Research Article

Effect of Different Irrigation Intervals and Sowing Methods on Growth and Productivity of Lentil Crop Grown in Semi-Arid Conditions

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Abstract | Lentil is one of the most valuable pulse crops in the world that is enriched with a good quantity of mineral and protein. Sowing methods and irrigation application are an important agronomic consideration to get maximum production of lentil crop. Therefore, this study was conducted in RCBD with a two-factor split plot to determine the impact of various levels of irrigation and sowing methods on the growth and yield of lentil. Crop was sown by three sowing methods; flat, bed and ridge and with four different irrigations levels; I_1: one irrigation, 60 days after sowing (DAS), I_2: two irrigations 30 and 60 DAS, I_3: three irrigations 30, 60 and 90 DAS and I_4: four irrigations 30, 40, 60 and 80 DAS. The variable irrigation levels and sowing methods significantly affected growth and yield of lentil crop. The maximum plant height (47.66 cm), branches per plant (11.66), pods/plant (85.33), biological yield (5204 kg/ha), 1000 grain weight (20 g) and grain yield (1145.30 kg/ha) were recorded in ridge sowing with three irrigations applied 30, 60 and 90 days after sowing (DAS) and minimum plant height (38.33 cm) branches/plant (5), pods/plant (61.33), biological yield (4820 kg/ha), 1000 grain weight (10 g) and grain yield (809 kg ha^{-1}) were recorded in flat sowing with first irrigation applied 60 DAS. The results indicated that ridge sowing method and three irrigation levels are an important practice to get the maximum productivity of lentil crop grown in semi-arid conditions of Faisalabad.

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1. Introduction

Pulses are the important source of protein and nutrient across the globe. Lentil is an important pulse crop after chickpea and it has great importance as a pulse and legume crop globally (Kazmi *et al*., 2002). Lentil has great importance as food for humans and animals owing to fact it contains an appreciable amount of proteins and nutrients (Cheng *et al*., 2019). Lentil can fix atmospheric nitrogen and increase the nitrogen content in soil and subsequently soil fertility (Humayun, *et al*., 2019). It is grown in arid region and it has a great ability to with stand harsh environmental situations such as low water and high temperature (Yadav *et al*., 2007). The lentil has different types red, green and black which is also a great source of vitamin B-complex and dietary fiber (Lardy and Anderson, 2009).

The pulses production in Pakistan is very low because the cultivated area under pulses is less as compared to other major crops (Ahmad *et al*., 2021). Moreover, poor agronomic practices including lack of good quality seed, land preparation, inappropriate sowing and irrigation method, along with diseases and insects attacks are the major problems for lower pulses production in Pakistan (Ahmad *et al*., 2021). During the growth of pods and seeds, a sufficient supply of moisture substantially increased the crop yield and grain production (Assaduzaman *et al*., 2008). However, water deficiency induced serious alterations in plant physio-biochemical and metabolic processes which in turn caused huge yield losses (Hassan *et al*., 2017, 2020a; Mehmood *et al*., 2021; Zahra *et al*., 2021; Batool *et al*., 2022). Moreover, water shortage also contracts the cells and compact the soil which adversely affect the ion water and nutrient transportation (Mahajan and Tuteja, 2005). Water stress also induced production of ROS that damage membrane, proteins and other major molecules of plants (Chattha *et al*., 2021; Dustgeer *et al*., 2021; Imran *et al*., 2021; Seleiman *et al*., 2021; Sultan *et al*., 2021). Although the lentil is drought tolerant crop, but irrigation application can significant increase its yield (Soltani *et al*., 2001). In addition, lentil is cultivated as irrigated crop to improve its yield and to attain maximum potential of the crop (Erman *et al*., 2011).

Sowing method is one of the indispensable actions in agricultural operations and skill of seed placing in the soil has significant importance in achieving high yield. Sowing method affects the interception of radiation and moisture extraction from soil (Rehman, 2002). Among different sowing techniques, raised bed planting is an effective agronomic intervention particularly in high rainfall and irrigated areas to minimize the damage caused by waterlogging, especially in rainy-season. In pigeonpea, ridge and furrow method of planting reduced the disease incidence (Chauhan *et al*., 2005). Further, better drainage under raised bed planting also minimizes the risk of root rots and collar rot diseases (Chaudhary *et al*., 2014). Bed sowing also saves the irrigation water and costly inputs like seeds and fertilizers (Kumar *et al*., 2012). Yield enhancement in pulses like pigeonpea, lentil and chickpea is also observed owing to better nodulation and crop growth under raised bed (Kumar *et al*., 2015). It is widely known that line planting in suitable rows is the most effective method for increasing yield (Ansari *et al*., 2000). The sowing of lentil in ridge has significant effect on the production of lentil where the soil moisture is high because ridge provided good drainage condition (El-Ashry *et al*., 2009). Though, broadcasting is still the most common technique of lentil production, and it is one of the most significant yield limiting factors. We hypothesized that application irrigation can improve lentil growth and production under bed sowing. Therefore, present research was performed to determine the influence of diverse irrigation intervals and sowing methods on growth and yield of lentil crop grown in semi-arid conditions.

2. Materials and Methods

2.1 Site of experiment

The current research was performed to observe the response of lentil crop to different sowing method and irrigation at the Agronomic Research Area, University of Agriculture Faisalabad during winter, 2020. The studied site had hot and humid summer (Hassan *et al*., 2019, 2020b) with dry winter whereas; overall research area is characterized with semi-arid climatic region.

2.2 Experimental treatments

The experiment was performed in RCBD with a two-factor split plot layout having three replications. Experimental treatments comprised of different irrigations levels; 1 irrigation (60 DAS), 2 irrigations (30 DAS and 60 DAS), 3 irrigations (30 DAS, 60 DAS and 90 DAS) and 4 irrigations (30 DAS, 40

DAS, 60 DAS and 80 DAS) and different sowing methods; flat sowing, bed sowing and ridge sowing.

2.3 Crop husbandry

The field was prepared by one rota-vator and two cultivations (by using cultivator) followed by planking to prepared seedbed. The seed @ 20 kg ha^{-1} was used in all methods and the fertilizers were used at rate of 30:60:25 (N: P: K) kg ha^{-1}. All potash and phosphorus was applied at sowing and remained N was used in two splits; one dose was applied in first irrigation and second dose used at flowering stage. Urea (46% N), single super phosphate (SSP: 18% P) and sulphate of potash (SOP: 50% K) are fertilizer source was used for N: P: K, respectively.

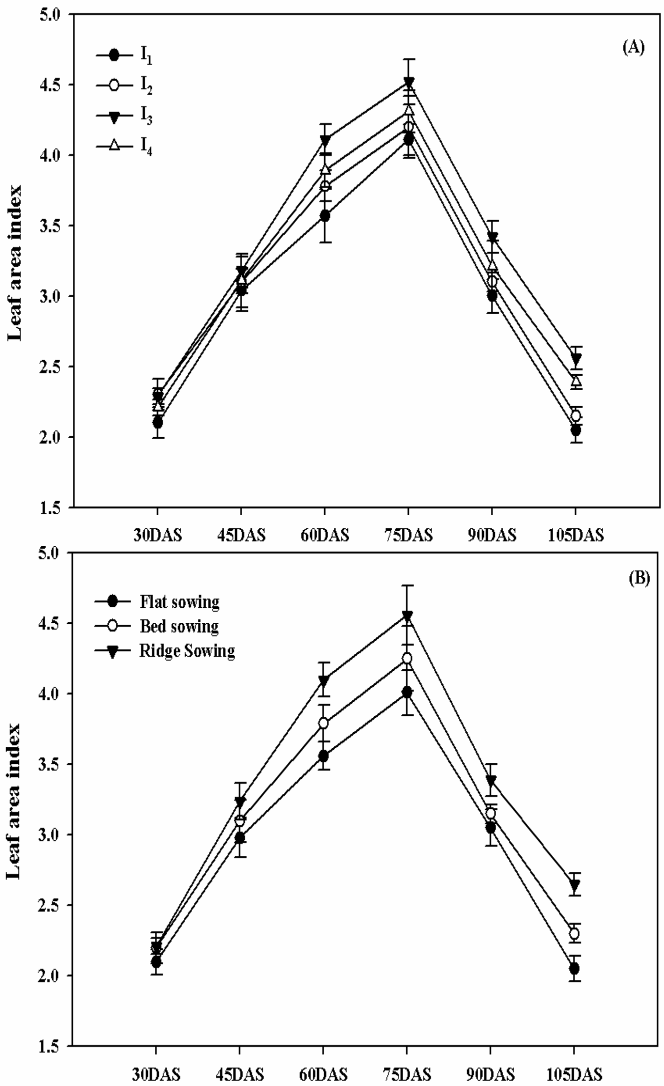

Figure 1: Effect of different irrigation levels (A) and sowing methods (B) on leaf area index of lentil. I_1: irrigation applied after 60 DAS, I_2: irrigation applied after 30 and 60 DAS, I_3: irrigation applied after 30, 60 and 90 DAS, I_4: irrigations applied after 30, 40, 60 and 80 DAS.

2.4 Procedure for recording observations

Plants were harvested from the unit area from each plot and then leaves were detached from the branches and weighed. A sub sample of 2 g leaves was taken to measure and leaf area index (LIA) was measured with procedure of Watson (1947). Moreover, leaf area duration (LAD) was calculated by the method of Hunt (1979). Moreover, crop growth and net assimilate rates were measured with methods of Hunt (1979). Five plants in each plot were marked and their height was measured along with counting the number of branches and nodes per plant and averaged. Likewise, 10 pods from different plants in each plot were taken and pods were counted and averaged. The plots were harvested for determination of grain and biomass production. Moreover, A sub-sample of 1000 grains from harvested grains were taken and 1000 GW was determined. Finally, harvest index (HI) was determined as a ratio of grain and biological yield.

2.5 Statistical analysis

The data was analyzed statistically by using the fisher's analysis of variance methods (Steel *et al.*, 1997) and means of treatment were compared by using LSD test at 5 % level of probability.

3. Results and Discussion

Irrigation frequency and sowing methods had significant impacts on the LAI. The maximum LAI was recorded with application of three irrigations (after 30, 60 and 90 DAS) and lowest was noticed in one irrigation (after 60 DAS), whilst amongst the sowing methods, maximum LAI was attained with ridge sowing method and lowest was reported with flat sowing method (Figure 1). The application of irrigation increases nutrient uptake which in turn improve leaves production therefore resulting in more LAI. Ridge sowing method improved the good environment for the roots which ultimately improved the leaves of plant and consequently, increased the LAI and LAD (Yadav and Singh, 2014). The maximum LAD throughout growing period was recorded with three irrigations (after 30, 60 and 90 DAS) and lowest was recorded in one irrigation (after 60 DAS), whilst ridge sowing methods had the maximum LAD whilst flat sowing had the lowest LAD (Figure 2). The maximum LAD was noticed with three irrigations and ridge sowing method. The application of three irrigations significantly increased the LAI which resultantly increased the LAD owing to facto LAD is product of LAI. Ridge sowing method improve the good environment for the roots which ultimately improve the leaves of plant and increase the LAI and LAD Rathore *et al*. (2006) also found same results.

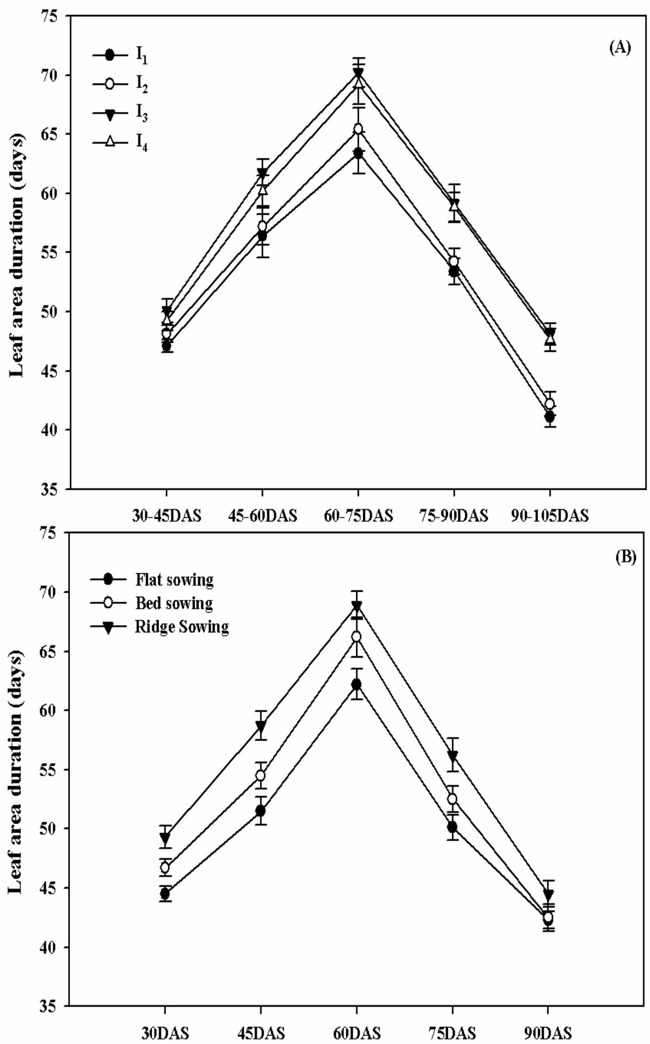

Figure 2: Effect of different irrigation levels (A) and sowing methods (B) on leaf area duration of lentil. $I_{1:}$ irrigation applied after 60 DAS, I_2: irrigation applied after 30 and 60 DAS, I_3: irrigation applied after 30, 60 and 90 DAS, I_4: irrigations applied after 30, 40, 60 and 80 DAS.

The CGR increased progressively over the time and reached to highest value after 60-75 DAS. The maximum CGR during growing period was recorded in I3 (after 30, 60 and 90 DAS) and lowest was recorded in one irrigation (Figure 3). Moreover, in sowing methods, maximum CGR was recorded in ridge and lowest was recorded in flat sowing. After 60-75 DAS the CGR also started decreasing and maximum reduction was reported for one irrigation and lowest reduction was recorded in three irrigations levels. The increase in LAI increased the light

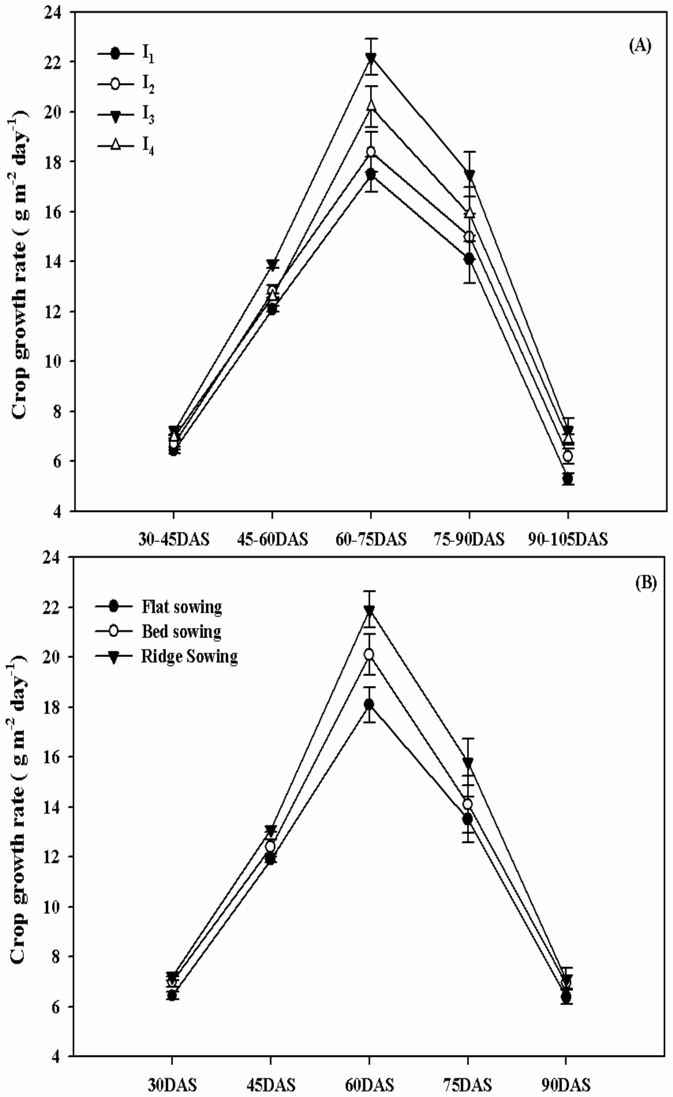

Figure 3: Effect of different irrigation levels (A) and sowing methods (B) on crop growth rate of lentil. $I_{1:}$ irrigation applied after 60 DAS, I_2: irrigation applied after 30 and 60 DAS, I_3: irrigation applied after 30, 60 and 90 DAS, I_4: irrigations applied after 30, 40, 60 and 80 DAS.

harvesting and produce more assimilates which leads to better dry matter production consequently better CGR. Total dry matter production was more responsive to irrigation that caused a large increase in dry matter production (McKenzie *et al*., 1985). The maximum NAR (6.21 g m-2 day^{-1}) was recorded with I_3 (30, 60 and 90 DAS) followed by I_4 (30, 40, 60 and 80 DAS) and lowest NAR (5.06 g m-2 day^{-1}) was recorded in I_1 where one irrigation was applied. Sowing methods also had significant difference as maximum NAR (5.73 g m-2 day^{-1}) was recorded with the ridge sowing that is followed by bed sowing and lowest NAR (5.44 g m-2 day^{-1}) was noted with flat sowing. The maintenance of moisture contents with ridges helped the plants to produce the good assimilates production which resulted in increase in LAI. The increase in LAI leads to more light harvesting which favors better dry matter production thus resulting in higher NAR (Hari *et al*., 2011).

Table 1: Effect of different sowing methods and irrigation levels growth and yield traits of lentil crop.

Irrigations levels	NAR g m^{-2} day^{-1}	PH (cm)	BPP	NPP	GPP
I_1	5.06D	39.77D	5.33D	61.33C	1.00C
I_2	5.18C	44.33B	6.66C	68.44B	1.22BC
I_3	6.21A	47.66A	9.22A	77A	2.11A
I_4	5.83B	43.00C	8.11B	76.33A	1.77AB
LSD≤0.05P	0.11	1.15	0.59	3.66	0.76
Sowing methods					
Flat sowing (FS)	5.44C	43.16B	6.50B	68.16C	1.50A
Bed sowing (BS)	5.55B	43.16B	7.41A	69.58B	1.25B
Ridge sowing (RS)	5.73A	44.75A	8.08A	74.58A	1.83A
LSD≤0.05P	0.09	0.82	0.66	1.08	0.43
Interaction					
I_1 × FS	4.98	38.33fg	5.00d	61g	1.66
I_1 × FS	5.10	47.66a	5.33d	67.33f	2.33
I_1 × FS	6.11	48.33ab	7.33bc	71de	2.67
I_1 × FS	5.55	37.33g	8.33b	73.33cd	2.33
I_2 × BS	5.08	39.33f	5.66d	61.33g	1.67
I_2 × BS	5.12	39.00fg	7.00c	68.66ef	1.33
I_2 × BS	6.23	47.66ab	8.66b	74.66c	2.00
I_2 × BS	5.78	46.66bc	8.33b	73.66c	2.33
I_3 × RS	5.12	41.66e	5.33d	61.66g	1.33
I_3 × RS	5.33	45.33cd	7.66bc	69.33ef	2.00
I_3 × RS	6.30	48.33abc	11.66a	85.33a	2.67
I_3 × RS	6.17	45.00d	7.66bc	82b	2.33
LSD≤0.05P	NS	1.76	1.33	2.16	NS

I_1: irrigation after 60 DAS; I_2: after 30 and 60 DAS; I_3: after 30, 60 and 90 DAS; I_4: after 30, 40, 60 and 80 DAS. NAR: net assimilation rate; PH: plant height; BPP: branches per plant; NPP: nodes per plant; GPP: grains per plant. Means with different letters differed at 0.05 P level.

The maximum plant height, branches/plant, nodes/plant and grains/pod were recorded with I_3 (30, 60 and 90 DAS) and lowest values for these parameters were recorded in I_1 irrigation after 60 DAS (Table 1). The application of proper amount of irrigation water favors the better assimilates production which improve the plant growth in terms of better plant height (Adeoye *et al*., 2014). The maximum plant height was recorded in ridge sowing that remained same with bed sowing whereas; flat sowing gave the minimum plant height. Ridges and beds ensured the better root growth which facilitate the better nutrient and water uptake and ensured the better assimilates production, in resulting plants got maximum height as compared to flat sowing (Hassan *et al*., 2019). The number of branches per plant has association with irrigation because irrigation improves the vegetative growth of plant and ultimately increases branches per plant (Ali *et al*. 2003). The maximum branches, nodes per plant and grains/pod was obtained in ridged sowing and ridges provide the better environment for roots development and roots can uptake more water which improve the plant growth and increase branches per plant (Al-Issawi, 2016).

Table 2: Effect of different sowing methods and irrigation levels yield components and yield of lentil crop.

Irrigations levels	1000 GW (g)	BY (kg ha^{-1})	GY (kg ha^{-1})	HI (%)
I_1	9.72D	4822.1C	870.4D	18.052C
I_2	14.00C	4967.7B	910.9C	18.326C
I_3	17.33A	5046.7A	1007.1A	19.920A
I_4	15.44B	4995.6B	940.9B	18.826B
LSD≤0.05P	1.38	29.86	18.86	0.42
Sowing methods				
Flat sowing (FS)	13.66B	4895.3C	846.1C	17.28C
Bed sowing (BS)	13.37B	4964.4B	933.8B	18.80B
Ridge sowing (RS)	15.33A	5014.2A	1017A	20.25A
LSD≤0.05P	1.12	9.40	11.95	0.20
Interaction				
I_1 × FS	10e	4820e	809.3h	16.793e
I_1 × FS	14.33cd	4891d	835.0gh	17.070f
I_1 × FS	15.67bc	4925c	889.3f	18.060e
I_1 × FS	14.66bcd	4945c	850.7g	17.070f
I_2 × BS	9.50e	4830e	892.3ef	18.477de
I_2 × BS	13.00d	4998.3b	918de	18.367de
I_2 × BS	16bc	5011b	986.7c	19.690c
I_2 × BS	15.00bcd	5018.3b	938.3d	18.697d
I_3 × RS	9.66e	4816e	909.7ef	18.887d
I_3 × RS	14.66bcd	5013.3b	979.7c	19.540c
I_3 × RS	20.33a	5204a	1145.3a	22.01a
I_3 × RS	16.66b	5023.3b	1033.7b	20.58b
LSD≤0.05P	2.30	18.81	27.08	0.59

I_1: irrigation after 60 DAS; I_2: after 30 and 60 DAS; I_3: after 30, 60 and 90 DAS; I_4: after 30, 40, 60 and 80 DAS. GW: grain weight; BY: biological yield; GY: grain yield; HI: harvest index. Means with different letters differed at 0.05 P level.

The maximum grain weight, grain and biomass productivity and harvest index was recorded from plots where irrigations were applied 30, 60 and 90 DAS and minimum values were recorded with irrigation application after 60 DAS (Table 2). In case of sowing methods bed sowing performed appreciable well with maximum GW, grain and biomass productivity where flat sowing remained the poor performed with minimum GW, grain and biomass productivity. In I_3 the maximum 1000 grain weight was recorded because proper amount of water plays an important role in transportation of assimilates from leaf to grain and resulted in production of bolder seeds with more weight. Maximum 1000 grain weight was recorded ridge sowing because the ridges provides the better environments to plant for better growth and increase the photosynthetic activity of leafs which ultimately more assimilates move into the seed and increase the grain weight (Alam *et al*., 2020; Chattha *et al*., 2020). The total biomass increases when the I_3 were applied because proper amount of water helps in the plants metabolism and photosynthetic activity as compared to the minimum irrigations and resulted in production of more biomass (Mondal *et al*., 2012). Ridge sowing method provided better environment for plant root growth and absorbed more nutrient and increase biomass production These results are same with findings of Hussain (2002) who noted maximum biological yield in ridge sowing method as compared to flat sowing method. The application of proper amount of irrigation water favors the better assimilates production which favors the better growth in terms of better grain yields (Assaduzaman *et al*., 2008). The maximum grain yield was recorded in ridge sowing method because in ridges the roots moves downward easily and uptake more nutrients and water which ultimately increased the final yield (El-Tawwab *et al*., 2007).

Conclusions and Recommendations

The different irrigation levels and sowing methods significantly affected the growth and productivity of lentil crop. The application of three irrigations 30, 60 and 90 DAS along with sowing on ridges significantly improved the lentil growth and productivity. Therefore, irrigation application 30, 60 and 90 DAS along with ridge sowing can be used to get maximum productivity of lentil crop growth in semi-arid conditions of Faisalabad. However, more studies are direly needed to optimize the time of irrigation for lentil crop under different climatic conditions before marking its recommendation for farmers.

Novelty Statement

Limited information is available about the effect of different irrigation intervals and sowing methods on growth and productivity of lentil crop. Therefore, this study was performed to determine impact of different irrigation intervals and sowing methods on the growth and yield of lentil crop.

Author's Contribution

Junaid Ali: Performed experiment.
Muhammad Umer Chattha and Imran Khan: Conceived and designed the experiment and wrote original draft.
Muhammad Nawaz, Muhammad Ilyas, Muhammad Bilal Chattha, Muhammad Arshad, Muhammad Akram, Mina Kharal, Ehsan Ullah, Muhammad Talha Aslam, Fareeha Athar, Ayesha Mustafa and Muhammad Umair Hassan: Reviewed and edited.

Conflict of interest

The authors have declared no conflict of interest.

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