International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM February 2023, 14(2):285-290 Print ISSN 0976-3988 Online ISSN 0976-4038 **Article** AR3310a

Research Article *Natural Resource Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2023.3310a

Weed Management in Ajwain (*Trachyspermum ammi* L.) at Farmer's Fields in South East Rajasthan

R. P. Meena[1], Hargilash[2], Mani Ram[3] and R. N. Sharma[4]

[1]Dept. of Agronomy, AICRP on Dryland Agriculture, Dry Land Farming Research Station, Arjia, Bhilwara, Maharana Pratap University of Agriculture & Technology, Udaipur, Rajasthan (311 001), India

[2]Dept. of Agronomy, AICRP on Maize, Agriculture Research Station, Banswara, Bhilwara, Maharana Pratap University of Agriculture & Technology, Udaipur, Rajasthan (311 001), India

[3]Dept. of Soil Science, KVK, Rajsamand, Maharana Pratap University of Agriculture & Technology, Udaipur, Rajasthan (311 024), India

[4]Dept. of Plant Pathology, College of Agriculture, Bharatpur, SKN Agriculture University, Jobner, Jaipur, Rajasthan (303 329), India

Open Access

Corresponding meenarpmpuat@gmail.com

0009-0004-2310-8361

ABSTRACT

The field experiments were conducted during *kharif* (July–October) seasons of 2014–15 and 2015–16 at KVK, Rajsamand, Rajasthan and farmers' field with objective to explore and test other alternative and economical methods of weed control. On-farm Trial, technology option Oxadiargyl applied 50 g a.i. ha^{-1} applied as early post emergence at 20 DAS proved the best over farmers' practice as well over recommended practice of 1.0 kg a.i. ha^{-1} pendimethalin pre-emergence in terms of growth and yield attributing characters viz., plant height, primary and secondary branches, number of umbels, number of umbellets umbel^{-1}, number of seeds umbel^{-1} and remained statistically at par with weed free treatment. Weed indices namely weed count, weed dry weight, weed index and weed control efficiency were statistically significant by oxadiargyl applied 50 g a.i. ha^{-1} as early post emergence at 20 DAS and pre-emergence application of pendimethalin 1.00 kg a.i. ha^{-1} pendimethalin over farmer's practice. Lower WI and higher WCE was observed by oxadiargyl applied 50 g a.i. ha^{-1} followed by pendimethalin 1.00 kg *a.i* ha^{-1}. Grain and starw yield recorded in weed free plot was statistically at par with yield obtained by application of oxadiargyl 50 g a.i. ha^{-1}. Net returns and B:C were also high in refined technology option i.e. of 50 g a.i. ha^{-1} oxazdiargyl (₹ 127570 ha^{-1} and 4.77) over recommended practice of 1.0 kg a.i ha^{-1} pendimethalin pre-emergence (₹ 107930 ha^{-1} and 4.19) and farmers' practice (₹ 75930 ha^{-1} and 3.49).

KEYWORDS: *Ajwain*, On-farm Trial, oxadiargyl, pendimethalin, Technology option

***Citation* (VANCOUVER):** Meena et al., Weed Management in Ajwain (*Trachyspermum ammi* L.) at Farmer's Fields in South East Rajasthan. *International Journal of Bio-resource and Stress Management*, 2023; 14(2), 285-290. HTTPS://DOI.ORG/10.23910/1.2023.3310a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 05th November 2022 RECEIVED in revised form on 25th January 2023 ACCEPTED in final form on 06th February 2023 PUBLISHED on 21th February 2023

1. INTRODUCTION

Ajwain (*Trachyspermum ammi*) is native of Egypt and is cultivated in Iraq, Afghanistan, Pakistan and India known as Bishop' weed, an annual herbaceous plant belonging to family Apiaceae. It is grown in Gujarat, Rajasthan, Madhya Pradesh and Andhra Pradesh in arid and semi-arid regions. Major ajwain production in Rajasthan are in Chittorgarh, Udaipur, Banswara, Jhalawar, Rajsamand, Kota and Bhilwara. Important seed spice crop of Rajasthan with an area of 12475 ha, 7479 t production with average productivity of 600 kg ha^{-1} (Anonymous, 2021a). At national level, ajwain having area of 29.00 t ha, 21.84 mt production with 753 kg ha^{-1} productivity (Anonymous, 2021b). Ajwain seed contains 2.5–5.0% volatile oil which is used in many ayurvedic medicines and industries (Anonymous, 2016). The thymol content makes ajwain a potent fungicide and antiseptic ranging from 4.17–5.17% (Asangi et al., 2020) with an agreeable odour useful in controlling a variety of fungal infections of the skin (Dutta et al., 2021). Essential oils therapy approach is successful in economically disadvantaged countries where cost of this therapy can be supported by the national health system (Stea et al., 2014). Ajwain essential oil showed the presence of 26 identified components which account for 96.3% of the total amount in which thymol (39.1%) was found as a major component exhibited a broad spectrum of fungitoxic behavior (Singh et al., 2004). The methanolic extracts of Ajwain seed possess natural antioxidant properties (Aghdam et al., 2021).

India has wide range of agro-climates and soil types and highly diverse agriculture farming systems with different types of weed problems. Herbicide provide high degree of specificity of target weed and have no effect on non-target, beneficial plants or man and do not form any residues in the environment (Basu and Rao, 2020). Unfortunately, majority of the farmers are quite ignorant about the proper doses of herbicides, time of application and their economics (Rao, 2018). Traditionally, weed control is largely dependent on manual weeding (Moyer et al., 2003, Punia and Tehlan, 2017). But scarcity and cost of agriculture labour gradually increased the adaptation of cost saving options, these include herbicides (Rao et al., 2015), more specifically chemical herbicides. The use of herbicides has revolutionized weed control in seed spices and reduced the cost of production resulting maximization of net returns (Kamboj et al., 2004, Ahmed et al., 2010, Mathukia et al., 2018a). Interference of weeds, being one of the most important hindrances, declines crop yields (Soloneski and Larramendy, 2013). Choudhary (1999), Meena et al. (2015), Malik et al. (2021), Malunjkar et al. (2022) have reported increased yield of various seed spices with application of oxadiargyl @ 75 g to 100 g ha^{-1} followed by manual weeding once or twice. Enzymatic stimulation has been reported by Rao et al. (2012) by use of oxadiargyl at lower doses as soil application (0. 75 kg a.i. ha^{-1}) whereas greater activity of oxadiargyl under anaerobic conditions has been reported under wet conditions (Gitsopoulos and Williams, 2004). Initially, being a slow growing seed spice, ajwain is more prone to weed competition during *kharif* season under rainfed conditions of south east Rajasthan. Herbicides are the most effective and economic weed control measures. Therefore, it is necessary to explore and test other alternative and economical methods of weed control (Mahatma et al., 2021). Manual weeding is the commonly applied practice, but availability of labour is a problem involving high cost (Singh et al., 2013). Keeping in view the aforesaid reasons, various technology options under On-farm Trials at various locations was carried out to evaluate economic feasibility and best technology option for famers for weed management under sever weed infestation in ajwain.

2. MATERIALS AND METHODS

An On-farm Trial in different villages at five locations at farmers' fields and at Krishi Vigyan Kendra Rajsamand at Rajsamand (25.0276° N, 73.8895°E) district representing South East Rajasthan was conducted during *kharif* (July–October) seasons of 2014–15 and 2015–16 under rainfed conditions for the management of intervening points including sever weed infestation, broadcasting of seeds and improper depth of seed. Mainly, the problem was assessed and refined for the overcome of the problem of the heavy weed infestation during kharif ajwain crop under Rajsamand agro-climatic conditions (Zone-IVa, Sub-humid Southern plain and Aravalli hills of Rajasthan) at farmers' fields and technology options/treatments having farmers' practice (broadcasting of seed and no use of weedicides), recommended weedicide 1.0 kg a.i ha^{-1}. pendimethalin ha^{-1} as pre-emergence and refined treatment of 50 g oxazdiargyl a.i. ha^{-1} applied as early post emergence at 20 DAS for weed management. Oxadiargyl mainly used as a selective contact herbicide works by contact and absorption by the sprouts or seedlings of sensitive weeds such as barnyard grass before and after the emergence of the weeds. After being applied to field water, after sedimentation, it is gradually adsorbed by the surface soil colloids to form a stable sealing layer of the drug film. When the seedlings of weeds that germinate after passing through the drug film, contact adsorption and limited conduction, under light conditions, rupture the cell membrane and chlorophyll decomposition of the contact site, and destroy the meristem of the vigorous growth site, and eventually cause the damaged weed shoots to wither and die. Application of herbicide oxadiargyl at lower dose of 0.75 kg ha^{-1} soil application stimulated the enzymatic activity. Changes in microbial cavity occurred only at herbicide

concertation much higher than what is normal applied in field. The doses of herbicide applied in the field may not pose very serios threat to the soil ecological balance (Rao et al., 2012). The recommended dose of 30 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} was applied and sown in lines adopting standard package of practice in field conditions at the farmer's fields as well as at the instructional farm of Krishi Vigyan Kendra, Rajsamand (Rajasthan) of Maharana Pratap University of Agriculture and Technology, Udaipur jurisdiction area.

The experiment was conducted on a sandy load to loamy sand at five locations of farmer's field and at instructional farm of Krishi Vigyan Kendra, Rajsamand (Rajasthan) India. The soils of the of the experimental field ranged from sandy loam to loamy sand having low in organic carbon (0.43%), available N (226 kg ha^{-1}), medium in P_2O_5 (28.0 kg ha^{-1}) and was sufficient in available K (370 kg ha^{-1}), slightly alkaline with pH 8.11 and EC 0.27 d Sm^{-1}. The ajwain variety Lam Seelction-1 was sown on 15th September during both the years on the same site at 30 cm row to row and 10 cm plant to plant spacing with a seed rate of 4.0 kg ha^{-1} on conserved soil moisture. All other standard cultural practices were followed during the cropping season. Under weed control options/treatments, farmers' practice (one or two hand weeding at 30 and 45 DAS), pre-emergence application of pendimethalin @1.00 kg ha^{-1} and early post emergence application of oxadiargyl 0.50 g a.i ha^{-1} was applied at 25 DAS with a spray volume of 500 l ha^{-1}. Further, weedy check and weed free plots were also maintained both at farmer's fields and at KVK instructional farm. In weed free plots, weeds were removed manually at seven days interval for ensuring complete weed free condition. After uprooting of weeds, the weeds were sun dried to constant weight and finally the dry weight was recorded for each treatment and expressed as kg ha^{-1}. Weed control efficiency and weed index were calculated by the formulae suggested by Kondap and Upadhya (1985) and Gill and Kumar (1969). Statistical analysis was done as per process suggested by Panse and Sukhatme (1985).

The weed flora recorded during On-farm Trials were mostly kharif season weeds as vegetative growth take place in Kharif and harvested in *rabi* season. The weeds mostly grass like *Cynodon dactylon, Digitaria sanguinalis* L., *Parthenium hysterophorus* and *Polycurpea corymbosa* L., sedges like *Cyprus rotundus* L. and *Cyprus irria* L. and broad leaf weeds *Solanum nigrum, Tridax procumbens, Amaranthus viridis, Digera arvensis*, *Euphorbia hirta, Solanum nigrum, Tridax procumbens* etc. Verma et al. (2017) and Mathukia et al. (2018b) also reported similar weed species.

3. RESULTS AND DISCUSSION

3.1. Growth and yield attributing characters

Data in Table 1 revealed that refined technology option oxadiargyl applied 50 g a,i. ha^{-1} as early post emergence at 20 DAS proved the best over farmers' practice as well over recommended practice of 1.0 kg a.i. ha^{-1} pendimethalin pre-emergence in ajwain in terms of growth and yield attributing characters of *Ajwain* and remained statistically at par with weed free treatment. The technology of option of 1.00 kg a.i ha^{-1} pendimethalin and oxadiargyl applied 50 g a,i. ha^{-1} resulted in enhanced plant height, primary and secondary branches, number of umbels, number of umbellets $umbel^{-1}$ and number of seeds $umbel^{-1}$ over farmers' and remained at par each other. Perceptible higher growth in growth and yield attributing characters in pendimethalin and oxadiargyl technology option of On-farm trials may be attributed due to better weed control over farmer's practice. These results are in close conformity with results of Meena et al. (2015). Use of pendimethalin and oxadiargyl have been advocated by Mehta et al. (2010), Meena et al. (2013), Kumar et al.

Table 1: Response of weed control technology options on growth and yield attributing characters of Ajwain

Technology option	Plant height (cm)	Primary branches	Secondary branches	No. of umbels $Plant^{-1}$	No. of umbellets $umbel^{-1}$	No. of seeds $umbel^{-1}$
Farmer's practice (Broadcasting of seed and hand weeding at 30 and 45 DAS)	83.00	10.53	41.50	32.80	9.80	14.70
Recommended practice (1.0 kg a.i. ha^{-1} pendmethalin pre-emergence)	90.40	12.00	47.98	37.60	11.49	16.94
Oxadiargyl 50 g a.i. ha^{-1} early post emergence at 20 DAS	94.40	13.40	53.60	43.40	13.52	18.97
Weed free	95.80	13.68	55.40	45.40	13.97	19.12
Weedy check	79.60	8.25	33.60	22.60	7.00	11.43
SEm±	1.70	0.40	1.32	1.30	0.45	0.55
CD (p=0.05)	5.09	1.19	3.95	3.91	1.36	1.65

(2016) and Bhutia et al. (2017) in fenugreek.

3.2. Weed indices

Weed indices namely weed count, weed dry weight, weed index and weed control efficiency were significantly affected due to adoption of technology option of oxadiargyl applied 50 g a.i. ha^{-1} as early post-emergence at 20 DAS and pre-emergence application of pendimethalin 1.00 kg a.i ha^{-1} pendimethalin over farmers' practice (Table 2). Malunjkar et al. (2022) has reported weed indices in fenugreek with the use of pendimethalin and oxadiargyl. Higher weed count was recorded in weed check (5.42) which was controlled due to application of oxadiargy and pendimethalin and lowest was recorded in weed free check. The refined weed control technology option of oxadiargyl applied 50 g a.i. ha^{-1} as early post emergence at 20 DAS proved to be the best followed by pendimethalin 1.00 kg a.i ha^{-1} over farmers' practice. Lower weed index (WI) 5.07% and higher weed control efficiency (79.88%) was observed in technology option of oxadiargyl applied 50 g a.i ha^{-1} as early post emergence at 20 DAS followed by pendimethalin 1.00 kg a.i. ha^{-1} (17.79 and 71.84%), respectively. Samant (2016) and Meena and Mehta (2010) has reported increased weed control efficiency and reduced weed biomass and weed density with the use of oxadiargyl. The higher weed control efficiency may be attributed due to lowering of weed indices namely weed count, weed dry weight and weed index under improved technology option of oxadiargyl applied 50 g a.i ha^{-1} as early post emergence at 20 DAS.

3.3. Yield and economics

Grain and straw yield recorded in technology option oxadiargyl 50 g a.i. ha^{-1} early pre-emergence and recommended practice i.e. 1.0 kg a.i. ha^{-1} pendimethalin

Table 2: Response of weed control technology options on weed count, weed dry weight, weed index and weed control efficiency of ajwain

Technology option	Total weed count			Weed dry weight (Kg ha^{-1})	Weed Index (%)	Weed control efficiency (%)
	20 DAS	40 DAS	60 DAS			
Farmer's practice (Broadcasting of seed and hand weeding at 30 and 45 DAS)	4.30	3.40	3.13	347	40.03	64.60
Recommended practice (1.0 kg a.i. ha^{-1} pendmethalin pre-emergence)	1.97	2.68	2.87	276	17.79	71.84
Oxadiargyl 50 g a.i. ha^{-1} early post emergence at 20 DAS	4.16	1.81	2.01	197	5.07	79.88
Weed free	0.67	0.67	0.67	27	0	97.28
Weedy check	4.34	5.34	5.42	981	65.31	0
SEm±	0.10	0.14	0.08	15	2.72	1.11
CD (p=0.05)	0.30	0.43	0.25	45	8.15	3.32

Table 3: Response of weed control technology options on yield and economics of ajwain

Technology option	Total weed count		Gross returns (₹ ha^{-1})	Net Returns (₹ ha^{-1})	B:C ratio
	Grain	Straw			
Farmer's practice (Broadcasting of seed and hand weeding at 30 and 45 DAS)	488	844	97680	75930	3.49
Recommended practice (1.0 kg a.i. ha^{-1} pendmethalin pre-emergence)	668	1068	133680	107930	4.19
Oxadiargyl 50 g a.i. ha^{-1} early post emergence at 20 DAS	772	1172	154320	127570	4.77
Weed free	817	1217	163480	135730	4.89
Weedy check	282	724	56480	34730	1.60
SEm±	22	30	4486	4486	0.17
CD (p=0.05)	67	89	13449	13449	0.51

pre-emergence application recorded perceptible higher grain and straw yields as compared to farmers' practice. Application of oxadiargyl 50 g a.i. ha^{-1} resulted in 58.19% higher yield over farmers' practice. Further, recommended practice i.e.1.0 kg a.i. ha^{-1} pendimethalin pre-emergence also increased yield to the tune of 36.88% over farmer's practice. Yield recorded in weed free plot was statistically ap par with yield obtained by application of oxadiargyl 50 g a,i. ha^{-1}. These results are in concordant with Yadav et al. (2004). These results are in consonance with Meena et al. (2015). Further, net returns and B:C were high in refined technology option i.e. of 50 g a.i. ha^{-1} oxadiargyl (₹ 127570 ha^{-1} and 4.77) over recommended practice of 1.0 kg a.i. ha^{-1} pendimethalin pre-emergence (₹ 107930 ha^{-1} and 4.19) and farmers' practice (₹ 75930 ha^{-1} and 3.49). The increased yield attributing characters and yield is the results of increased enzymatic activity by use of herbicide herbicide oxadiargyl as reported by Rao et al., (2012). Similar results have been advocated by Meena et al. (2015) and Mahatma et al. (2021) in ajwain. These results are in consonance with Kumar (2002), Yadav et al. (2004), Birla et al. (2016) and Mathukia et al. (2018b) also reported use of pendimethalin and oxadiargyl in cumin.

4. CONCLUSION

Oxadiargyl applied 50 g a.i. ha^{-1} applied as early post emergence at 20 DAS proved the best over farmers' practice as well over recommended practice of 1.0 kg a.i. ha^{-1} pendimethalin pre-emergence in ajwain in terms of growth and yield attributing characters, grain and straw yields, weed indices and economics of ajwain for management of sever weeds infestation at farmer's field in South East Rajasthan.

4. ACKNOWLEDGEMENT

Authors are highly thankful to The Director, ATARI, ICAR, Jodhpur for financial and technical assistance to carry out this work. Authors are also thankful to The Director Extension, Maharana Pratap University of Agriculture & Technology for providing timely guidance, support and cooperation by providing resources and technical help while doing the study.

5. REFERENCES

Aghdam, N.B., Peighambardoust, S.H., Bodbodax, S., Ghafan, A.O., 2021. Evaluation the effect of incorporating Ajowan powder (*Carum copticum*) on quality properties of gluten-free cake. Journal of Food Science and Technology (Iran) 18(120), 85–98. DOI 20.1001.1.20088789.1400.18.120.7.9.

Ahmed, A., Thakral, S.K., Yadav, A., Balyan, R.S., 2010. Grain yield of wheat as affected by different tillage practices varieties and weed control methods. In: Proceedings of National Symposium on Integrated Weed Management in the Era of Climate Change, NAAS, New Delhi, 21–22 August.

Anonymous, 2016. The ayurvedic pharmacopoeia of India (Part 1, Vol. 9, 1st Edn.). Ministry of Ayush, Government of India, India, 1–182.

Anonymous, 2021a. National Horticulture Board Data Base-2021. Ministry of Agriculture, Government of India, Sector-18, Gurgaon, 6.

Anonymous, 2021b. Data-agriculture. Area, production and productivity of Ajwain in India (2002–2003 to 2006–2007 and 2008–2009 to 2020–2021) 3rd Advance Estimates. Selected State-wise Area, Production and Productivity of Ajwain. Available at www.indiastat.com.

Asangi, H., Saxena, S.N., Kattimani, K.N., Kulkarni, M.S., Kotikal, Y.K., Mastiholi, A.B., Jameel Jhalegar, M.D., Siddappa, R., 2020. Genetic variation in essential oil constituents of ajwain (*Trachyspermum ammi* L. Sprague) varieties at varying nitrogen levels under semiarid tropics of Northern Karnataka, India. Journal of Essential Oil-Bearing Plants 23(6), 1324–1333. DOI 10.1080/0972060 X.2020.1871075.

Basu, S., Rao, Y.V., 2020. Environmental effects and management strategies of the herbicides. International Journal of Bio-resource and Stress Management 11(6), 518–535. DOI https://doi.org/10.23910/1.2020.2069d.

Bhutia, P.H., Choudhary, N., Hore, J.K., Yonzone, R., Lepcha, R., 2017. Weed and water management in fenugreek (*Trigonella foenum graecum* L.). Journal of Crop and Weed 13(3), 204–208.

Birla, L., Naruka, I.S., Shaktawat, R.P.S., Ajnave, S.R., 2016. Integrated weed management in cumin. Indian Journal of Weed Science 48(1), 102–104.

Choudhary, G.R., 1999. Weed management in fenugreek (*Trigonella foenum* graecum). Indian Journal of Agronomy 44 (4), 846–850.

Gill, G.S., Kumar, V., 1969. Weed index: A new method for reporting weeds control traits. Indian Journal of Agronomy 14(2), 96–98.

Gitsopoulos, T.K., Froud-Williams, R.J., 2004. Effects of oxadiargyl on direct-seeded rice and *Echinochloa crus-galli* under aerobic and anaerobic conditions. Weed Research 44(4), 329–334. DOI https://doi.org/10.1111/ j.1365-3180.2004.00407.x.

Kamboj, O.P., Bhatia, A.K., Batra, V.K., Thakral, K.K., Lal, M., 2004. Effect of weed control treatments on weed spectrum and nutrients uptake by weeds in fenugreek. Haryana Journal of Horticulture Science 33(1–2), 132–134.

Kondap, S.M., Upadhaya, U.C., 1985. A practical manual on weed control. Oxford and IBH Publishing, Company, New Delhi, 55.

Kumar, R., Malik, Y.P., Punia, S.S., 2016. Weed control

in fenugreek with pendimethalin and imazethapyr. Indian Journal of Weed Science 48(2), 225–227.

Kumar, S., 2002. Weed management in cumin (*Cuminum cyminum*). Indian Journal of Agronomy 47(1), 142–146.

Mahatma, H., Biradar, I.B., Hiremath, J.S., Shrikantaprasad, D., Masuthi, D.A., Desai, S., 2021. Studies on weed management practices in fennel (*Foenicum vulgare* Mill.). The Pharma Innovation Journal 10(9), 986–989.

Malik, S., Duary, B., Jaiswal, D.K., 2021. Integrated use of herbicide and weed mulch with closer spacing for weed management in dry direct seeded rice. International Journal of Bio-Resource and Stress Management 12(3), 222–227. DOI https://doi.org/10.23910/1.2021.2189d.

Malunjkar, B.D., Verma, A., Choudhary, R., Choudhary, R.S., Kaushik, M.K., Mali, G.R., 2022. Production of fenugreek (*Trigonella foenum-graecum*) as influenced by weed management practices and vermicompost application. Legume Research 45(1), 68–72. DOI 10.18805/LR-4363.

Mathukia, R.K., Sagarka, B.K., Panara, D.M., Gohil, B.S.S., 2018a. Efficacy of some post-emergence herbicides and their mixtures against complex weed flora in wheat. International Journal of Economic Plants 5(1), 023–026. DOI https://doi.org/ 10.23910/ijep/ 2018.5.1.0230.

Mathukia, R.K., Sagarka, B.K., Panara, D.M., Vekariya, S.J., 2018b. Management of diverse weed flora of cumin by sole and combined herbicide application. Journal of Crop and Weed 14(2), 143–148.

Meena, R.L., Meena, S.S., Mehta, R.S., Meena, R.D., 2015. Weed management in ajwain (*Trachyspermum ammi* L.). Journal of Spices and Aromatic Crops 24(2), 124–128.

Meena, S.S., Mehta, R.S., 2010. Economic feasibility of weed management practices in cumin. Indian Journal of Horticulture 67(Special Issue), 189-192.

Meena, S.S., Mehta, R.S., Lal, G., Anwer, M.M., 2013. Economic feasibility of weed management practices in fenugreek (*Trigonella foenumgraecum* L.). Indian Journal of Horticulture 70(1), 150–153.

Mehta, R.S., Meena, S.S., Lal, G., 2010. Effect of irrigation levels and weed control methods on dry matter accumulation, growth dynamics and yield of fenugreek (*Trigonella foenium-graecum* L.). Indian Journal of Horticulture 67(2), 219–224.

Moyer, J.R., Archarya, S.N., Mir, Z., Doram, R.C., 2003. Weed management in irrigated fenugreek grown for forage in rotation with other annual crops. Canadian Journal of Plant Science 83(1), 181–188. DOI 10.4141/P02-030.

Panse, V.G., Sukhatme, P.V., 1985. Statistical methods for agriculture workers (4th Edn.). ICAR, Pub., New Delhi, 1–359.

Dutta, P., Sarma, N., Saikia, S., Gogoi, R., Begum, T., Lal, M., 2021. Pharmacological activity of *Trachyspermum ammi* L. seeds essential oil grown from Northeast India. Journal of Essential Oil Bearing Plants 24(6), 1373–1388.

Punia, S.S., Tehlan, S., 2017. Bio-efficacy of different herbicides in fenugreek. Indian Journal of Weed Science 49(3), 298–299.

Rao, A.N., 2018. The historical and future perspective of Weed Science research in India. In: Kumar, S., Mishra, J.S. (Eds.), Fifty years of weed science research in India. Indian Society of Weed Science, Jabalpur, India, 1–24.

Rao, A.N., Wani, S.P., Ramesha, M., Ladha, J.K., 2015. Weeds and weed management of rice in Karnataka state, India. Weed Technology 29(1), 1–17.

Rao, P.C., Laxmi, C.S.R., Sireesha, A., Madavi, M., Swapna, G., 2012. Effect of oxadiargyl on soil enzyme activity. Journal of Crop and Weed 8(1), 52–56.

Samant, T.K., 2016. Effect of oxadiargyl on weed density, yield and economics in dry seeded rice through front line demonstration (2016). Journal of Crop and Weed 12(1), 120–124.

Singh, G., Maurya, S., Catalan, C., de Lampasona, M.P., 2004. Chemical constituents, antifungal and antioxidative effects of ajwain essential oil and its acetone extract. Journal of Agricultural and Food Chemistry 52(11), 3292–3296. DOI 10.1021/if035211c.

Singh, I., Rathore, M.S., Mehriya, M.L., Chawra, R.S., Chandawat, M.S., 2013. Bio-efficacy of herbicides applied in cumin (*Cuminum cyminum*) and their carryover effects on succeeding pearl millet (*Pennisetum glaucum*). Indian Journal of Agronomy 58(4), 490–494.

Soloneski, S., Larramendy, M.L., 2013. Weed and pest control- conventional and new challenges. InTech Publisher, Janeza Trdine 9, 51000 Rijeka, Croatia. ISBN 978-953-51-0984-6.

Stea, S., Beraudi, A., De Pasquale, D., 2014. Essential oils for complementary treatment of surgical patients: State of art. Evidence-Based Complimentary and Alternate Medicine 2014, 726341.

Verma, A., Choudhary, R., Choudhary, R.S., 2017. Efficacy of imazethapyr and its ready mix on weed growth and yield of black gram. Chemical Science Review and Letters 6(24), 2474–2477.

Yadav, R.S., Sharma, S.K., Poonia, B.L., Dahama, A.K., 2004. Selectivity and phytotoxicity of oxadiargyl on cumin and weeds and its residual effect on succeeding moth bean and pearl millet. Indian Journal of Weed Science 36(1–2), 83–85.