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Performance of Cluster Bean (*Cyamopsis tetragonoloba*) under Varying Levels of Irrigation and Nitrogen

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ABSTRACT

Background: Clusterbean (*Cyamopsis tetragonoloba* L.) is important commercial crop which belongs to family Leguminosae and has capacity to fix the atmospheric nitrogen. The nitrogen fixed by the legume crop is not enough to meet the demand of short duration crop like clusterbean. Besides, the experimental site falls under arid region where drought stress and poor distribution of rain during the crop growing cycle is common which affects the crop growth and productivity. Drawing on these insights, the study was planned to assess the performance of cluster bean with objectives to quantify water balance and to calculate suitable levels of irrigation and nitrogen.

Methods: The experiment was conducted at research farm, Agricultural research sub-station, Hanumangarh, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *Kharif*, 2016. Cluster bean variety RGC-1055 with seed rate of 16 kg ha^{-1} was planted with 3 levels of irrigation (100, 200 and 300 mm) and 4 levels of nitrogen (0, 20, 40 and 60 kg ha^{-1}) and analyzed in split plot design with three replications.

Result: Results showed by that the irrigation and nitrogen application rates significantly influenced the growth parameters, yield, nitrogen content and uptake by cluster bean. Irrigation level 200 mm significantly increased leaf area index at 60 DAS (2.62), dry matter accumulation (DMA) at 60 DAS and harvest (16.51 and 42.62 g $plant^{-1}$), crop growth rate at 30-60 DAS and at harvest (0.36 and 0.62 g m^{-2} day^{-1}), relative growth rate at 60- at harvest (1.59 g g^{-1} day^{-1}), grain yield (1624 kg ha^{-1}), straw yield (3645 kg ha^{-1}) and biological yield (5270 kg ha^{-1}) over irrigation level 100 mm, but statistically at par with irrigation level 300 mm. However, leaf area index at harvest (1.24) was highest at 300 mm irrigation level. Nitrogen level at 40 kg ha^{-1} significantly increased leaf area index at 30, 60 DAS and at harvest (0.19, 2.65 and 1.16), dry matter accumulation at 60 DAS and at harvest (19.62 and 49.58 g $plant^{-1}$), crop growth rate at 30-60 DAS and 60- harvest (0.46 and 0.71 g m^{-2} day^{-1}), relative growth rate at 30-60 DAS and 60-harvest (1.26 and 1.66 g g^{-1} day^{-1}), grain yield (1668 kg ha^{-1}), straw yield (3696 kg ha^{-1}) and biological yield (5364 kg ha^{-1}) over control. The highest nitrogen content and uptake in grain and straw was obtained with irrigation level at 300 mm and nitrogen level @ 60 kg ha^{-1}.

Key words: Cluster bean, Irrigation, Nitrogen, Yield.

INTRODUCTION

Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.], commonly known as guar, is recognized as one of the most important commercial crop of arid and semi-arid region of Rajasthan (Kumar *et al*., 2020). This Leguminous crop is well suited under climatic condition of Rajasthan due to its drought, hardy nature and require low humidity and nutrients (Kherawat *et al*., 2013) as well as its deep tap rooting system has high capacity to recover from water stress under limited water supply (Rathore *et al*., 2007a). Cluster bean is a short duration (3-4 months) crop that can tolerate prolonged dry spell and soil salinity. The seed of cluster bean contains about 30-33% gum in the endosperm which plays role in reducing the cholesterol, blood pressure, blood sugar levels and general weight loss (Sharma *et al*., 2011). This crop has been established in various arid and semi-arid regions of world as a high-value cash crop because of its drought hardiness and multitude of usage and has occupied a special place in the commercial scene because of its gum (Wong *et al*., 1997). This legume is a very valuable plant within a crop rotation cycle, as it lives in symbiosis with nitrogen-fixing bacteria. In fact, agriculturists in semi-arid regions of

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Rajasthan follow crop-rotation and use guar as a source to replenish the soil with essential nutrients and nitrogen fixation, before the next crop (Anuradha *et al*., 2017). Clusterbean occupies an important role in Indian economy because of its industrial importance and presence of gum in its endosperm. It had been grown since ancient era for various purposes *viz*., vegetable, green fodder, manure and feed. The information pertaining to effects of irrigation on growth, yield and nitrogen uptake of cluster bean is inadequate. As the *Kharif* legume, it is grown under rainfed conditions which experience water stress at varying degrees and durations at different growth stages. The crop of cluster bean has potential to grow under arid and semi-arid climatic conditions receiving less than 250 mm annual rainfall with minimum nutrients and abundant sunshine (Ashraf *et al*., 2005). In the arid region of Rajasthan, drought stress occurs due to low rainfall or poor distribution of rain during the crop growing cycle which affect the crop growth and productivity. Rajasthan is predominantly a rainfed state and precipitation being major source of annual renewable water supply (Kumar *et al*., 2016). As many researchers say that the seeds of guar have been produced with 2650 m^{-3} ha average water supply (Gresta *et al*., 2013). Therefore, irrigation is the most important factor in crop production for semi-arid regions throughout dry season. For this, we need to irrigate the crop 3-4 times during growing period when it is grown under irrigated system.

There have been many factors which affect the productivity of cluster bean like poor soil fertility status, imbalanced application of fertilizers, moisture supply and lack of nutrients. So, augmenting of nutrient supply assumes prime significance to improve crop productivity (Kumar *et al*., 2019). Among different plant nutrients, nitrogen is one of the utmost important for plant growth and development. Nitrogen plays an important role in synthesis of chlorophyll, metabolism, being an essential constituent of several metabolically active compounds, amino acids and other organic compounds of physiological significance in plant system (Kumar *et al*., 2022 and Anuradha *et al*., 2017). It is a major structural component of cell and even of cell wall, thus it increases growth and development of all living tissues and improves the yield, protein content of food grains and quality of fodder, vegetables and other crops (Saxena *et al*., 2003). Insufficient supply of nitrogen may reduce yield drastically and deteriorates the quality of produce specially protein content. However, the over use of nitrogen may reduce number of nodules and nodule growth and thus adversely affects the capacity of nitrogen fixation and yield. Therefore, adequate supply of nitrogen is prime requisite for better growth, development and yield and there is a need to study the effect of different irrigation and nitrogen levels on growth, yield and nitrogen uptake of cluster bean. So, the present study was conducted with the objective to see the performance of cluster bean under varying level of water and nitrogen.

MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Sub Station, Hanumangarh, SKRAU, Bikaner, during *kharif* season 2016-17. The soil of experimental field was silty clay in texture, neutral in reaction (pH 7.4), having 0.21% organic C, 198.41 kg ha^{-1} available N, 34.56 kg ha^{-1} available P and 383.65 kg ha^{-1} available K. The experiment was laid out in split plot design with 2 factors. Irrigation with 3 levels (100, 200 and 300 mm) in main pot and nitrogen with 4 levels (0, 20, 40 and 60 kg ha-1) in sub plot and replicated thrice. The clusterbean variety 'RGC-1055' was sown with hand-plough in 45 cm rows spacing on 17th 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 at 4 (30, 45, 60 and 75 DAS) times. The rate of application of water was 25 mm each irrigation in case of I_{100} treatment. In, I_{200} treatments the rate of application 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 nitrogen was applied in the form of urea. The nitrogen was applied as per treatments in sub plots whole as basal at the time of sowing. The phosphorus was applied @ 40 kg P_2O_5 ha^{-1} through SSP as per recommendation of cluster bean. Five random plants were selected from each plot, excluding the border row, for taking observations on growth parameters and yield. For, quality parameter a fraction of dry mass grinded and packed into polythene beg. The nitrogen content in seed and straw was analysed with the help of kjheldhal method and then multiplied with yield for calculation of uptake.

RESULTS AND DISCUSSION

Growth parameters

Irrigation levels

Different irrigation levels significantly influenced the growth parameters *viz.* leaf area index, dry matter accumulation crop growth rate (CGR), relative growth rate (RGR) and branches $plant^{-1}$ (Table 1 and 2). At 30 DAS stage, the leaf area index of clusterbean did not got influenced by irrigation levels. At 60 DAS stage, significantly higher leaf area index was observed under irrigation level 200 mm which was 13.66 per cent more than the 100 mm irrigation level. At harvest stage leaf area index increased significantly with increasing levels of irrigation up to 300 mm. The irrigation level 200 mm showed 11.78 and 15.16 per cent increment in dry matter accumulation over 100 mm at 60 DAS and harvest stage, respectively. The number of branches $plant^{-1}$ significantly increased with increasing levels of irrigation up to 300 mm. The significant increase in leaf area index, dry matter accumulation and branches $plant^{-1}$ with progressive increase in irrigation levels were might be due to increased cell division and elongation at higher moisture regime and optimum moisture status available in soil which in turn maintained favourable physicochemical process for better dry matter accumulation and leaf area index in plant. These results are in conformity with the findings of Rajanna *et al*., (2016) and Kumar *et al*., (2015).

The different irrigation levels did not influence crop growth rate at 0-30 DAS stage and relative growth rate at 30-60 DAS stage while at other stages it influenced significantly. The irrigation level 200 mm gave significantly higher crop growth rate at 30-60 DAS and 60-harvest stages which was 16.13 and 16.98 per cent higher over 100 mm, respectively. The irrigation level 200 mm gave 3.92 per cent higher relative growth rate over 100 mm at 60- harvest stage. Further, increase in irrigation level did not increase the crop and relative growth rate significantly. Higher water content in plants with higher irrigation levels increased photosynthetic activities in plant, which might have increased crop and relative growth rates. These results are in conformity with the findings of Rajanna *et al*., (2016).

Nitrogen levels

The leaf area index, dry matter accumulation, crop growth rate, relative growth rate and number of branches plant^{-1} of clusterbean was significantly affected by various nitrogen levels (Table 1 and 2). The leaf area index (LAI) of clusterbean increased markedly with each successive increase of nitrogen levels at all observational stages. Further, the leaf area index values were highest at 60 DAS and declined there after due to senescence (leaf and reproductive parts). The nitrogen level 40 kg ha^{-1} recorded 30.40 and 55.15 per cent higher LAI over 0 kg N ha^{-1} at 30 and 60 DAS stages, respectively. Under an adequate nitrogen supply, optimum leaf nitrogen concentration were maintained for longer period that helped in more chlorophyll formation leading to prolonged photosynthesis and their

Table 1: Effect of irrigation and nitrogen levels on leaf area index (LAI) and Dry Matter accumulation (DMA) during various growth stages of cluster bean.

Treatments	LAI (30 DAS)	LAI (60 DAS)	LAI (at harvest)	DMA-30 DAS (g plant^{-1})	DMA-60 DAS (g plant^{-1})	DMA- at harvest (g plant^{-1})
Irrigation levels						
I_{100}	0.174	2.305	0.809	5.56	14.77	37.01
I_{200}	0.177	2.620	1.078	5.69	16.51	42.62
I_{300}	0.182	2.678	1.243	5.75	18.61	46.52
SEm±	0.014	0.075	0.034	0.04	0.65	1.17
CD (P=0.05)	NS	0.29	0.133	NS	2.54	4.60
Nitrogen levels						
N_0	0.148	2.280	0.747	5.50	10.68	28.49
N_{20}	0.182	2.529	1.066	5.60	14.62	36.00
N_{40}	0.193	2.646	1.159	5.70	19.62	49.58
N_{60}	0.198	2.682	1.201	5.86	21.60	54.11
SEm±	0.007	0.042	0.036	0.09	0.67	1.03
CD (P=0.05)	0.020	0.011	0.108	NS	1.98	3.07

Table 2: Effect of irrigation and nitrogen levels on crop growth rate (g m^{-2} day^{-1}), relative growth rate (g g^{-1} day^{-1}) and number of branches plant^{-1} of cluster bean at various stages.

Treatments	CGR (0-30 DAS)	CGR (30-60 DAS)	CGR (60-harvest)	RGR (30-60 DAS)	RGR (60-harvest)	No. of branches plant^{-1}
Irrigation levels						
I_{100}	0.185	0.31	0.53	1.14	1.53	7.61
I_{200}	0.190	0.36	0.62	1.18	1.59	9.03
I_{300}	0.192	0.43	0.66	1.21	1.60	9.99
SEm±	0.001	0.023	0.017	0.017	0.013	0.22
CD (P=0.05)	NS	0.089	0.065	NS	0.052	0.87
Nitrogen levels						
N_0	0.183	0.17	0.42	1.00	1.43	7.20
N_{20}	0.187	0.30	0.51	1.14	1.53	9.06
N_{40}	0.190	0.46	0.71	1.26	1.66	9.52
N_{60}	0.195	0.52	0.77	1.30	1.69	9.71
SEm±	0.003	0.023	0.03	0.015	0.011	0.16
CD (P=0.05)	NS	0.067	0.08	0.046	0.033	0.48

supply to the plant results in extension of growth, which is ultimately reflected in leaves. In contrast, inadequate nitrogen supply reduces the leaf area and thus reduces photosynthetic activity. The increase in leaf area with increasing nitrogen levels in present study is in close agreement with the finding of Sammauria *et al*., (2009) and Rathore *et al.,* (2007a).

Except 30 DAS, graded nitrogen levels significantly affect the dry matter accumulation at all growth stages. Application of 40 kg N ha^{-1} recorded significantly higher dry-matter production at 60 DAS and number of branches plant^{-1} which is 83.71 and 32.22 per cent higher over 0 kg N ha^{-1}, respectively. However, at harvest stage, the dry matter production increased significantly with increasing levels of nitrogen and it was highest in higher nitrogen level 60 kg ha^{-1}. The significantly higher crop and relative growth rate was observed under nitrogen level 40 kg ha^{-1} as compared to other nitrogen levels except crop growth rate at 30 DAS stage where it was not affected by nitrogen levels. The increase in dry matter production with increase in nitrogen application might be due to increase in plant height and LAI which resulted into enhanced photosynthesis and their supply to the plant parts. The increase in dry matter accumulation led to increase in crop growth rate during 30-60 DAS and 60 DAS-harvest and relative growth rate during all the growth stages under study. Similar finding regarding crop growth rate and relative growth rate are also reported by Rathore *et al*., (2007a).

Yield

Irrigation level

The different irrigation levels significantly influenced the grain, straw and biological yields and test weight (Table 3). All these parameters increased with increasing levels of irrigation from 100 to 300 mm. Significantly higher grain, straw and biological yields were recorded under irrigation at 200 mm, which was statistically at par with 300 mm. The grain, straw and biological yield recorded at irrigation level of 200 mm was 19.08, 15.63 and 16.71 per cent higher than 100 mm irrigation level. Test weight was increased significantly up to irrigation at 300 mm. The increase in yields might be due to favourable moisture status in the root zone of the crop through irrigation 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 clusterbean over irrigation at 100 mm. The results corroborate with the findings of Rajanna *et al*., (2016) and Kumar *et al*., (2015).

Nitrogen level

Test weight, grain yield, straw yield and biological yield (Table 3) significantly increased with increasing rates of nitrogen. The highest test weight, grain, straw and biological yields observed with 40 kg N ha^{-1} was 30.82, 10.28 and 14.41 percent higher as compared to control and these values remained statistically at par with 60 kg N ha^{-1}, respectively. Improved overall growth and profuse branching due to nitrogen fertilization led to increased net photosynthesis on one hand and greater mobilization of photosynthates towards reproductive structures on the other, might have increased the yield attributes significantly. Conversely deficiency of nitrogen in the experimental field affected the crop growth, flowering seed setting adversely under unfertilized plots. Similar results was also recorded by Singh and Kumar (2016), Prasanna *et al*., (2014), Sammauria *et al*., (2009) and Rathore *et al.,* (2007a)

Nitrogen content and uptake

Irrigation level

The irrigation levels had significant influence on nitrogen content and its uptake by all plant parts and total nitrogen uptake by the plant (Table 4).The highest nitrogen content in grain and straw was recorded with irrigation level 300

Table 3: Effect of irrigation and nitrogen levels on yields and harvest index of cluster bean.

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Test weight (g.)
Irrigation levels					
I_{100}	1314	3075	4389	30.01	27.70
I_{200}	1624	3645	5270	30.79	28.71
I_{300}	1613	3956	5554	28.95	33.75
SEm±	47	94	88	0.96	1.004
CD (P=0.05)	185	368	344	NS	3.942
Nitrogen levels					
N_0	1275	3316	4591	27.98	25.43
N_{20}	1457	3458	4915	29.87	29.24
N_{40}	1668	3696	5364	31.07	32.21
N_{60}	1672	3766	5412	30.73	33.33
SEm±	19	37	38	0.34	0.873
CD (P=0.05)	55	108	112	1.02	2.595

Table 4: Effect of irrigation and nitrogen levels on nitrogen content and uptake of cluster bean.

Treatments	N content (%)		N uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Irrigation levels					
I_{100}	2.89	0.88	38.10	27.03	65.12
I_{200}	3.01	0.94	49.07	34.08	83.14
I_{300}	3.52	1.02	57.72	40.67	98.39
SEm±	0.04	0.01	1.50	1.23	1.31
CD (P=0.05)	0.15	0.03	5.88	4.83	5.14
Nitrogen levels					
N_0	2.79	0.90	35.67	29.80	65.47
N_{20}	3.15	0.95	45.88	32.86	78.73
N_{40}	3.23	0.96	54.49	35.53	90.02
N_{60}	3.39	0.99	57.14	37.51	94.65
SEm±	0.02	0.01	0.92	0.45	0.89
CD (P=0.05)	0.11	0.01	2.72	1.33	2.64

mm which was 17.89 and 13.72 per cent higher as compare to irrigation level 100 mm, respectively. The uptake of nitrogen by grain and straw and total uptake was also higher in irrigation level 300 mm and it was 33.99, 33.53 and 33.81 per cent higher than irrigation level 100 mm, respectively. The uptake of nitrogen by crop is the function of nitrogen content of plant and yield. The significant increase in content and yield of clusterbean with an increase in irrigation is responsible for an increase in total nitrogen uptake with increasing irrigation levels which was observed in the present study. A significant increase in nitrogen uptake with irrigation levels has been reported by Kumar *et al*., (2015).

Nitrogen level

The nitrogen content in grain and straw, its uptake by grain and straw and total uptake by the plant was (Table 4) increased with increase in nitrogen levels. The highest nitrogen content in grain and straw and its total uptake were found with 60 kg N ha^{-1} which was 17.69, 9.09 and 30.82 percent higher as compared to nitrogen rate @ 0 kg ha^{-1}, respectively. Nitrogen application to soil at higher rate might have enhanced the nitrogen availability to clusterbean crop plants leading to greater leaf area index that probably help in photosynthates production. Thus, the increased demand for nutrients led to more uptakes 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 clusterbean plant parts due to varying levels of N fertilization were also reported by Singh and Kumar (2016), Prasanna *et al*., (2014) and Rathore *et al.,* (2007a).

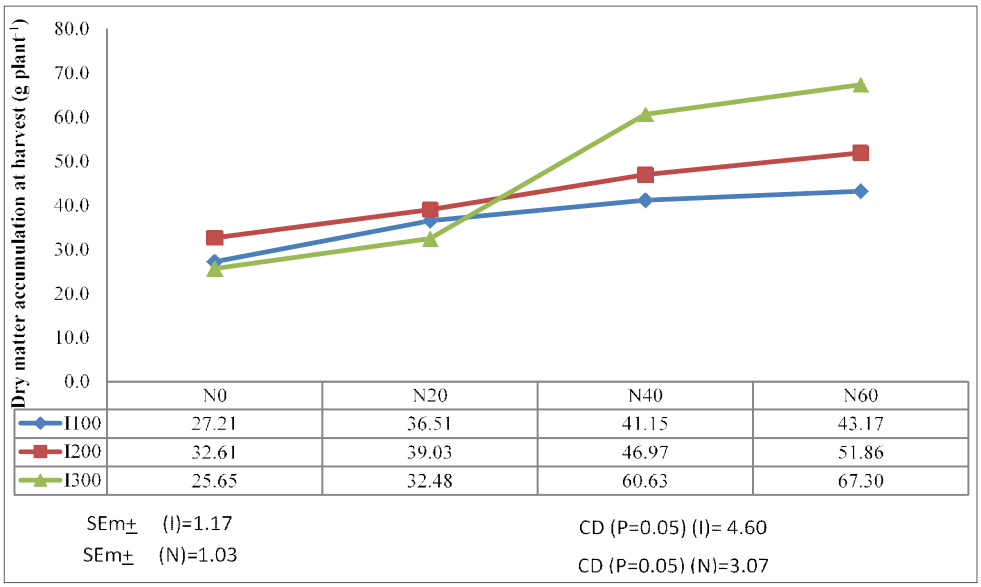

Fig 1: Combined effect of irrigation and nitrogen levels on dry matter accumulation at harvest (g plant^{-1}) of cluster bean.

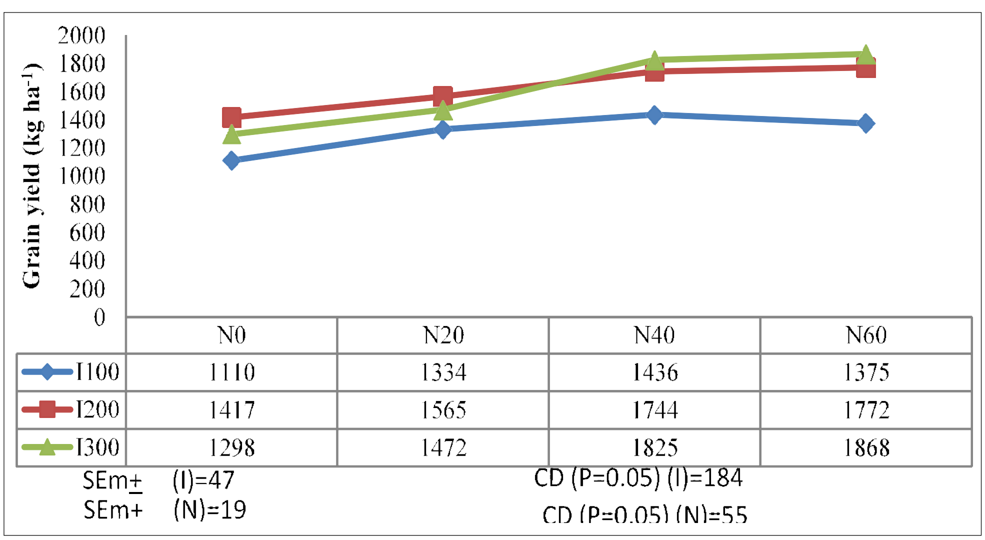

Fig 2: Combined effect of irrigation and nitrogen levels on grain yield (kg ha^{-1}) of cluster bean.

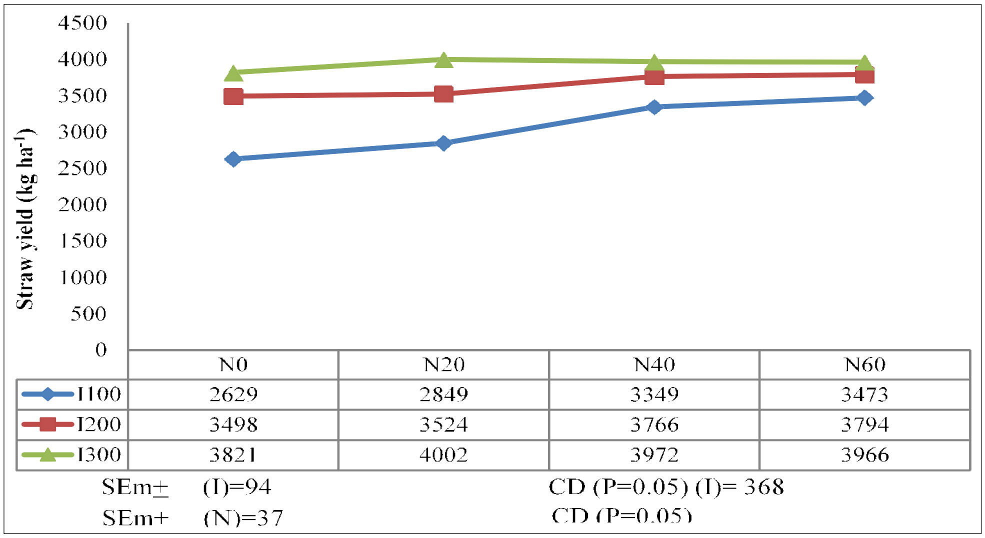

Fig 3: Combined effect of irrigation and nitrogen levels on straw yield (kg ha^{-1}) of cluster bean.

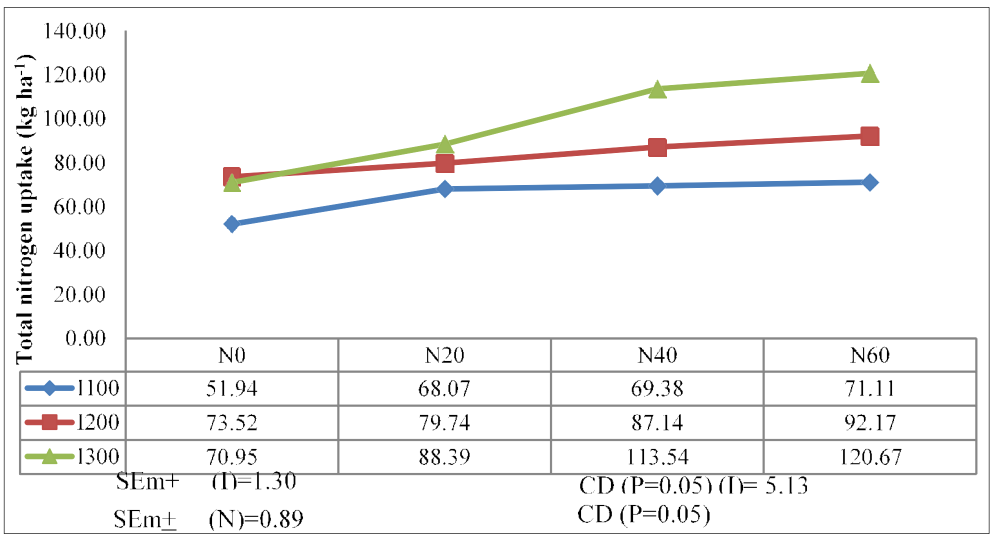

Fig 4: Combined effect of irrigation and nitrogen levels on total nitrogen uptake (kg ha^{-1}) of cluster bean.

Combined effect of irrigation levels and nitrogen levels

Irrigation along with nitrogen levels significantly influenced the dry matter accumulation at harvest, grain yield, straw yield and total nitrogen uptake of clusterbean (Fig 1-4). Irrigation at 200 mm and nitrogen rate @ 40 kg ha^{-1} significantly improved these parameters in comparison to all the other parameters. Application of 20 kg N ha^{-1} is a blanket recommendation for all the pulse crops in general. Soils of arid tract of Rajasthan in particular are hungry and thirsty which is evident by the soil nutrient status of the experimental field. Though the legume crops are considered as self-sustained crops due to their nitrogen fixing habit, but poor nutrient status in general and nitrogen in particular leads to less nitrogen fixation and poor utilization of this potential of cluster bean as a legume crop. Graded levels of irrigation boosts the crop growth which further increased the nitrogen demand of the crop as mentioned in Fig 3 with $I_{300}N_{40}$ also supports the present finding of increased performance of cluster bean with higher nitrogen levels and irrigation levels Kumar *et al*., (2015).

CONCLUSION

Based on results of experimentation, it may be concluded that irrigation with 200 mm significantly influenced the growth and yield attributes, yields, nitrogen content and uptake of clusterbean crop. Application of 40 kg N ha^{-1} significantly influenced the growth and yield parameters, yields and nitrogen content and uptake of clusterbean. Combined application of irrigation at 300 mm and nitrogen at 40 kg ha^{-1} ($I_{300}N_{40}$) could be a better option for increasing the performance and productivity of clusterbean.

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Conflict of interest: None.

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