported by Singh & Rao (1994) in the case of cumin grown at the same site.

Water-use efficiency : Irrigation water-use efficiency (IWUE) was predicted using the relationship : IWUE = Y/I = a/I + b − c I, where Y is seed yield in kg ha^{-1}, I is irrigation water in mm and a, b and c are the constants of the regression equation between yield and irrigation water. The highest efficiency with which water was utilized was found to be 6.5 kg ha^{-1} (Table 3) for each added mm of water under water stress condition (120 mm of water). This finding is contrary to reduced WUE under stress conditions reported by Baldocchi *et al.* (1985) in soybeans, Steiner (1987) in grain sorghum and Squire *et al.* (1986) in pearl millet. At this level of irrigation (120 mm) the seed yield was 785 kg ha^{-1}, and therefore, it underexploited the production potential of the coriander crop in the arid region.

In their comprehensive review of literatures on WUE in crop production, Sinclair *et al.* (1984) concluded that a greater potential apparently exists for improving WUE in the water scarce regions. The reality, however, remains that without additional water, these areas cannot be expected to become regions of high crop yields. Adequate irrigation and optimal exploitation of production potential are seemingly of highest priority in attempting to increase the production in view of the conservative nature of crop WUE. In agreement to this, it may be in order to recommend 480 mm of water so as to achieve seed yield of 2366 kg ha^{-1} or 4.9 kg ha^{-1} for each added millimetre of water. It may not be safe to use 600 mm of water, as this amount is beyond the upper experimental range of 550 mm of water.

Least cost combination of water and nitrogen : Shown in Fig. 3 are the yield isoquants (equal yield contours) and isoclines (which show the optimum combination of the two inputs for each yield level) drawn for two nitrogen price (Pn)to per 10 mm of water price (Pw) ratios. If a farmer

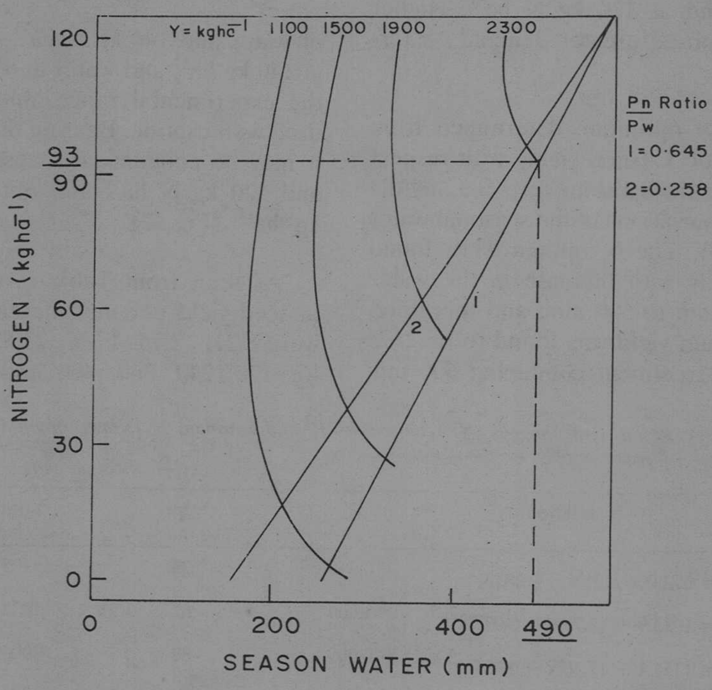

Fig 3 Yield isoquants (equal yield contours) and yield isoclines (optimum combinations of water and nitrogen) at 2-price of N (Pn) to price of per 10 mm of water (Pw) ratios

sets his yield goal to 2300 kg ha^{-1} (found to be the optimal yield) and N : water price ratio were 0.645, then the least-cost combination was 490 mm of water and 93 kg N ha^{-1}, which was determined by dashed line from the point the isocline for Pn : Pw ratio of 0.645 intersected the yield isoquant of 2300 kg ha^{-1}. Similarly, water and N optima can be determined for any specified yield and input cost condition.

Nitrogen utilization efficiency : The N utilization efficiency increased with each irrigation level up to 600 mm of water (Table 4). This showed that the higher water supplies to the crop maintained higher amount of nitrogen fertilizer in the soil solution and its absorption by the plant roots therefrom. Increased N utilization under higher water supplies was reflected in the seed yield (Fig. 2).

Table 4 *Nitrogen utilization efficiency as affected by applied N and irrigation water*

N rate kg ha^{-1}	Irrigation water (mm)				
	120	240	360	480	600
30	5.6	10.1	14.7	19.2	23.8
60	3.0	7.5	12.1	16.6	21.2
90	0.4	4.9	9.5	14.0	18.5
120	−2.2	2.3	6.9	11.4	15.9

Nitrogen utilization efficiency decreased with each increment of N level (Table 4). Under similar conditions the N utilization efficiencies by the coriander plants were twice the reported (Singh & Rao 1993) N utilization efficiencies by the cumin plants (Fig. 4). It was due to higher production potential of the former crop ECe 477 micromhos/10 mm, than the latter one at the given supplies of water and applied N.

On clay loam soils in southern subhumid zone of Rajasthan, the highest seed yield of 1341 kg ha^{-1} was obtained with the application of 90 kg N ha^{-1} and when irrigations were scheduled (amount not given) by crop growth stages at the branching plus the capsule formation stage (Katole *et al.* 1989). On a loamy sand soil under our study a yield of 2000 kg ha^{-1} was obtained from the application of 88 kg N ha^{-1} and 360 mm of water (Table 3). This led us to conclude that loamy sand soils are as good for the cultivation of coriander as the clay soils. Moderate cool winter plus no winter rains in the arid, northwest India is an added advantage to favour its production in the region. The study provides information for the first time about scheduling of irrigation and N application in this crop. A package combining 490 mm of water and 93 kg N ha^{-1} would cost least to the farmers to produce a specified yield of 2300 kg ha^{-1}.

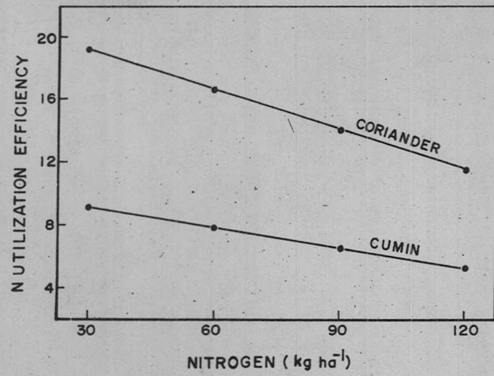

Fig 4 Relative nitrogen utilization efficiencies (kg seed ha^{-1} kg^{-1} of N) by cumin and coriander as affected by N rate, at the optimal water supply of 480 mm

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