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Integrated Nutrient Management, Irrigation Scheduling and Moisture Conservation Effects on Water Use Efficiency of Garden Cress (*Lepidium sativum*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Garden cress (*Lepidium sativum* L.), a nutritious and medicinal herb widely cultivated in parts of India, is gaining importance due to its health benefits and increasing demand. However, its productivity and water use efficiency are influenced by appropriate nutrient management, irrigation scheduling, and moisture conservation practices, particularly under limited water resources. A field experiment was conducted during the Rabi seasons of 2015–16 and 2016–17 at the Soil Conservation and Water Management Farm of Chandra Shekhar Azad University of Agriculture and Technology (C.S.A.U.A&T), Kanpur, to evaluate the effects of irrigation scheduling, integrated nutrient management (INM), and moisture conservation practices on growth attributes, total water use, and water use efficiency (WUE) of garden cress (*Lepidium sativum* L.). The experiment was laid out in a split-plot design with three replications, comprising three irrigation schedules (irrigation at 35 DAS; 35 and 60 DAS; and 35 and 70 DAS), three INM treatments (100% nitrogen through fertilizer; 75% nitrogen through fertilizer + 25% nitrogen through FYM; and 75% nitrogen through fertilizer + 25% nitrogen through vermicompost + PSB), and three moisture conservation practices (control, organic residue mulch @ 4 t ha^{-1}, and weeding and hoeing + mulch @ 4 t ha^{-1}).The results revealed that irrigation scheduling, INM, and moisture conservation practices had non-significant effects on initial and final plant stand as well as weed density during both years. However, these treatments significantly influenced total water use and WUE. Irrigation at 35 and 60 DAS recorded the highest total water use, whereas irrigation at 35 and 70 DAS resulted in the highest WUE. Among INM treatments, application of 75% nitrogen through fertilizer combined with 25% nitrogen through vermicompost + PSB recorded the lowest water use and highest WUE. Moisture conservation practices significantly improved water productivity, with weeding and hoeing combined with organic residue mulch showing superior performance. Overall, integrated nutrient management along with efficient irrigation scheduling and mulching practices enhanced water use efficiency and sustainability of garden cress production.

Keywords: Chandrasur (garden cress); total water use (mm); water use efficiency (kg seed ha-1 mm-1); growth attributes; integrated nutrient management.

1. Introduction

Garden cress (*Lepidium sativum* L.) is commonly referred to as chandrasur in Hindi, halim in Marathi, and shargundai in Punjabi. In India, it is predominantly cultivated in Uttar Pradesh, Madhya Pradesh, Rajasthan, Gujarat, and Maharashtra, while its cultivation is also reported in parts of North America and Europe (Gokavi et al., 2004; Kumar & Kumar, 2019). Garden cress is recognised as a highly nutritious and medicinal herb, with both its leaves and seeds being of considerable importance. The seeds are particularly valued for their potent antioxidant activity and a wide range of therapeutic properties, including anti-diabetic, hypocholesterolaemic, antihypertensive, antispasmodic, hepatoprotective, antipyretic, and potential anti-carcinogenic effects. Morphologically, the seeds resemble certain oilseeds, with the dicotyledonous endosperm constituting approximately 80–85% of the total seed mass, while the seed coat and embryo account for about 12–17% and 2–3%, respectively. The seed coat typically varies in colour from brick red to cream, whereas the endosperm is yellow in appearance. Chemically, the seeds contain several bioactive compounds, including the alkaloid lepidin, glucotropaeolin, sinapin, and sinapic acid, along with mucilaginous substances (approximately 5%) and uric acid (0.108 g kg^{-1}). They are also a source of essential vitamins, particularly vitamin C and B-complex vitamins. In terms of proximate composition, the seeds contain approximately 5.69% moisture, 23.5% protein, 15.9% fat, and 5.7% ash, along with significant mineral content, including phosphorus (1.65%), calcium (0.31%), and sulphur (0.9%) (Yildirim et al., 2025; Kumar & Kumar, 2019). Owing to their rich nutritional profile, these seeds are considered beneficial for enhancing milk yield in both cattle and lactating mothers. Fresh leaves and young seedlings are commonly consumed as a spice and salad ingredient and are rich in glucosinolates. They are also known to support digestion and contribute to the healthy growth of children. In addition, seed oil is used externally for the management of rheumatic conditions, while seed extracts have been reported to exhibit hypotensive effects accompanied by transient respiratory stimulation (Jamali et al., 2023; Kumar & Kumar, 2019).

At present, the cultivation of garden cress is largely restricted to the northern states of India. However, with its increasing utilisation and the prospect of assured economic returns, there is a clear need to expand the area under this valuable medicinal crop. Consequently, systematic research is required on integrated nutrient management, irrigation scheduling, and moisture conservation practices to ensure the production of garden cress seeds of both high yield and superior quality.

2. Materials and Methods

A field experiment was carried out over two consecutive winter seasons (2015–16 and 2016–17) to evaluate the effects of integrated nutrient management and irrigation on growth parameters, total water use, and water use efficiency of garden cress (*Lepidium sativum* L.) under varying moisture conservation practices at the Soil Conservation and Water Management Farm of C.S.A.U.A&T, Kanpur. Geographically, Kanpur is situated at 26.30° N latitude, 80.15° E longitude, and an altitude of 125.9 m above mean sea level. The study comprised treatment combinations involving three irrigation schedules, namely irrigation at 35 days after sowing (DAS), irrigation at 35 and 60 DAS, and irrigation at 35 and 70 DAS. Three integrated nutrient management strategies were evaluated: 100% nitrogen (60 kg ha^{-1}) supplied through fertiliser, 75% nitrogen through fertiliser combined with 25% nitrogen through farmyard manure (FYM), and 75% nitrogen through fertiliser combined with 25% nitrogen through vermicompost along with phosphate-solubilising bacteria (PSB). In addition, three moisture conservation practices were assessed, viz. control, organic residue mulch at 4 t ha^{-1}, and weeding and hoeing combined with organic residue mulch at 4 t ha^{-1}. The experiment was arranged in a split-plot design with three replications, where irrigation scheduling was assigned to main plots, integrated nutrient management to sub-plots, and moisture conservation practices to sub-sub plots. The crop (chandrasur) was sown at a seed rate of 4 kg ha^{-1} in furrows using a traditional plough, maintaining a row spacing of 30 cm and plant spacing of 15 cm. Sowing was carried out on 19 November 2015 and 25 November 2016, while harvesting was completed on 2 April 2016 and 6 April 2017 for the first and second years, respectively. The crop received a basal fertiliser dose of 60 kg N, 30 kg P_2O_5, and 30 kg K_2O per hectare. Half of the nitrogen along with the full doses of phosphorus and potassium was applied at sowing, while the remaining half of nitrogen was top-dressed 30 days after sowing. Nitrogen was supplied through both organic and inorganic sources according to the treatment structure. During the experimental period, winter rainfall amounted to 49.9 mm and 32.8 mm in 2015–16 and 2016–17, respectively. Data on yield attributes, yield, and economic returns were analysed using Fisher's analysis of variance technique as described by Panse and Sukhatme (1967). For oil content estimation, 100 g seed samples from each plot were uniformly dried and analysed using nuclear magnetic resonance (NMR) spectroscopy, with results expressed as percentage.

3. Results and Discussion

i. Growth attributing characters

(a) Initial plant stand and Final plant stand

Data pertaining to initial plant stand and final plant stand (000 ha^{-1}) of chandrasur as affected by different irrigation scheduling, integrated nutrient management and moisture conservation practices during 2015-16 and 2016-17 have been presented in Table (1).

It is evident from the Table (1) that different irrigation scheduling showed non significant effect on initial plant stand and final plant stand of chandrasur during both the years of investigation. Maximum initial plant stand and final plant stand (227330 and 228000 plants ha^{-1}) and (217310 and 218880 plants ha^{-1}) of chandrasur was obtained in irrigation given at 35 and 70 days after sowing followed by irrigation given at 35 and 60 days after sowing (226380 and 227820 plants ha^{-1}) and (216340 and 217660 plants ha^{-1}) during 2015-16 and 2016-17 respectively. Minimum initial plant stand and final plant stand (224790 and 225620 plants ha^{-1}) and (211710 and 212530 plants ha^{-1}) was obtained when irrigation given at 35 days after sowing during 2015-16 and 2016-17, respectively. Similar results has also been reported by Verma et al. (2014) and (Yildirim, et al., 2025).

Among the different integrated nutrient management showed non significant effect on initial plant stand and final plant stand of chandrasur during both the years of experimentation. Application of 75% N through fertilizer + 25% N through vermicompost + PSB produced maximum initial plant stand and final plant stand (227230 and 228250 plants ha^{-1}) and (216420 and 217470 plants ha^{-1}) followed by 75% N through fertilizer + 25% N through FYM (226190 and 227640 plants ha^{-1}) and (215380 and 216570 plants ha^{-1}) during 2015-16 and 2016-17, respectively. Minimum initial plant stand and final plant stand (225080 and 226340 plants ha^{-1}) and (213560 and 215030 plants ha^{-1}) of chandrasur was obtained with the application of 100% N (60 kg ha^{-1}) through fertilizer during 2015-16 and 2016-17, respectively. Similar results has also been reported by Bhat (2018).

Table 1. Growth attributing characters of garden cress as affected by different irrigation scheduling, integrated nutrient management and moisture conservation practices

Treatments	Initial plant stand (000 ha^{-1})		Final plant stand (000 ha^{-1})		No. of weeds per m^2 at initial stage		No. of weeds per m^2 at harvest stage	
	2015-16	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**
Irrigation Scheduling								
Irrigation at 35 DAS	224.79	225.62	211.71	212.53	1.77 (3.13)	2.06 (4.24)	3.13 (9.80)	3.30 (10.89)
Irrigation at 35 and 60 DAS	226.38	227.82	216.34	217.66	1.87 (3.50)	2.08 (4.33)	3.63 (13.18)	3.80 (14.44)
Irrigation at 35 and 70 DAS	227.33	228.80	217.31	218.88	1.94 (3.76)	2.13 (4.54)	3.76 (14.14)	3.96 (15.68)
SE (d)	2.35	1.87	2.75	2.49	0.12	0.14	0.22	0.27
CD (P=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Integrated Nutrient Management								
100% N (60 kg ha^{-1}) through fertilizer	225.08	226.34	213.56	215.03	1.81 (3.28)	1.92 (3.69)	3.24 (10.50)	3.46 (11.97)
75% N through fertilizer + 25% N through FYM	226.19	227.64	215.38	216.57	1.93 (3.72)	2.23 (4.97)	3.73 (13.91)	3.86 (14.90)
75% N through fertilizer + 25% N through vermicompost + PSB @ 2.5 kg ha^{-1} in soil	227.23	228.25	216.42	217.47	1.85 (3.42)	2.13 (4.54)	3.55 (12.60)	3.74 (13.99)
SE (d)	2.41	1.89	2.21	2.23	0.09	0.13	0.22	0.16
CD (P=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Moisture Conservation Practices								
Control	226.37	227.83	212.05	213.33	1.94 (3.46)	2.17 (4.71)	3.69 (13.61)	3.88 (15.05)
Organic residue mulch @ 4 t ha^{-1}	224.89	225.82	216.12	217.49	1.86 (3.76)	2.10 (4.41)	3.56 (12.67)	3.73 (13.91)
Weeding and hoeing + Organic residue mulch @ 4 t ha^{-1}	227.24	228.59	217.19	218.26	1.79 (3.20)	2.01 (4.04)	3.27 (10.69)	3.45 (11.90)
SE (d)	1.98	1.59	2.31	2.39	0.10	0.13	0.20	0.26
CD (P=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

Table 2. Effect of irrigation scheduling, integrated nutrient management and moisture conservation practices on total water use (mm) and water use efficiency (kg seed ha^{-1} mm^{-1}) of Chandrasur

Treatments	Seed yield (kg ha^{-1})		Total water use (mm)		Water use efficiency (kg seed ha^{-1} mm^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Irrigation Scheduling						
Irrigation at 35 DAS	1012	1128	249.94	250.55	4.06	4.51
Irrigation at 35 and 60 DAS	1199	1285	254.25	256.48	4.73	5.03
Irrigation at 35 and 70 DAS	1420	1522	250.85	252.94	5.68	6.04
Integrated Nutrient Management						
100% N (60 kg $ha^{-1)}$ through fertilizer	1071	1169	255.24	256.40	4.20	4.56
75% N through fertilizer + 25% N through FYM	1204	1306	252.23	253.99	4.78	5.16
75% N through fertilizer + 25% N through vermicompost + PSB @ 2.5 kg ha^{-1} in soil	1355	1460	247.58	249.59	5.48	5.86
Moisture Conservation Practices						
Control	1089	1187	255.98	259.92	4.26	4.56
Organic residue mulch @ 4 t ha^{-1}	1194	1293	251.83	253.77	4.75	5.10
Weeding and hoeing + Organic residue mulch @ 4 t ha^{-1}	1347	1456	247.24	246.29	5.46	5.92

Among different moisture conservation practices showed non significant effect on initial plant stand and final plant stand of chandrasur during both the years of study. Weeding and hoeing + organic residue mulch @ 4 t ha^{-1} recorded maximum initial plant stand and final plant (227240 and 228590 plants ha^{-1}) and (217190 and 218260 plants ha^{-1}) of chandrasur followed by application of organic residue mulch @ 4 t ha^{-1} (224890 and 225820 plants ha^{-1}) and (216120 and 217490 plants ha^{-1}) during 2015-16 and 2016-17, respectively. Control plots recorded minimum initial plant stand and final plant stand (226370 and 227830 plants ha^{-1}) and (212050 and 213330 plants ha^{-1}) of chandrasur during 2015-16 and 2016-17, respectively. Similar results has also been reported by Tetarwal et al. (2013) and Akarsh, et al., (2020).

(b) Number of weeds at initial stage and Number of weeds at harvest stage:

Data on number of weeds per m^2 at initial stage and number of weeds per m^2 at harvest stage of chandrasur as influenced by different irrigation scheduling, integrated nutrient management and moisture conservation practices during 2015-16 and 2016-17 have been presented in Table (1).

It is evident from the Table (1) that different irrigation scheduling did not affect significantly on number of weeds per m^2 at initial stage and number of weeds per m^2 at harvest stage during both the years of study. Highest number of weeds (1.94 and 2.13 per m^2) and (3.76 and 3.96 per m^2) was recorded in irrigation given at 35 and 70 days after sowing followed by irrigation given at 35 and 60 days after sowing (1.87 and 2.08 per m^2) and (3.63 and 3.80 per m^2) and irrigation given at 35 days after sowing (1.77 and 2.66 per m^2) and (3.13 and 3.30 per m^2) during 2015-16 and 2016-17, respectively. Maximum number of weeds per m^2 at initial stage and number of weeds per m^2 at harvest stage was recorded in irrigation given at 35 days after sowing in the respective years of study. Data given in parentheses are $\sqrt{x}$ + 0.50 transformed value. Similar results has also been reported by Verma et al. (2014) and Darshini, (2016).

Among the different integrated nutrient management did not significantly influence on number of weeds per m^2 at initial stage of chandrasur during both the years of study. Application of 75% N through fertilizer + 25% N through vermicompost + PSB produced highest number of weeds per m^2 at initial stage and number of weeds per m^2 at harvest stage (1.85 and 2.13 per m^2) and (3.73 and 3.86) followed by 75% N through fertilizer + 25% N through FYM (1.93 and 2.23 per m^2) and (3.55 and 3.74 per m^2) and 100% N through fertilizer (1.81 and 1.92 per m^2) and (3.24 and 3.46 per m^2) during 2015-16 and 2016-17, respectively. Application of 100% N through fertilizers recorded minimum number of weeds per m^2 at initial stage and number of weeds per m^2 at harvest stage during both the years of study. Similar results has also been reported by Singh et al. (2009) and Kiremit, et al., (2023).

It is clear from the data (Table-1) that different moisture conservation practices did not significantly influence number of weeds per m^2 at initial stage and number of weeds per m^2 at harvest stage during both the years of study. Weeding and hoeing + organic residue mulch @ 4 t ha^{-1} recorded minimum number of weeds per m^2 at initial stage (1.79 and 2.01 per m^2) and (3.27 and 3.45 per m^2) followed by organic residue mulch @ 4 t ha^{-1} (1.86 and 2.10 per m^2) and (3.56 and 3.73 per m^2) and control (1.94 and 2.17 per m^2) and (3.69 and 3.88 per m^2) in the respective years of study. Minimum number of weeds per m^2 at initial stage and number of weeds per m^2 at harvest stage was recorded in control during both the years of study. Similar results has also been reported by Kiremit, et al., (2023).

ii. Total water use and water use efficiency:

Data pertaining to total water use and water use efficiency of chandrasur as influenced by different irrigation scheduling, integrated nutrient management and moisture conservation practices during 2015-16 and 2016-17 have been presented in Table (2).

It is clear from the data (Table 2) that different irrigation scheduling greatly influenced total water use and water use efficiency of Chandrasur during both the year of investigation. Irrigation given at 35 and 60 days after sowing registered highest rate of water use (254.25 and 256.48 mm) while minimum water use (249.94 and 250.55 mm) were recorded in irrigation given at 35 and 70 days after sowing during 2015-16 and 2016-17, respectively. Irrigation given at 35 and 70 days after sowing also used water at higher rate (250.85 and 252.94 mm) compared with irrigation given at 35 days after sowing in the respective years of study. The water use under irrigation given at 35 and 60 days after sowing was found 3.4 and 4.31 mm in 2015-16 and 3.54 and 5.93

mm in 2016-17 more over irrigation given at 35 and 70 days after sowing and irrigation given at 35 days after sowing, respectively. Highest water use efficiency (5.68 and 6.04 kg seed $ha^{-1}mm^{-1}$) was registered with irrigation given at 35 and 70 days after sowing followed by irrigation given at 35 and 60 days after sowing (4.73 and 5.03 kg seed $ha^{-1}mm^{-1}$) during 2015-16 and 2016-17, respectively. Minimum water use efficiency (4.06 and 4.51 kg seed $ha^{-1}mm^{-1}$) was registered with irrigation given at 35 days after sowing in the respectively years of study. The water use efficiency under irrigation given at 35 and 70 days after sowing was 0.95 and 1.62 kg $ha^{-1}mm^{-1}$ during 2015-16 and 1.01 and 11.53 kg seed $ha^{-1}mm^{-1}$ during 2016-17 more over irrigation given at 35 and 60 days after sowing and irrigation given at 35 days after sowing, respectively. Similar results has also been reported by Patel et al. (2009) and Sharma, N (2023).

Among the different integrated nutrient management practices greatly influenced water use and water use efficiency during both the years of study. Maximum water use by chandrasur was recorded with 100% N through fertilizer (255.24 and 256.40 mm) followed by 75% N through fertilizer + 25% N through FYM (252.23 and 253.99 mm) during 2015-16 and 2016-17, respectively. Application of 75% N through fertilizer + 25% N through vermicompost + PSB registered minimum water use (247.58 and 249.59 mm) in the respective years of study. The water use under treatment of 100% N through fertilizer was found 3.01 and 7.66 mm in 2915-16 and 2.41 and 6.81 mm in 2016-17 more over 75% N through fertilizer + 25% N through FYM and 75% N through fertilizer + 25% N through vermicompost + PSB, respectively. Maximum water use efficiency (5.48 and 5.86 kg seed $ha^{-1}mm^{-1}$) was recorded more under treatment of 75% N through fertilizer + 25% N through vermicompost + PSB followed by 75% N through fertilizer + 25% N through FYM (4.78 and 5.16 kg seed $ha^{-1}mm^{-1}$) during 2015 and 2016, respectively. Minimum water use efficiency (4.20 and 4.56 kg seed $ha^{-1}mm^{-1}$) of chandrasur was registered with the application of 100% N through fertilizer in the respective years of study. Application of 75% N through fertilizer + 25% N through vermicompost + PSB gave 0.70 and 1.28 kg seed $ha^{-1}mm^{-1}$ in 2015-16 and 0.70 and 1.30 kg $ha^{-1}mm^{-1}$ in 2016-17 more water use efficiency than water use efficiency recorded in 75% N through fertilizer + 25% N through FYM and 100% N through fertilizer, respectively. Similar results has also been reported by Singh et al. (1998).

The data furnished on water use and water use efficiency greatly influenced by moisture conservation practices during both the years of study. Weeding and hoeing + organic residue mulch @ 4 t ha^{-1} recorded minimum water use (247.24 and 246.29 mm) followed by organic residue mulch @ 4 t ha^{-1} (251.83 and 253.77 mm) in the respective years of study. Control plots recorded highest water use (255.98 and 259.92 mm) during 2015-16 and 2016-17, respectively. The water use under control was found 4.15 and 8.74 mm in 2015-16 and 6.15 and 13.63 mm in 2016-17 more over organic residue mulch @ 4 t ha^{-1} and weeding and hoeing + organic residue mulch @ 4 t ha^{-1}, respectively. Maximum water use efficiency (5.46 and 5.92 kg seed $ha^{-1}mm^{-1}$) was registered under weeding and hoeing + organic residue mulch @ 4tha^{-1} followed by organic residue mulch @ 4t ha^{-1} (4.75 and 5.10 kg seed $ha^{-1}mm^{-1}$) during 2015-16 and 2016-17, respectively. Minimum water use efficiency (4.26 and 4.56 kg seed $ha^{-1}mm^{-1}$) of chandrasure was registered in control in the respective years of study. Weeding and hoeing + organic residue mulch @ 4t ha^{-}1 gave more water use efficiency by 0.71 and 1.2 kg seed $ha^{-1}mm^{-1}$ in 2015-16 and 0.81 and 1.36 kg seed $ha^{-1}mm^{-1}$ in 2016-17 than organic residue mulch @ 4 t ha^{-1} and control, respectively. Similar results has also been reported by Regar et al. (2007) and Tetarwal et al. (2013) and Sharma, N. (2023).

4. Conclusion

Based on two years of study, irrigation scheduling, integrated nutrient management (INM), and moisture conservation practices had no significant effect on plant population and weed density of garden cress. However, they markedly influenced total water use and water use efficiency (WUE). Irrigation at 35 and 70 DAS recorded the highest WUE, whereas irrigation at 35 and 60 DAS resulted in greater water use. Among INM treatments, application of 75% nitrogen through fertilizer combined with 25% nitrogen through vermicompost along with PSB proved most efficient in improving WUE and reducing water use. Moisture conservation practices significantly enhanced water productivity, with weeding and hoeing combined with organic residue mulch @ 4 t ha^{-1} performing best. Therefore, the combined use of efficient irrigation scheduling (35 and 70 DAS), integrated nutrient management, and mulching practices is recommended for improving water use efficiency and ensuring sustainable cultivation of garden cress.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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