Indian Journal of Ecology (2022) 49(6): 2071-2075
DOI: https://doi.org/10.55362/IJE/2022/3787

Manuscript Number: 3787
NAAS Rating: 5.79

Optimization of Irrigation and Nitrogen Levels in Chickpea (*Cicer arietinum* L.) under Loamy Sand Soil of North Gujarat

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Abstract: Shrinking of water resources and poor fertility status of soil in semi-arid region, call for diversification from wheat to low inputs demanding crop chickpea in North Gujarat. A field experiment was conducted during the *rabi* seasons of 2021-22 at Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat to optimize irrigation and nitrogen fertilizer for chickpea under loamy sand soil. All growth traits, yield components and seed and straw yield of chickpea increased significantly with at each higher level of irrigation scheduling up to 0.8 IW/CPE ratio with water application of 450 mm along with 100% RDN. The highest field water use efficiency of chickpea with 0.6 IW/CPE ratio. Seed yield with applied water and field water use efficiency followed quadratic function with regression coefficient (R^2) of 0.99. The predicted maximum seed yield of chickpea was 2306 and 2217 kg/ha with optimum irrigation and nitrogen level of 549.6 mm and 24.03 kg N/ha beyond which yield seed yield shows decreased in trends.

Keywords: Chickpea, Economics, Irrigation, Nitrogen, WUE, Yield

Demand for agricultural products will further increase to satisfy the needs of an increasing population. However, the availability of water for agriculture has been declining due to an increasing demand of water for non-agricultural sectors (Srivastava et al 2018, Jafarikouhini et al 2020). Shortage of irrigation water is seriously affecting agricultural production particularly in arid and semi-arid regions because irrigated agriculture is required for agricultural production in these regions. In Northwestern semi-arid region of India, particularly in Gujarat, the wheat based cropping system has dominated other cropping systems because of the introduction of high yielding varieties, availability of favorable soil and climatic factors and better remunerative support prices. With the large scale adoption of wheat based cropping system even on coarse textured and light soils, Gujarat state has led to overexploitation of water resources caused a decline in the water table in several districts leads to sever water scarcity. As frequent drought in every 2-3 years in North Gujarat areas were very common. Farmers and planners in this area are seeking alternative suitable crops with low water and energy requirement for diversification and long term sustainable agricultural productivity point of view. Chickpea was identified as an alternative crop to North Gujarat area, because of its lower water demand (evapotranspiration) and irrigation requirement has been identified as a suitable alternate crop to wheat.

Among the pulses, chickpea (*Cicer arietinum* L.) is one of the major crop of tropics and sub-tropics and top most important pulse crop of India cultivated over an area of 9.99 million hectare with a production of 11.91 million tonnes and productivity of 1092 kg/ha (DES 2020-21). Earlier chickpea was cultivated in Maharashtra, Punjab, Haryana, Rajasthan as rainfed *rabi* crop only for subsistence and not for commercial in heavy black soil, resulting in low yield. In Gujarat, chickpea was cultivated as rainfed crop only in Saurashtra region under black heavy soil. Commercial cultivation of crop in loamy sand soil with limited irrigation facility was started in water scarcity area of North Gujarat with yield potential of 2500 kg/ha. Though, chickpea crop doesn't require much amount of nitrogen fertilizer due to legume-rhizobia association fix nitrogen in root nodules. However, in light textured soil which was deficit in organic carbon and nitrogen, there may be good response of irrigation along with nitrogen fertilization. As these two factors which are very important for proper growth and development of plant, rather than by crop genetics (Sinclair and Rufty 2012). Although, number of experiment in chickpea were conducted under heavy black soil. However, research on light textured soil where there is potential to get higher yield due to proper cultivar selection and inputs management is very meagre. Considering the above fact the present study was conducted to optimize the irrigation and nitrogen levels to chickpea under loamy sand soil of North Gujarat.

MATERIAL AND METHODS

A field experiment was carried out during winter (*Rabi)* season of 2021-22 at S. D. Agricultural University, Sardarkrushinagar. The site is geographically situated at 24° 19' N Latitude and 72° 19' E Longitude with an elevation of 154.52 m above the mean sea level. The region is characterised by tropical and semi-arid with dry winter (November-February)and soil is loamy sand in texture having low in organic carbon (0.21%) and available nitrogen (168.4 kg/ha) and medium in available phosphorus (35.22 kg/ha) and available potassium (264.10 kg/ha). Chickpea variety "Gujarat Gram 5" was sown manually on 22nd November 2021 with recommended dose of fertilizer was 20:40:00 NPK kg/ha. The experiment was laid out in a split plot design with four replications, consisting of nine treatment combinations comprising three irrigation levels in main plot *viz*., 0.6 IW/CPE (I_1), 0.8 IW/CPE (I_2) and 1.0 IW/CPE ratio (I_3) with 50 mm depth of irrigation water at each irrigation and three nitrogen levels in sub plot *viz.*,125% RDN (N_1), 100% RDN (N_2) and 75% RDN (N_3).One common pre sowing irrigation was applied for crop establishment in all treatments thereafter; 50 mm depth of irrigation water was given through flood method as per the treatment wise. Full dose of phosphorus was applied as basal dose through SSP and nitrogen was given in two splits at half in basal and remaining half at 30 DAS as per the treatment wise. Crop yield (dependent variable) was assumed as a function of various growth traits, yield components and nutrient uptake (independent variables) and the following straight line model was established by least square technique (Gomez and Gomez 1984):

$$Y = a + b\ (x)$$

where, Y = Grain yield of chickpea(kg/ha), a = Y–axis intercept, b = Regression coefficient, x = Growth and yield components

The functional relationship between crop yield with irrigation water applied (W) defined as water production function and crop yield with applied nitrogen (N) is fertilizer production function. The production function equations evaluated in this study are as follows.

Linear production functions:

$$Y = a + b\ (W)$$

$$Y = a + b\ (N)$$

Quadratic production functions:

$$Y = a + b\ (W) + c\ (W^2)$$

$$Y = a + b\ (N)\ c\ (N^2)$$

where in: Y = Crop yield (kg/ha), W = Applied irrigation water, N = Applied nitrogen (kg/ha), a = Y – axis intercept, b and c = Regression coefficients reflecting the yield variation per unit change in irrigation/nitrogen.

The data obtained on the different growth and yield components and yield were analyzed statistically by the method of analysis of variance as per the procedure outlined for split plot design given by Gomez and Gomez (1984) in Microsoft excel sheet. Statistical significance was tested by P–value at 0.05 level of probability and critical difference was worked out wherever the effects were significant.

RESULTS AND DISCUSSION

Growth and yield attributes: The higher level of irrigation from 0.6 to 1.0IW/CPE ratio produced significantly higher growth parameters and yield attributes of chickpea (Table 1). Maximum growth parameters and yield attributesof chickpea were with irrigation scheduled at 1.0 IW/CPE ratio which was at par with 0.8 IW/CPE and significantly superior over 0.6 IW/CPE ratio.Adequate moisture supply promoted the elongation, division and expansion of cell components and ultimately, increased plant growth causes higher yield attributing characters. Similar result reported by Pawar et al (2013) and Srinivasulu et al (2016). Chickpea fertilized with

Table 1. Effect of irrigation scheduling and nitrogen levels on growth and yield attributes of chickpea

Treatment	Plant height (cm) at harvest	Dry matter accumulation at harvest (g/plant)	Days to 50% flowering	Number of branches per plant	Number of pods per plant	Number of seeds per pod	Seed index (g)
Irrigation scheduling: (I)							
I_1: 0.6 IW/CPE ratio	44.06	24.62	53.77	7.56	40.80	1.36	19.47
I_2: 0.8 IW/CPE ratio	49.69	27.63	57.38	9.53	49.45	1.41	20.86
I_3: 1.0 IW/CPE ratio	52.24	28.95	58.37	9.82	52.39	1.42	21.49
C.D. at 5%	6.16	2.37	3.64	0.68	8.93	NS	1.57
Nitrogen levels: (N)							
N_1: 125% RDN	50.82	28.37	57.60	9.48	51.21	1.42	21.05
N_2: 100% RDN	49.00	27.47	56.75	9.37	49.12	1.40	20.90
N_3: 75% RDN	46.18	25.37	55.16	8.06	42.31	1.37	19.87
C.D. at 5%	3.65	2.34	NS	1.20	3.70	NS	NS

125% RDN increased growth and yield attributes which was at par with 100% RDN and significantly superior over 75% RDN. The overall improvement in growth and yield attributes with an application of nitrogen might have stimulated increased activity of nucleotide, protein, chlorophyll formation, cell division, cell elongation and enzymes involve in various metabolic process which have direct impact on vegetative phase. Similar results were also reported by Rani and Krishna (2016), Bhadoria (2018), Verma et al (2019).

Seed and straw yield: Irrigation scheduled at 1.0 IW/CPE ratio recorded significantly the highest seed yield (2306 kg/ha) and straw yield (3123 kg/ha) of chickpea which was at par with 0.8 IW/CPE ratio and significantly superior over 06 IW/CPE ratio (Table 2). Increase in irrigation frequency from 0.6 to 1.0 IW/CPE ratio tented to increase consumptive use of water, which provided congenial condition throughout the growth period of the crop. Besides adequate soil moisture in the rhizosphere of chickpea crop which results in higher photosynthesis and translocation of photosynthesis towards reproductive structures. Several researchers reported improved seed yield with irrigation scheduled at 0.8 and 1.0 IW/CPE (Pawar et al 2013, Kumbhar et al 2015, Srinivasulu et al 2016, Khot et al 2021). Application of 125% RDN recorded significantly the highest seed yield (2213 kg/ha) and straw yield (3068 kg/ha) which was at par with 100% RDN. The improvement in yield components might have resulted from favorable influence of nitrogen on growth attributes and efficient and greater partitioning of metabolites and adequate translocation of nutrients to developing reproductive structure. The results were in agreement with the findings of Bhadoria (2018), Dwivedi et al (2019) and Verma et al (2019).

Interaction effect between irrigation scheduling and nitrogen levels: The irrigation scheduled at 1.0 IW/CPE ratio along with application of 125% RDN recorded significantly higher seed yield (2521 kg/ha) which was at par with irrigation scheduled at 1.00IW/CPE along with 100% RDN, 0.8 IW/CPE along with 125% RDN and 0.8 IW/CPE with 100% RDN and significantly superior over rest of treatments (Table 3). The results are in agreement with the Gadade et al (2021). The crop fertilized with nitrogen along with adequate amount of irrigation can increased in nitrogen uptake by plant. Nitrogen accumulation during vegetative growth period, which was conducive to transfer to seed at maturity stage improved dry matter accumulation at harvest and ultimately seed yield.

Regression of growth traits and yield components on seed yield of chickpea: All the independent variables showed a significant positive and linear relationship with seed yield suggesting an increment in seed yield of chickpea with increase in given growth trait and yield component (Table 4). However, the magnitude of this reinforcement varied with the independent variable, *viz.,* growth trait and yield component and their units. The explained total variation as indicated by coefficient of determination (R^2) in grain yield by various growth traits and yield components (number of pods per plant, number of seeds per pod, seed index) chosen as independent variables individually ranged from 88.51 to

Table 3. Seed yield of chickpea as influenced by interaction between irrigation scheduling and nitrogen levels

Irrigation scheduling (I)	Nitrogen levels (N)		
	N_1: 125% RDN	N_2: 100% RDN	N_3: 75% RDN
I_1: 0.6 IW/CPE ratio	1734	1711	1702
I_2: 0.8 IW/CPE ratio	2384	2280	1854
I_3: 1.0 IW/CPE ratio	2521	2436	1961
C.D. at 5%	277.8		

Table 2. Effect of irrigation scheduling and nitrogen levels on yield, FWUE and economics of chickpea

Treatment	Seed yield (kg/ ha)	Straw yield (kg/ha)	Harvest index (%)	FWUE (kg/ha/mm)	Gross realization (₹/ha)	Total cost of cultivation (₹/ha)	Net realization (₹/ha)	BCR
Irrigation scheduling: (I)								
I_1: 0.6 IW/CPE ratio	1715	2660	39.20	4.90	96390	48109	48281	2.00
I_2: 0.8 IW/CPE ratio	2173	2953	42.39	4.83	120462	50470	69992	2.39
I_3: 1.0 IW/CPE ratio	2306	3123	42.48	4.19	127792	52832	74960	2.42
C.D. at 5%	357.6	265.9	NS	-	-	-	-	-
Nitrogen levels: (N)								
N_1: 125% RDN	2213	3068	41.90	4.92	122922	40189	82733	3.06
N_2: 100% RDN	2142	2927	42.26	4.76	118808	40120	78688	2.96
N_3: 75% RDN	1839	2742	40.14	4.09	102918	40251	62667	2.56
C.D. at 5%	160.4	248.9	NS	-	-	-	-	-

94.08% and 81.24 to 98.58%. The variance ratio for testing R^2 was highly significant in all the relationships. This suggests that the seed yield of chickpea can be adequately predicted using the tested independent variables, *viz.,* growth traits and yield components.

Irrigation water and yield relation: The relation between seed yield (Y) of chickpea under each level of applied water (water production function) was developed which explained 99% variation (Fig. 1). It showed quadratic response. The resultant water production function and test statistics are as follows.

$$Y = -2447 + 17.58W - 0.016W^2 \quad (R^2 = 0.99)$$

Quadratic: The test statistic (R^2 and F – value) of quadratic production function were highly significant. The water production functions developed for chickpea under different irrigation scheduling were used to determine economic irrigation water level that a farmer can use.The predicted maximum seed yield was 2306kg/ha with applied water of 549.4 mm beyond which the yield decreased (Fig. 2). However, the maximum grain yield (Y_{max}) during experimental period was bracketed within the tested range of applied water levels (350 to 550 mm). Similar results were in tune with the finding of Malve et al (2017).

Nitrogen levels and yield relation: The relation between chickpea seed yield (Y) under each nitrogen levels (N) was established following quadratic production function (Fig. 2). The resultant fertilizer production function and test statistics are as follows.

$$Y = -462 + 223\,N - 4.64\,N^2 \qquad (R^2 = 0.99)$$

Quadratic: The test statistic (R^2 and F – value) of fitted quadratic production function were highly significant. The yield – nitrogen production function did not emerge through the origin and the value of regression constant (intercept 'a') was positive indicating that some minimum grain yield of 462kg/ha can be realized based on the native fertility of the experimental soil. The positive linear coefficient for N term denoted that grain yield increased linearly from the addition of initial N levels. On the other hand, the negative second power (quadratic) regression coefficient (N^2) suggested that the increase in grain yield from each increment of N diminished at higher levels. The predicted maximum grain yield was 2217kg/ha with an input level of 24.03 kg N/ha, beyond which the yield decreased (Fig. 3). However, the maximum grain yield (Y_{max}) during experimental period was bracketed within the tested range of nitrogen levels (20 to 30 kg N/ha).

Yield water use efficiency (Y-WUE): Y-WUE was significantly affected by irrigation water applied during

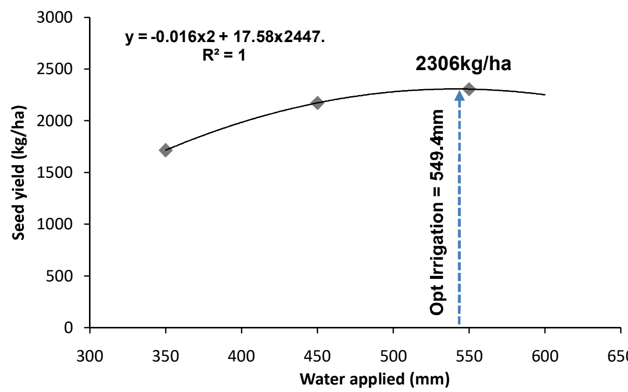

Fig. 1. Predicted yield response of chickpea to applied water applied

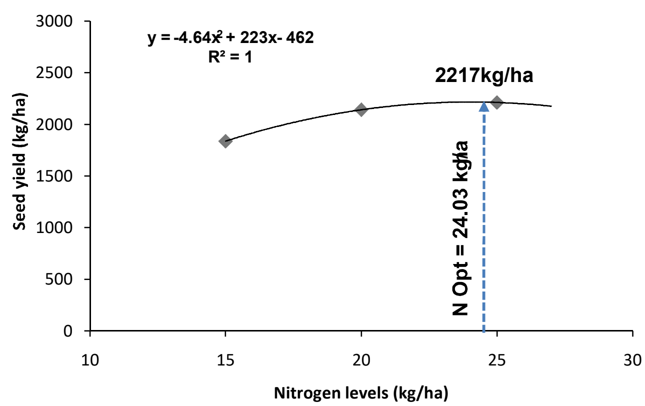

Fig. 2. Predicted yield response of chickpea to nitrogen levels

Table 4. Empirical estimates for the regression of growth traits and yield components on seed yield of chickpea

Relationship	Regression constant		Coefficient (R^2)	Test statistic F value for testing R^2
	a	b		
Yield – Plant height (cm)	-1611	75.53	0.885**	53.94
Yield – Dry matter production (g/plant)	-1625.8	136.33	0.897**	60.98
Yield – Days to 50% flowering	-5670.2	136.89	0.940**	111.14
Yield – No. of branches per plant	-231.12	255.95	0.922**	83.03
Yield – No. of pods per plant	-185.92	47.33	0.985**	484.64
Yield – No. of seeds per pod	-10455.2	8974.7	0.812**	30.31
Yield –Seed index (g)	-4203.22	304.15	0.964**	189.34

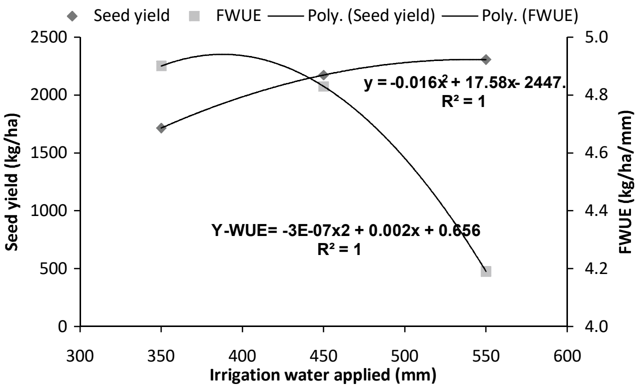

Fig. 3. Relationship of irrigation water applied to seed yield and water use efficiency

experimental period. Each higher level of irrigation from 0.6 to 1.0 IW/CPE ratio decreased water use efficiency of chickpea. Numerically, highest water use efficiency (4.90 kg/ha/mm) was recorded at 0.6 IW/CPE ratio. The relationship between Y-WUE was curvilinear (polynomial of second order) graphically depicted in Fig 3. This relationship could be expressed as follows:

$$Y-WUE= -3E-07x^2 + 0.002x + 0.656 \ (R^2 = 1)$$

Y-WUE increased with increasing water shortage in the root zone, indicating that yield losses was proportionally smaller than the amount of water used by crops. The different effects of water deficit on Y-WUE observed in various studies can be attributed to the level of water stress experienced by the crop. Chickpea crop develop deep root system which potentially increases the water availability for the plants and attenuates negative effects of water deficit. This may bring up the crop more resistant to water stress and a greater Y-WUE. In the shallow soils, as in our experiment, the development of the rooting system was very limited; it resulted in severe water stress with a very negative impact on the yield and Y-WUE. The application of each higher level of nitrogen improved Y-WUE, as well as yield, in agreement with results reported by Gadade et al (2021).

Economics: The application of irrigation at 1.0 IW/CPE ratio gave the highest net return (74960 ₹/ha) with maximum BCR value 2.42 followed by 0.8 and 0.6 IW/CPE ratio. In case of 125% RDN application recorded the highest net monetary returns (82733 ₹/ha) with maximum B:C ratio of 3.06 followed by 100% and 75% RDN (Table 2).

CONCLUSIONS

The remunerative higher yield of chickpea can be achieved by irrigation scheduled at 0.8 IW/CPE ratio along with application of 100% recommended dose of nitrogen (20 kg/ha). The predicted maximum seed yield of chickpea was 2306 and 2217 kg/ha with optimum irrigation and nitrogen level of 549.6 mm and 24.03 kg N/ha beyond which yield seed yield shows decreased in trends. However, the maximum seed yield was bracketed within the tested ranged of irrigation scheduling and nitrogen levels which confirmed optimum inputs levels for getting yield of chickpea on loamy sand soil.

Received 22 August, 2022; Accepted 12 November, 2022

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