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Influence of Different Irrigation and Nitrogen Levels on Water and Nitrogen Use Efficiency of Cluster bean (*Cyamopsis tetragonoloba*)

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ABSTRACT: The field experiment was carried out at research farm, Agricultural research sub-station, Hanumangarh, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *Kharif,* 2016 to see the impact of different irrigation and nitrogen levels on water and nitrogen use efficiency of cluster bean (*Cyamopsis tetragonoloba*). For that, Cluster bean variety RGC-1055 with seed rate of 16 kg ha^{-1} was planted using 3 levels of irrigation (100, 200 and 300 mm) and 4 level of nitrogen (0, 20, 40 and 60 kg ha^{-1}) and studied in Split plot Design with three replication. Results showed that the different irrigation and nitrogen levels significantly influenced the yield, total nitrogen uptake, water and nitrogen use efficiency and profitability of cluster bean. The irrigation level 200 mm recorded significantly superior grain yield, PEN, PFPN and economics over 100 mm. The total nitrogen uptake, AEN and REN were higher in irrigation level 300 mm over both the lower level. The irrigation water productivity and INUE were higher in 100 mm irrigation level as compared to other treatments. The nitrogen level 40 kg ha^{-1} recorded highest grain yield, total nitrogen uptake, AEN, PEN, INUE, irrigation water productivity and gross return of cluster bean over remaining treatments. The maximum values of REN and PFPN were recorded under nitrogen level 20 kg ha^{-1}.

Keywords: Cluster bean, Irrigation and Nitrogen.

INTRODUCTION

Clusterbean (*Cyamopsis tetragonoloba*), drought tolerance crop, is widely grown under rainfed conditions in hot arid parts of Rajasthan and India. However, soil moisture availability in the hot arid zone of Rajasthan is generally low and highly variable from year to year and season to season due to low and erratic distribution of rainfall. Further, high evaporative demand of the atmosphere coupled with high wind velocity result in elevated evapo-transpirational losses that severely restrict the length of growing season (Bhatt *et al*., 2017). Aside from the state's quickly growing population and rising living standards, as well as the exponential rise of industrialization, water supply in the state is swiftly dwindling, and water scarcity is rapidly increasing. Water scarcity and increasing competition for water in various sectors diminish irrigation's availability. Therefore, effective water management approach for crop production in water-scarce area is the need of hour to increasing water productivity (Kumar *et al*., 2020). Hence, technical actions are necessary to boost the area's crop water yield.

Crop performance is severely limited in the hot arid region due to coarse textured soils with low fertility and water retention capability. Additionally, inadequate soil fertility has a negative impact on crop growth and output. In arid regions, improved soil fertility has been shown to reduce the negative impacts of drought on agricultural productivity. Although leguminous crops are less responsive to applied nitrogen (N), a tiny beginning dose can help plants grow faster in the early stages (Sammuria *et al*., 2009). In cluster bean, Singh and Singh (1989) discovered higher grain yield, water-use efficiency (WUE) and gross returns with 20 kg N ha^{-1}. Thus, nutrient management preferably integrated with reduced risk and cost that can improve the yield to some stable level assumes the greatest significance.

After carbon, hydrogen, and oxygen, nitrogen is the most important nutrient for photosynthetic processes, phytohormonal changes, proteomic changes, and plant growth and development. Excessive and wasteful use of nitrogen fertilizer raises crop production costs and pollutes the environment. There is an urgent need to improve nitrogen use efficiency in agricultural farming systems for the world's sustainable food supply and environmental benefits. The product of nitrogen uptake efficiency and nitrogen utilization efficiency is nitrogen usage efficiency, which ranges from 30.2 to 53.2 percent. Nitrogen losses are too high, up to 70% of total available nitrogen, due to excess amounts, insufficient plant population, inefficient application methods, and other factors. Improved agronomic measures, such as nitrogen dosage optimization, can reduce these losses by up to 15%–30%. The physiological and metabolic changes, such as soil nitrogen uptake, assimilation from roots to other parts, source-sink tissues interaction for transportation, signaling and regulatory pathways that are responsible for N status within plants and growth, are all exploiting issues for discussion and research. The ratio of yield to total N provided is sometimes referred to as NUE. Other methods for observing NUE include nitrogen recovery and agronomic nitrogen efficiency (NRE). Nitrogen doses, application methods, and other agronomic parameters that aid in nitrogen management have a significant impact on both lucrative crop production and the environment (Anas *et al*., 2020). Keeping these above facts in mind, the present study was undertaken.

MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Sub Station, Hanumangarh, SKRAU, Bikaner, Rajasthan during *Kharif* season of 2016-17. The soil of experimental site was silty clay with pH 7.4, having 0.21% organic carbon, 198.4 kg ha^{-1} available nitrogen, 34.5 kg ha^{-1} available phosphorus and 383.6 kg ha^{-1} available potassium. The experiment was carried out in split plot design having three replications with 3 irrigation level (100, 200 and 300 mm) and 4 N level (0, 20, 40 and 60 kg/ha). The cluster bean variety 'RGC-1055' was sown with the help of hand-plough in 45 cm rows spacing on 17 July 2017. The net plot size was 3.6 × 3.5 m. A uniform pre sowing irrigation of 60 mm was applied to all plots. The measured quantity of irrigation to each plot was applied via a 5 cm PVC pipe fitted with water flow meter (Kranti). The plots receiving 100, 200 and 300 mm irrigation were irrigated 4 times at 30, 45, 60 and 75 DAS with variable quantities. The amount of water was 25 mm each irrigation in case of I_{100} treatment. In, I_{200} treatments the quantity of water was 50 mm each irrigation. In case of I_{300} treatment, the first and second irrigation was of 70 mm, and rest of 2 irrigations of 80 mm. The N was applied as per treatments (0, 20, 40 and 60 kg ha^{-1}) in the form of urea as basal at the time of sowing. The phosphorus was applied @ 40 kg P_2O_5 ha^{-1} through single super phosphate as per recommendation for cluster bean. Five random plants were harvested from each plot, excluding the border row, and produce was weighed and after multiplying with suitable conversion factor, expressed as grain yield per ha. The water productivity was computed by dividing yield by total water used. The indices of nitrogen use efficiency was worked as suggested by Meena *et al*., 2018; Peng *et al*., 2006: Singh *et al*., 2021; Ballester *et al*., 2021. The representative dry samples of shoots and seeds were analyzed for ascertaining the nitrogen content. The nitrogen content was analyzed by micro-Kjeldahl methods. The nutrient uptake by cluster bean at harvest was calculated by multiplied the content with respective grain and straw yields to calculate total nitrogen uptake by grain and straw and were expressed as kg ha^{-1}.

RESULTS AND DISCUSSION

Yield and total N uptake

Irrigation levels. The grain yield and nitrogen uptake of cluster bean significantly increased with increasing levels of irrigation (Fig. 1 and 2). The irrigation levels 200 mm gave 23.59 per cent higher grain yield over 100 mm. The difference between irrigation level 200 mm and 300 mm was not found significant. The lowest grain yield of cluster bean was found under irrigation level 100 mm. The total N uptake by cluster bean crop was higher in irrigation level 300 mm over both the lower level of irrigation. When compared with irrigation at 200 mm and 100 mm, it resulted in increase in N uptake of straw by 18.34 and 51.09 per cent, respectively. Significantly higher grain yield was recorded under irrigation at 200 mm, which was statistically at par with 300 mm. The increase in yields might be due to favorable moisture status in the root zone of the crop through irrigation of optimum quantity at 200 mm which favoured the better root growth and development of plant and thus increased growth and yield attributes which increased grain yield of cluster bean over irrigation at 100 mm. The results corroborate with the findings of Rajanna *et al*. (2016); Kumar *et al*. (2015); Bana *et al*. (2018).The irrigation levels had significant influence on total nitrogen uptake by the plant. The nitrogen uptake of crop is function of nitrogen content of plant and yield. The significant increase in both content and yield of cluster bean with an increase in irrigation is responsible for an increase in total nitrogen uptake with increasing irrigation levels observed in the present study. A significant increase in nitrogen uptake with irrigation levels has also been reported by Bana *et al*. (2016); Kumar *et al*., (2015).

Nitrogen levels: Increasing nitrogen levels up to 40 kg ha^{-1} increased the cluster bean grain yield dramatically (Fig. 1). The nitrogen level 40 kg ha^{-1} yielded 30.82 and 14.48 per cent greater grain yield as compared to 0 kg N ha^{-1} and 20 kg N ha^{-1}, respectively. However, further increase in the amount of nitrogen did not result in a considerable improvement in grain yield. With increasing nitrogen levels, cluster bean crop increased total nitrogen uptake considerably. The nitrogen level 60 kg ha^{-1} gave 5.14, 20.22, and 44.57 percent higher total nitrogen uptake in comparison to 40 kg N ha^{-1}, 20 kg N ha^{-1}, and 0 kg N ha^{-1}, respectively (Fig. 2). Improved general growth and branching due to nitrogen fertilization resulted in improved net photosynthesis, and better mobilization of photosynthates towards reproductive structures on the other, which could have greatly increased yield characteristics and yield. Conversely, a nitrogen shortage in the experimental field was observed, which had a negative impact on crop growth and blooming seed set leading to low yield and uptake value in unfertilized plots. The results are confirmed with the findings of Ahmad *et al*. (2018); Singh and Kumar (2016); Sammauria *et al*. (2009); Rathore *et al*., (2007a). The total nitrogen uptake by the plant was increased with increase in nitrogen fertilization. The nitrogen application to soil at higher rate might have enhanced the nitrogen availability to cluster bean crop plants leading to greater leaf area index that probably help in photosynthates production. Thus the increased demand for nutrients led to more uptake from soil and their accumulation in various plant parts and thus was reflected in increased concentration of nitrogen in plant parts. The greater yield coupled with higher nitrogen concentration in plant parts has led to higher nitrogen uptake. Similar variation in N concentration and uptake by cluster bean plant parts due to varying levels of N fertilization were also reported by Singh and Kumar (2016); Rathore *et al*., (2007a).

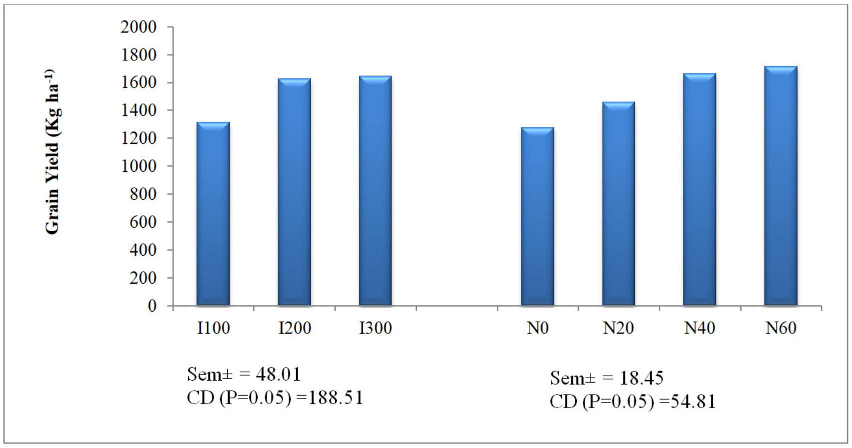

Fig. 1. Effect of irrigation and nitrogen levels on grain yield of cluster bean.

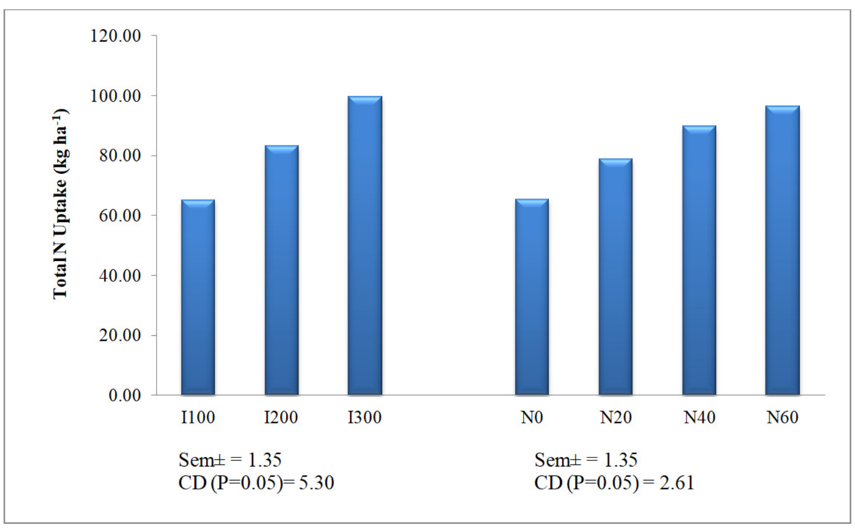

Fig. 2. Effect of irrigation and nitrogen levels on total N uptake of cluster bean.

Nitrogen Use Efficiency Indices

Irrigation levels: All the irrigation levels significantly influenced the indices of nitrogen use efficiency of cluster bean (Table 1). The significantly higher agronomic efficiency of nitrogen (AEN) was recorded under irrigation level 300 mm over 200 and 100 mm. The difference between irrigation level 200 mm and 100 did not find significant. The lowest value of AEN was recorded under irrigation level 100 mm. The highest physiological efficiency of nitrogen (PEN) was recorded under irrigation level 200 mm as compared to 100 mm. The lowest PEN was recorded under irrigation level 300 mm over the remaining treatments. The significantly higher recovery efficiency of nitrogen (REN) was recorded under irrigation level 300 mm while the lowest in 200 mm. The partial factor productivity of nitrogen (PFPN) increased with increasing levels of irrigation and the highest value was recorded with higher level of irrigation. However, the difference between irrigation level 200 mm and 300 mm did not differ significantly. The internal use efficiency of nitrogen (INUE) was decreased significantly with each successive increase in irrigation level and the highest value was recorded with lowest level of irrigation.

Nitrogen levels: The different nitrogen levels significantly influence the indices of nitrogen use efficiency of cluster bean (Table 1). The highest AEN, PEN and REN were recorded under nitrogen level 40 kg ha^{-1} but found on par with 20 kg N ha^{-1}. The lowest value of AEN, PEN and REN was recorded under nitrogen level 60 kg ha^{-1}. The PFPN was decreased with increasing levels of nitrogen and highest value was recorded with 20 kg N ha^{-1}. The highest value of INUE was recorded under nitrogen levels 40 kg ha^{-1} over remaining nitrogen levels, but the difference between the nitrogen levels was found non-significant. The indices of nitrogen use efficiency first increased up to 40 kg N ha^{-1} and thereafter decreased with subsequent increase in nitrogen application. The nitrogen application beyond 40 kg ha^{-1} failed to cause proportionate increase in grain yield with an increment of nitrogen doses. This study partially supported by the study of Rathore *et al*. (2007b); Saxena *et al*. (2003).

Table 1: Effect of irrigation and nitrogen levels on nitrogen use efficiency (kg grain kg N ha^{-1}) indices of cluster bean.

Treatments	AEN	PEN	REN	PFPN	INUE
Irrigation levels					
I_{100}	7.90	15.36	0.52	41.83	20.25
I_{200}	7.16	22.77	0.32	50.46	19.54
I_{300}	11.10	11.83	0.95	50.75	16.71
SEm+	0.47	1.64	0.04	1.36	0.45
CD (P=0.05)	1.84	6.46	0.17	5.35	1.77
Nitrogen levels					
N_0	-	-	-	-	-
N_{20}	9.09	16.53	0.66	72.84	18.64
N_{40}	9.72	18.37	0.61	41.60	18.92
N_{60}	7.35	15.06	0.52	28.60	18.14
SEm+	0.53	0.80	0.03	0.63	0.184
CD (P=0.05)	1.64	2.45	0.10	1.94	0.548

Irrigation water Productivity

Irrigation levels: The irrigation water productivity of cluster bean decreased with an increase in irrigation levels (Table 2). The significantly superior irrigation water productivity was recorded with irrigated crop at 100 mm over the remaining levels of irrigation. The lowest irrigation water productivity was recorded with irrigation level 300 mm. The water productivity was decreased with an increase in irrigation levels. The application of 100 mm irrigation recorded highest water productivity followed by 200 mm and 300 mm irrigation level. The effect of irrigation levels on water productivity is in contrast to its effects on yield, as yield increased with an increase in irrigation levels. The relatively smaller increase in yield compared to amount of irrigation applied with an increase in irrigation levels is probable explanation of decrease in water productivity at higher irrigation levels observed in present study. The decrease in water productivity with increasing irrigation levels has been reported by Abdulmohsin *et al*. (2018); Rajanna *et al*. (2016); Kumar *et al*., (2015).

Table 2: Effect of irrigation and nitrogen levels on irrigation water productivity of cluster bean.

Treatments	Irrigation water productivity (kg m^{-3})
Irrigation levels	
I_{100}	1.31
I_{200}	0.81
I_{300}	0.55
SEm+	0.03
CD (P=0.05)	0.13
Nitrogen levels	
N_0	0.75
N_{20}	0.87
N_{40}	0.97
N_{60}	0.98
SEm+	0.01
CD (P=0.05)	0.03

Nitrogen levels: The nitrogen levels had significant effect on irrigation water productivity of cluster bean and increased with an increase in nitrogen level up to 40 kg ha^{-1} (Table 2). The significantly higher irrigation water productivity was recorded with N 40 kg ha^{-1} as compared to remaining nitrogen levels. Further increase in nitrogen levels did not bring about significant difference in the irrigation water productivity of the cluster bean. The water productivity increased with an increase in nitrogen levels, although the difference between N 40 kg ha^{-1} and N 60 kg ha^{-1} levels were non-significant. The improved water productivity with an increase in nitrogen fertilization observed in the present study might be attributed to increased leaf area which leads to reduction in evaporation component of evapo-transpiration, smaller increase in evapo-transpiration compared to yield and better utilization of available soil water. The results are in agreement with the findings of Rathore *et al*. (2007a), who demonstrated that the addition of nitrogen in nitrogen deficient soil increased water productivity, when water is available.

Economics

The cost of cultivation for cluster bean were worked out on the basis of cost of inputs and labour charges prevailing during the crop growing period and market values of produce during the *Kharif* 2016, respectively (Table 3). The cost of cultivation was higher in irrigation level 300 mm and nitrogen level 60 kg ha^{-1} while the lowest in irrigation level 100 mm and nitrogen level 0 kg ha^{-1}.

Gross return

Irrigation levels: All the irrigation levels progressively increased the gross returns of cluster bean (Table 3). The significantly higher gross return was recorded in irrigation level 200 mm while the lowest in 100 mm. Further increase in irrigation levels did not brought about significant improvement in gross return of cluster bean. A similar result was reported by Kumar *et al.* (2015).

Nitrogen levels: The application of nitrogen significantly improved the gross returns of cluster bean and increased with increasing levels of nitrogen (Table 3). Application of 60 kg N ha^{-1} gave 31.28 per cent higher gross return over 0 kg N ha^{-1}. The lowest gross return was observed in nitrogen level 0 kg ha^{-1}. Gross return was recorded higher with progressive increase in nitrogen levels and the results were significant up to 40 kg ha^{-1}. Rathore *et al*. (2007a) also recorded the higher gross returns with increasing dose of nitrogen fertilizer.

Table 3: Effect of irrigation and nitrogen levels on cost of cultivation and gross returns of cluster bean.

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross Return (Rs. ha^{-1})
Irrigation levels		
I_{100}	41101.30	53670.61
I_{200}	41245.30	65966.57
I_{300}	41430.30	67492.06
SEm+		1600.26
CD (P=0.05)		6283.41
Nitrogen levels		
N_0	40260.00	52918.87
N_{20}	41120.87	59635.82
N_{40}	41381.74	67478.27
N_{60}	41642.61	69472.69
SEm+		626.00
CD (P=0.05)		1859.95

CONCLUSION

From the results of the present investigation, it was concluded that irrigation at 200 mm found to be effective in improving the grain yield, PEN, PFPN, INUE and gross return of cluster bean. In different irrigation levels, irrigation at 100 mm found effective to enhance the irrigation water productivity of cluster bean. Among the nitrogen levels, application of 40 kg N ha^{-1} was found to be effective for improving grain yield, irrigation water productivity, PEN and INUE.

FUTURE SCOPE

The results of the study will provide the basis for future research to find out the optimum level of irrigation and nitrogen under hot arid region.

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Conflict of Interest. Nil.

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