Indian Journal of Ecology (2024) 51(2): 384-390
DOI: https://doi.org/10.55362/IJE/2024/4247

Manuscript Number: 4247
NAAS Rating: 5.38

Variable Irrigation Phasing and Establishment Techniques in Chickpea (*Cicer areitinum* L.) under Sprinkler and Flood Irrigation System in Tarai Region of Uttarakhand

Gurvinder Singh, Rupanjali Baurai, Mohini Singh and Sambita Bhattacharyya

Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar-263 145, India
E-mail: guruagronomy@gmail.com

***Abstract*:** Chickpea is a water sensitive crop, hence requires judicious water management to harness reasonable productivity from this crop. Therefore, a study was conducted in sandy loam soil to find out the effect of irrigation schedules, establishment methods and irrigation methods on yield, water saving, IWP and energy use efficiency of chickpea in sandy loam soil at GBPUAT, Uttarakhand from 2016-17 to 2018-19. The experiment consisted of three irrigation schedules (irrigation at branching, pod development and at both stages), two establishment methods (flat and raised bed) and two irrigation methods (flood and sprinkler irrigation) . Irrigation at both branching and pod development stages produced the highest chickpea grain yield. One irrigation at either stage saved 50% of irrigation water compared to irrigation at both stages. Raised bed and sprinkler irrigation method saved 18.8 and 29.5%irrigation water, respectively. Raised bed method and sprinkler irrigation method showed their superiority over flat bed and flood irrigation, respectively for irrigation and economic water productivity. Energy use efficiency of irrigation scheduled at either stage of crop growth was higher than irrigation at both stages but at the expense of yield. Raised bed method and sprinkler irrigation method were most energy efficient.

Keywords: Chickpea, Grain yield, Raised bed, Sprinkler irrigation, irrigation schedule, Water saving, Energy

Chickpea is the major pulse crop of India sharing approximate 37% in total area under pulses (Indiastat 2021) and is primarily grown as rainfed crop that typically rely on the residual soil moisture from the preceding season (Ramamoorthy et al 2017). It may be subjected to moisture stresses (excess and deficit) due to low and erratic distribution of winter rainfall which affects optimum plant stand in early stage and poor seed setting during later stages. Chickpea may also face terminal drought leading to forced maturity. Conventionally, chickpea is irrigated by check basin irrigation method (5-6 cm depth) in flat land configuration. This approach requires huge amount of water and is usually detrimental for root growth and nodule formation due to water stagnation in the root zone. Chickpea plants turn yellow due to decrease in photosynthesis under flooding which can hamper the overall crop growth and productivity (Komatsu et al 2021). Usually root growth and nodulation of chickpea; irreversibly destroyed by mid and terminal water logging (Worku 2016). The best possible approach to alleviate the illustrated problems is to provide controlled depth of irrigation which can be ensured by modifying land forms and adopting suitable irrigation method. Growing of chickpea on raised beds could improve the management of irrigation water and depth of applied water could be controlled more precisely. Crop roots do not have to face stagnated water conditions so plant growth does not hamper and ultimately crop yield increases. Kumar et al (2015) observed 20.2% increase in grain yield of chickpea grown on 75 cm wide raised beds as compared to flat bed planting. Sprinkler irrigation has the provision to apply controlled quantity of irrigation water and this not only saves a substantial amount of water but sensitive crops like pulses are unlikely to suffer. The importance of applying irrigation would be dented if not given at critical stages, as irrigation at these stages results into maximum output per unit water applied. Irrigation at flowering and pod development stages to chickpea increased grain yield to the tune of 7 and 27%, respectively over no irrigation (Singh et al 2015). Considering the above, the present investigation was carried out to verify the hypothesis that bed sowing, proper irrigation scheduling and sprinkler irrigation in chickpea would save irrigation water besides improving the crop and irrigation water productivity.

MATERIAL AND METHODS

Experimental site and soil: A three-year field experiment was conducted during Rabi season through 2016-17 to 2018-19 at GBPUAT, Pantnagar which is located at 29°N latitude and 79.5°E longitude and at an altitude of 243.8 m above mean sea level in the Tarai region of Himalayas (Fig. 1). The soil of the experimental field was sandy loam in texture and neutral in reaction (pH-7.5), medium in organic carbon (0.71%), low in available nitrogen (180.4 kg/ha), high in available phosphorus (22.8 kg/ha) and medium in potassium (265.6 kg/ha). Field capacity moisture of the field was 20.4% and PWP moisture was 8.4%.

Weather conditions: The study site is characterized by sub-humid and sub-tropical climate. Region has cold winters and hot, dry summers. During summer season, the maximum temperature exceeds 40°c in June while in winter, the minimum temperature touches 0 °c occasionally during January. The mean weekly weather data prevailing during the course of experiment (November to April of 2016-17, 2017–18, 2018-19) were obtained from the meteorological observatory located at Norman E. Borlaug Crop Research Centre, Pantnagar. During the first year of the study (2016-17), 75.2 mm rainfall was received against total water loss of 269 mm through evaporation. Due to good rainfall in the month of January (60.4mm), irrigation was skipped at the branching stage (Table 1). This way, crop under branching stage treatment was rainfed. In II and III year, the rainfall received during the growing period was 13.6 and 57.8 mm, respectively.

Treatments and experimental design: Experiment comprising three irrigation schedules (irrigation at branching stage, pod development stage and both at branching and pod development stages), 2- establishment methods(flat and raised bed) and two irrigation methods (flood and sprinkler irrigation) was arranged in factorial RBD design with three replications. Thus, the experiment was comprised of total 12 treatment combinations.

Crop management: Land preparation as well as execution of treatments was done manually. In flat bed sowing, furrows were opened manually with a furrow opener at 30 cm distance. Chickpea variety "Pant gram-186"was sown @ 80 kg/ha in the first fortnight of November and harvested in the first fortnight of April. Raised beds were prepared manually with spade having a 90 cm distance between centers of one furrow to another furrow. The width of the bed top was 65 cm having a furrow width of 25 cm. Three rows of chickpea were accommodated per bed, so that plant population remained the same in both the land configurations. The crop grown on flat beds was fertilized with 25 kg N/ha, 60 kg P_2O_5/ha and 40 kg K_2O/ha while two third doses of fertilizers were applied in raised bed conditions as compared to flat bed. For sprinkler irrigation, four sets of micro sprinklers having diameter 4.0 m were placed per plot. The irrigation depth was 5 cm in flat and 3.5 cm in raised bed. The irrigation depth of 3 cm was maintained in sprinkler method for both the establishment methods. Measured quantity of irrigation water was worked out by using standard flow (discharge) rate equation for open channel. The time of irrigation application was calculated as follows:

Time (minutes) = [Depth of irrigation (mm) x area of plot (m^2)]/discharge per min (L min^{-1})

Yield estimation: The grain yield was estimated from a harvested area of 8.0 m^2 (2.1 m × 4 m). The grain biomass yield was adjusted at 14% moisture content and expressed in Mg ha^{-1}

Irrigation water saving, irrigation water productivity and economic water productivity: Total irrigation depth for each year was calculated by summing up the total amount of irrigation water applied in every treatment (Table 3). Water saving in treatments where irrigation was provided at a single stage was calculated against the treatment where irrigation was provided at both stages. For establishment methods, water saving was calculated in raised bed against flat bed method while water saving through sprinkler irrigation was worked out against flood method (Table 3). Irrigation water productivity (IWP) and economic water productivity (EWP) were calculated and the mean of the three years is presented. For the treatment where irrigation scheduling was done only at branching stage, the mean of the year 2017-18 and 2018-19 was taken as crop received rainfall at branching stage in the first year of the study.

$$\text{IWP (kg/ha - mm)} = \frac{\text{Grain yield (kg/ha)}}{\text{Total irrigation applied (mm)}}$$

$$\text{EWP (Rs/mm)} = \frac{\text{Net return (Rs/ha)}}{\text{Total irrigation depth (mm)}}$$

Economics*:* The economics of treatments was computed on the basis of prevailing market rates of the different commodities.

Energy analysis: Energy used and produced in each treatment was computed using the standard procedure.

Input energy: Input energy was calculated by multiplying energy equivalent per unit of input (Table 1) with the amount of inputs (Table 2) used in various operations performed for growing chickpea under different treatments.

Output energy: Output energy of grain was calculated by multiplying grain yield (kg/ha) obtained under respective treatment with 14.7 *MJ/kg.*

Energy parameters: By using input energy and output energy, energy use efficiency, specific energy and energy productivity were calculated as follows.

$$\text{Energy use efficiency} = \frac{\text{Total energy output (MJ/ha)}}{\text{Total energy input (MJ/ha)}}$$

$$\text{Energy productivity (kg/MJ)} = \frac{\text{Grain yield (kg/ha)}}{\text{Total energy input (MJ/ha)}}$$

$$\text{Specific energy (MJ/kg)} = \frac{\text{Total energy input (MJ/ha)}}{\text{Grain yield (kg/ha)}}$$

Net energy gain (MJ/ha) = Energy output (MJ/ha) – Energy input (MJ/ha)

Statistical analysis: Data were analyzed using analysis of variance technique appropriate to Factorial RBD using R software. The least significant differences (LSD) at 5% level of probability were calculated for testing the significance of difference between any two means.

RESULTS AND DISCUSSION

Grain yield: Chickpea grain yield did not exhibit significant variations due to change in establishment methods as well as irrigation methods. Average grain yield in flat (1562 kg/ha) and raised bed (1572 kg/ha) establishment methods was almost comparable. Sprinkler irrigation produced 4.4 % higher grain yield as compared to the flood method. Availability of optimum soil moisture is crucial for getting higher yield in chickpea. Management options such as sowing of seeds on raised bed or use of sprinkler irrigation method ensure to maintain moisture at optimum levels. Relatively higher chickpea grain yield under sprinkler irrigation compared to flood irrigation method was due to maintaining good aeration in root zone as compared to flooding even after providing the required amount of water for crop growth throughout the growing season. Micro sprinklers provided optimum depth of irrigation which resulted in adequate soil moisture status in the root zone throughout the crop growth period. Moreover, the micro-climatic conditions in terms of reduced temperature and increased relative humidity in crop canopy are also favored by applying water in sprinkle form. Further, relatively more compact soil in the check basin plots may pose mechanical resistance and hinder exchange of air in the rhizosphere leading to reduced crop yields.

Irrigation applied at both branching and pod development stages did not increase the grain yield significantly over irrigation at pod development stage only but out-yielded the

Table 1. Energy equivalents of different inputs and output

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Reference
Input			
Human (adult man)	Man- hour	1.96	Rafiee et al (2010)
Diesel	litre	56.31	Canakci and Akinici (2006)
Electricity	Watt	16.93	Mobtaker et al (2010)
Chickpea seed	kg	14.7	Kitani (1999)
Water	m3	1.02	Rafiee et al (2010)
Fertilizer N P K	kg	60.6 11.1 6.7	Gundogmus (2006)
Machinery Electric motor Farm machinery	kg	68.40 62.10	Rafiee et al (2010)
Output			
Chickpea grain	kg	14.7	Kitani. (1999)

Table 2. Crop management details

Treatment	No. of tillage operations			Seed rate (kg/ ha)	NPK dose	Total irrigation volume (m^3) and time taken (hr)	Drying and packagi ng
	Harrowing	Planking	Raised bed formation				
Vegetative+flat+ flood	03	1	-	80	25:60:40	500 (15hr)	4 labor
Vegetative+flat+ sprinkler	03	1	-	80	25:60:40	300 (9hr)	4 labor
Vegetative+raised bed+flood	03	1	1	80	17:40:27	350 (10.5hr)	4 labor
Vegetative+raised bed+sprinkler	03	1	1	80	17:40:27	300 (9 hr)	4 labor
Pod devel.+flat+flood	03	1	-	80	25:60:40	500 (15 hr)	4 labor
Pod devel.+ flat+ sprinkler	03	1	-	80	25:60:40	500 (15 hr)	4 labor
Pod development+raised bed+flood	03	1	1	80	17:40:27	350 (10.5 hr)	4 labor
Pod development+raised bed+sprinkler	03	1	1	80	17:40:27	300 (9 hr)	4 labor
Both+flat+flood	03	1	-	80	25:60:40	1000 (30 hr)	4 labor

treatment where, irrigation was applied only at vegetative stage. Irrigation scheduled at both branching and pod development stages produced significantly higher grain yield as compared to irrigation at branching stage. Irrigation at both stages increased the grain yield by 13.2 and 8.7% over irrigation at only vegetative and pod development stage, respectively. Irrigation imposed at the pod development stage only also improved chickpea grain yield by 4.2% over branching stage irrigation. Irrigation provided at the pod development stage or both the stages contributed to better translocation and partitioning from source to sink resulted in better yield attributes and subsequently the crop productivity. It may infer that residual moisture from previously grown crop; can fulfill the crop demand during early phases of crop growth but during the pod filling stage the crop may experience terminal drought. This situation could hamper the seed filling. Singh et al. (2010) also reported the terminal moisture stress is the major constraint in achieving potential yield of chickpea. Irrigation provided only at vegetative stage was not able to bring irrigation induced yield advantage as moisture stress at subsequent stages can disrupt the metabolism of carbohydrates. It might have resulted in decreased transportation of water soluble carbohydrates (El Habti et al. 2020).Moisture stress at pod development stage of legumes delays the cessation of flowering and causes embryo abortion thereby reduces the overall pod development and ultimately results in reduction of grain yield (Ntukamazina et al., 2017). Irrigation provided only at pod development stage also experienced slightly lower productivity than the treatment where irrigation provided at vegetative as well as pod development stage.

Irrigation water saving: For first year of the study, irrigation water saving due to application of irrigation at various irrigation stages was not computed as crop received substantial amount of rainfall (60.4mm) in the month of January, hence supplemental irrigation during the vegetative growth phase was skipped. In the years 2017-18 and 2018-19; single irrigation given either at branching or pod development stage saved 50.0% irrigation water as compared to two irrigations at both branching and pod development stages due to net saving of one irrigation. The three years' study suggested that sowing chickpea on raised beds saved around 18.8 % irrigation water as compared to flat sowing. Chickpea irrigated through sprinkler method saved about 29.5 % irrigation water against flood irrigation method. Chickpea grown on raised bed saved irrigation water as compared to flat bed as in case of raised bed sowing; less depth of irrigation water (3 cm) was applied only in the furrows. It ultimately resulted in reduction in total volume of applied water. Kumar et al. (2015) also reported 26.2 % irrigation water saving in chickpea crop grown on raised beds as compared to flat bed sowing. Water saving in sprinkler irrigation against flood method was observed as water distribution by sprinkler method was more even and it applies less irrigation depth (3 cm) than flood method (5 cm) to irrigate the same area.

Irrigation water productivity: Irrigation water productivity indicated that single irrigation at pod development stage recorded the maximum irrigation water productivity (42.4 kg/ha-mm) followed by irrigation at branching stage (39.8 kg/ha-mm). Chickpea irrigated twice at vegetative and pod development stages recorded the lowest irrigation water productivity (31.4 kg /ha-mm). Irrigation at pod development did not bring significant reduction in the yield from the treatment where irrigation was applied at both vegetative and pod development stages; as well as irrigation water applied was 50% lesser which ultimately enhanced irrigation water productivity. Raised bed land configuration (40.7kg /ha-mm) enhanced the irrigation water productivity by 19.4% over flat sowing (32.8 kg /ha-mm). Crop irrigated through sprinklers recorded 32.9% higher irrigation water productivity than flood irrigation method. Comparable yield to flat method was produced under raised bed method with less application of water so irrigation water productivity was higher. Similar trend was obtained for the sprinkler irrigation method as compared to flood irrigation.

Economic water productivity: Economic water productivity was maximum (1072 Rs. /mm) when irrigation was applied at the pod development stage with higher net return per mm of water than two irrigations at vegetative and pod development stages. Raised bed and sprinkler irrigation earned 183 and 450 Rs. /mm higher economic water productivity than flat sowing and flood irrigation, respectively. Economic water productivity of raised bed as well as sprinkler irrigation method was also higher as EWP is the cumulative function of net return as well as total irrigation depth by the respective treatment. Relatively lower irrigation depth with good net return resulted in higher economic water productivity under raised bed and sprinkler irrigation treatments.

Economics: The highest net return (46470 Rs. /ha) was obtained when two irrigations were applied at both branching and pod development stages and was significantly higher than single irrigation either at vegetative or pod development stage. Flat sowing of chickpea gave almost similar net return with a very little margin of 462 Rs. /ha over raised bed sowing method. Net return was also statistically at par due to use of flood or sprinkler irrigation methods. B:C was maximum (1.52) with twice irrigation at branching and pod development stages and was 17.8 and 15.1 % higher than single irrigation either at branching or pod development stage, respectively.

Input energy: Irrigation applied at both stages; required about 34.9% more energy than the irrigation at either stage of the crop growth. Among different establishment methods; the crop grown on raised bed was more energy efficient as for crop growing on flat bed 21.7% more input energy was needed. Input energy consumption in flood method of irrigation was about 30.7% more than sprinkler irrigation method (Table 5). Despite the requirement of additional energy of 610 MJ/ha for raised bed preparation, the highest input energy (20161 MJ/ha) was observed when sowing was done on flat bed and flood irrigation was provided at both stages of crop growth. In this treatment, the maximum share (65.2%) in total energy was of irrigation water energy. Minimum input energy (9606 MJ/ha) was observed for the treatment where sowing was done on flat bed and a single irrigation was provided by using sprinkler method (Fig. 2). Despite more energy consumption for land preparation in the raised bed method, total input energy was lower than the flat bed method as irrigation water energy was considerably low. In single irrigation by flood method under raised bed as well as flatbed conditions an additional volume of 150m^3 water was provided in flat bed conditions along with 4.5 more hours for operating the pump which resulted in 96.8% increase in the irrigation water energy. Apart from this the input energy for fertilizer application was also lower under raised bed method. Input energy use under the sprinkler method was

Table 3. Irrigation depth applied and corresponding irrigation water saving in different treatments

Treatment	Irrigation depth (mm)			Irrigation water saving (%)			Mean irrigation water saving
	2016-17	2017-18	2018-19	2016-17	2017-18	2018-19	
Irrigation stage							
Branching	-	36.3	36.3	-	50	50	50
Pod development	36.3	36.3	36.3	-	50	50	50
Branching +Pod development	36.3	72.6	72.6	-	-	-	-
Establishment method							
Flat	40.0	53.3	53.3	-	-	-	-
Raised bed	32.5	43.3	43.3	18.8	18.8	18.8	18.8
Irrigation method							
Flood	42.5	56.7	56.7	-	-	-	-
Sprinkler	30.0	40.0	40.0	29.5	29.5	29.5	29.5

Table 4. Productivity, water use parameters and economics as influenced by various treatments

Treatment	Grain yield (kg/ha)	Irrigation water productivity (kg/ha-mm)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio	Economic water productivity (Rs/mm)
Irrigation schedule						
Branching	1481	39.8*	29871	37339	1.25	1029*
Pod development	1543	42.4	29608	38915	1.29	1072
Branching + Pod development	1677	31.4	30572	46470	1.52	640
L.S.D (p=0.05)	140	-	-	3794	-	-
Crop establishment method						
Flat	1562	32.8	30028	41139	1.37	842
Raised bed	1572	40.7	30356	40678	1.34	1025
L.S.D (p=0.05)	NS	-	-	NS	-	-
Irrigation method						
Flood	1533	30.2	29541	40715	1.36	783
Sprinkler	1601	45.0	30446	41101	1.35	1233
L.S.D (p=0.05)	NS	-	-	NS	-	-

*Irrigation water productivity and economic water productivity for the irrigation scheduled at branching stage is given in the form of a mean of two years as in the first year of the study there was no irrigation applied because rainfall coincided with the irrigation period

Table 5. Energy use parameters as affected by irrigation schedules, establishment methods and irrigation methods

Treatment	Input energy (MJ/ha)	Output energy (MJ/ha)	Energy use efficiency	Specific energy (MJ/Kg)	Net energy gain (MJ/ha)
Irrigation schedule					
Branching	10695	21771	2.04	7.22	11076
Pod development	10695	22682	2.12	6.93	11987
Branching + Pod development	14426	24652	1.71	8.60	10226
L.S.D (p=0.05)	-	2,212	0.19	0.78	NS
Crop establishment Method					
Flat	13109	22961	1.75	8.39	9852
Raised bed	10768	23108	2.15	6.85	12340
L.S.D (p=0.05)	-	NS	0.153	0.64	1806
Irrigation method					
Flood	13528	22535	1.67	8.82	9007
Sprinkler	10349	23535	2.27	6.46	13186
L.S.D (p=0.05)	-	NS	0.153	0.64	1806

lower than flood irrigated crops. Although additional 94 MJ/ha energy was required for installation of the micro sprinkler set up but flood method required about 51.1 and 10% more energy than the sprinkler under flat and raised bed conditions, respectively (Fig. 2).

Output energy: The highest output energy (24652 MJ/ha) was obtained with irrigation provided at both branching and pod development stages of crop growth. It was significantly higher where irrigation was provided only at vegetative stage of crop growth (21,771 MJ/ha). Output energy did not vary significantly with establishment methods and irrigation methods.

Energy use efficiency: Among irrigation scheduling the highest energy use efficiency was obtained for the treatment when irrigation was given only at pod development stage (2.12) and was significantly higher than irrigation scheduling at both stages (1.71). Energy use efficiency significantly varied for establishment and irrigation methods. Between establishment methods, the higher energy use efficiency was obtained for the raised bed method (2.15) as compared to flat bed method (1.75). The higher energy use efficiency was obtained with sprinkler method (2.27) than flood method (1.67). Despite of higher yield in irrigation scheduled at both stages of crop growth the higher energy use efficiency in the irrigation provided either at vegetative or pod development stage treatment might be due to less input energy required in these methods. Similarly, raised bed method and sprinkler method of irrigation had more energy use efficiency than flat and flood method, respectively due to less energy consumption.

Specific energy: Among irrigation schedules, the highest specific energy (8.6 MJ/kg) was for the treatment where irrigation was provided at both stages of crop growth. Specific energy of the other two methods did not vary significantly with each other. Significantly higher specific energy was in flat method of establishment (8.39 MJ/kg) and flood irrigation (8.82 MJ/kg) in establishment and irrigation methods respectively.

Net energy gain: Irrigation schedules were statistically at par for net energy. Statistically, higher net energy was observed for raised bed method (12,340 MJ/ha) and sprinkler method (13,186 MJ/ha) among treatments belonging to land forms and irrigation methods respectively. Lesser input energy consumption in raised bed method and sprinkler irrigation as compared to flat bed method and flood irrigation, respectively resulted in significantly higher net energy in both the treatments.

CONCLUSION

Scheduling of irrigation in chickpea at both branching and pod development stage is required to obtain the higher net return and B: C. However, skipping irrigation at branching can provide comparable yield with almost half amount of water use and improves irrigation water productivity. Formation of raised bed and use of micro-sprinkler do not bring yield advantage or improvement in net return but save the considerable amount of water in chickpea production. Irrigation scheduling only at branching or pod development stage, growing of chickpea in raised bed and use of micro-sprinkler for irrigation can be adopted for energy saving in chickpea production.

AUTHORS CONTRIBUTION

Dr. Gurvinder Singh: Planning and execution of the experiment at field level, writing. Rupanjali Baurai: Recording of observations. Mohini Singh: Data analysis. Sambita Bhattacharyya: Writing and editing

REFERENCES

Canakci M and Akinici I 2006. Energy use pattern analyses of greenhouse vegetable production. *Energy* **31**: 1243-1256.

El-Habti A, Fleury D, Jewell N, Garnett T and Tricker PJ 2020. Tolerance of combined drought and heat stress is associated with transpiration maintenance and water soluble carbohydrates in wheat grains. *Frontiers Plant Science* **11**: 568693.

Gundogmus E 2006. Energy use on organic farming: A comparative analysis on organic versus conventional apricot production on small holdings in Turkey. *Energy Conversion and Management* **47**: 3351- 3359.

Indiastat 2021. https://www.indiastat.com/data/agriculture/gram-or-bengal-gram-chickpea.

Kitani O 1999. *CIGR Handbook of Agricultural Engineering*. Vol. V., Energy and Biomass Engineering. ASAE Publication, St Joseph, MI. 330 pp.

Komatsu S, Maruyama J, Furuya T, Yin X, Yamaguchi H, Hitachi K, Miyashita N, Tsuchida K and Tani M 2021. Proteomic and biological analyses reveal the effect on growth under flooding stress of chickpea irradiated with millimeter waves. *Journal of Proteome Research* **20**(10): 4718-4727.

Kumar N, Singh MK, Praharaj CS, Singh U and Singh SS 2015. Performance of chickpea under different planting method, seed rate and irrigation level in Indo-Gangetic Plains of India. *Journal of Food Legumes* **28**(1): 40-44

Mobtaker HG, Keyhani A, Mohammadi A, Rafiee S and Akram A 2010. Sensitivity analysis of energy input for barley production in Hamedan Province of Iran. *Agriculture, Ecosystems and Environment* **137**(4): 367-372.

Ntukamazina N, Onwonga RN, Sommer R, Mukankusi CM, Mburu J and Rubyogo C 2017. Effect of excessive and minimal soil moisture stress on agronomic performance of bush and climbing bean (*Phaseolus vulgaris* L.). *Cognet Food and Agriculture* **3**(1): 1373414.

Rafiee S, Avval M and Mohammadi A 2010. Modeling and sensitivity analysis of energy inputs for apple production in Iran. *Energy* **35**: 3301-3306.

Ramamoorthy P, Lakshmanan K, Upadhyaya HD, Vadez V and Varshney RK 2017. Root traits confer grain yield advantages under terminal drought in chickpea (*Cicer arietinum* L.). *Field Crops Research* **201**: 146-161.

Singh AK, Singh SB, Singh AP, Singh AK, Mishra SK, Sharma and AK 2010. Effect of different soil moisture regimes on biomass partitioning and yield of chickpea genotypes under intermediate zone of J & K. *Journal of Food Legumes* **23**: 156-158.

Singh G, Ram H, Aggarwal N and Turner NC 2015. Irrigation of chickpea (*Cicer arietinum*

L.) increases yield but not water productivity. *Experimental Agriculture* **52**(1): 1-13.

Worku W 2016. Water logging effects on growth, nodulation and productivity of Desi and Kabuli chickpea (*Cicer arietinum* L.). *Ethiopian Journal of Biological Sciences* **15**(1): 55-77.

Received 25 September, 2023; Accepted 12 March, 2024