Recent Advances in Ajwain (*Trachyspermum ammi* L.) Cultivation: A Review

ABSTRACT:

Ajwain (*Trachyspermum ammi* L.), also known as carom seed, belongs to the family Apiaceae, a native from Egypt. It is a popular seed spice crop in India. It is an annual herbaceous plant bearing small egg shaped greyish brown fruits. Seeds contain medicinal values, especially for curing indigestion, stomach pain, and elements concerning the digestive system. Thymol (30-35%), γ-terpinene (23.92%), and p-cymene (22.9%) are the major constituents present in the seeds. The essential oil extracted from Ajwain seeds is being used in minor quantities in perfumery, food flavouring as preservatives, and most extensively in folk medicines, especially for remedies of stomach disorders. Dry and hot fruit fermentation is externally applied on the chest to cure asthma, and a crushed fruit paste is applied for colic pains. Evaluation and characterization of seed spices germplasm is required for their documentation and cataloging crop wise for further use by plant breeders and biotechnologists to improve yields, quality, and resistance against biotic as well as biotic stresses. There is an urgent need to enhance the productivity and quality of the crop by adopting suitable agronomic practices such as population densities per hectare and the nutritional status of the soil. Major research is needed on pesticide residue management to earn better foreign exchange. Recent available advanced research and development have been described in this article.

***Keywords*:** Ajwain, medicinal value, management, technologies, productivity, quality.

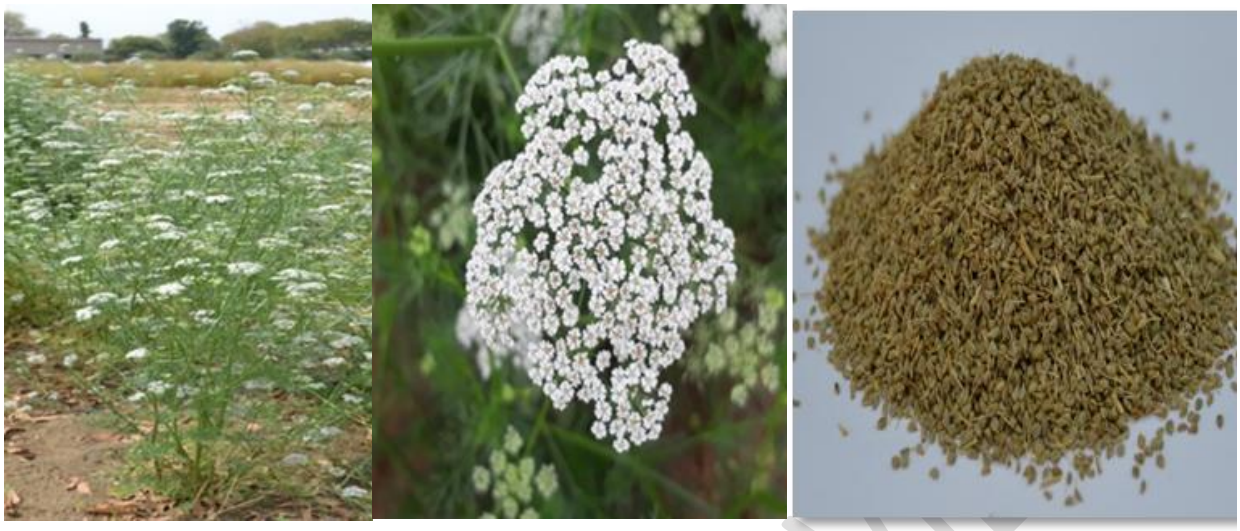
1. INTRODUCTION

"Ajwain （*Trachyspermum ammi* L.）, also known as Bishop's weed or Carom seed, belongs to the family Apiaceae, a native of Egypt. It is widely distributed and cultivated in various regions, such as Iran, Persia, Egypt, Pakistan, Afghanistan and India, as well as Europe" [1]. "In India, it is cultivated in Madhya Pradesh, Uttar Pradesh, Gujarat, Rajasthan, Maharashtra, Bihar, and West Bengal" [2]. "It is an erect, glabrous, or minutely pubescent, branched annual herb, 60–90 cm tall, with small-sized greyish brown fruits or seeds" [3]. "Fruits are ovoid, muricate, aromatic cremocarps that are greyish-brown; the mericarps are compressed, with distinct ridges and tubercular surfaces and one-seeded.

Herbal treatments have gained popularity as a dietary supplement for illness prevention and as alternative/complementary medicine in recent years" [4]. Essential oils are a natural substance produced by plants' secondary metabolism and are used for various applications[5]. "Plant parts usually consumed are herbs, volatile oil, and seeds. Ajwain has been shown to contain several phytochemicals, including alkaloids, chalcones, coumarins, flavonoids, glycosides, saponins, steroids, and tannins" [6][7]. "The essential oil extracted from ajwain seeds is being used in minor quantities in perfumery, food flavoring as preservatives, and most extensively in folk medicines, especially for remedies for stomach disorders" [8]. "Dry and hot fruit fermentation is externally applied on the chest to cure asthma, and a crushed fruit paste is used for colic pains. The seed has proven several biological activities, viz; anti-inflammatory, analgesic, anxiolytic, and antispasmodic activities" [9][10]. It is a source of antioxidants [11]. Because of its preservation properties, ajwain is used in confections and beverages as whole seed, powder, and oil [12]. Thymol (35-60%) is the principal constituent of ajwain seed [13], and it also comprises γ -terpinene (23.92%), and p-cymene (22.9%). According to the FDA's regulations (21 CFR 182.20), thymol volatile oil constituent is generally regarded as safe (GRAS) [14].

In India, it is grown in 38 thousand hectares with 28 thousand MT [15]. Rajasthan alone contributes about 73 percent of total ajwain production in India [16]. "There has been increasing demand for seed spices, and importing countries consider India a consistent source. India dominates in the world seed spices trade because of their intrinsic qualities. National Agriculture Research System has provided needed technology backup, and further promotion programs under Horticulture Mission have fuelled the growth" [17]. It necessary to examine various plant parts to understand their structure, function, and overall biology, single plant, flower umbel, seeds, and the field view are depicted in Figure 1, and Figure 2 represents line sowing of ajwain crop under field conditions. The global population is continuously growing, and there is a need to produce more food to meet the rising demand. Studying recent advances in crop cultivation helps researchers develop improved farming techniques, crop varieties, and technologies that enhance productivity and increase food production to feed the growing population. This knowledge can be used to develop genetically improved crop varieties with desirable traits such as higher yield, improved nutritional content, disease resistance, drought tolerance, and enhanced post-harvest characteristics, along with the development of suitable technologies to double the farmers' income. In the present review, we delve into the latest development in research and

development of the ajwain crop as a guide to the crop growers, breeders, and the different stakeholders.



a **b** **c**

Fig.1: Plant parts of the Ajwain, a) whole plant, b) flower and c) seeds

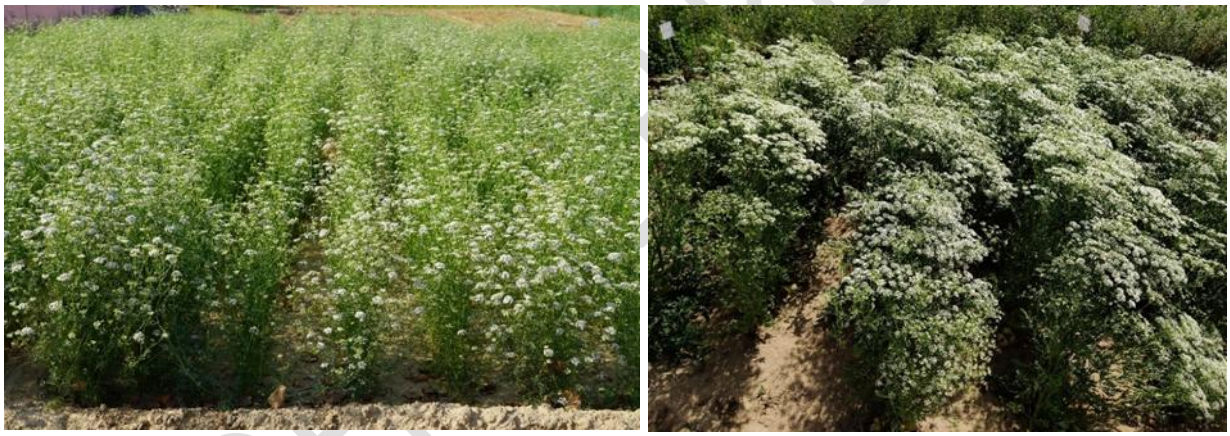


Fig. 2. Line sowing in Ajwain

2. COMPOSITION AND USES

"Ajwain contains a substantial amount of moisture (8.9%), protein (15.4%), fat or ether extract (18.1%), fiber (11.9 %), carbohydrates (38.6 %), and minerals (7.1%). It also contains 2.5 to 6.0 per cent volatile oil, yellow brownish in colour used in many ayurvedic medicines and industries of which 'thymol' is the main constituent" [18]. "Ajwain's characteristic aromatic smell and pungent taste is widely used as a curry spice. Ajwain seed is an economic part that is used as a spice for flavoring numerous foods as preservatives, in medicine, and for the manufacture of essential oil in perfumery" [19]. "Seeds contain medicinal values, especially for curing indigestion, stomach pain, and elements concerning the digestive system. It is also used in cholera, diarrhea, gastric and urinary trouble. Therapeutic uses of *Trachyspermum ammi* L. seeds are stomachic, carminative, expectorant,

antiseptic, act against amoebiasis, and possesses antimicrobial activity. It also cures abdominal tumors, pains, and piles" [20].

3. BOTANICAL DESCRIPTION

"It is an annual herbaceous, cross-pollinated crop bearing small egg-shaped greyish-brown fruits in the form of umbels. It is a profusely branched annual herb, 60-90 cm tall. Stem is striated, inflorescence compound umbel with 16 umbellets, each containing up to 16 flowers; flowers actinomorphic, white, male, and bisexual; corolla 5, petals bilobed; stamens 5, alternating with the petals; ovary inferior; stigma knob-like. Fruit is aromatic, ovoid, cordate, and Cremo carp with a persistent stylopodium. Leaves are pinnate, with a terminal and seven pairs of lateral leaflets" [50]. "The fruit consists of two mericarps, greyish brown, ovoid, compressed about 2 mm long and 1.7 mm wide, with five ridges and six vittae in each mericarp, usually separate, five primary ridges" [2].

4. GENETIC STUDIES AND CROP IMPROVEMENT

Evaluation and characterisation of ajwain germplasm is required for their documentation for further use by plant breeders and biotechnologists for improving yield, quality and resistance against biotic and abiotic stresses. Improved varieties of Ajwain available for cultivation in India were shown in Table 1. Germplasm maintenance can be achieved by preventing outcrossing with other species and reducing the effect of natural selection in an environment other than the original one. The germplasm collection available at National Research Centre on Seed Spices, Ajmer, consists of 92 ajwain accessions, of which one is collected from exotic. [21] and 59 indigenous germplasms are available at Jagudan, Gujarat [22].

Ravindra babu *et al*., 2012 [23] evaluated and reported the wide variability among the 43 genotypes for all the morphological and economic traits. Five selections have been identified for earliness and high yield. "In Ajwain ample amount of variability exists for the important component traits like the number of secondary branches, harvest index, number of seed umbel$^{-1,}$ and number of umbellate umbel^{-1} thus, the scope of improving the crop by selection in the available variability is high". [24].

Table 1: Improved varieties of Ajwain available for cultivation in India

Sl. No	Variety	Average yield (Kg/ha)	Remarks	Reference

1.	Ajmer Ajwain-1	1420	Bold seeded, essential oil 3.5%, suitable for rainfed and irrigated condition	[25]
2.	Ajmer Ajwain -2	1280	Early maturing (145-150 days). Moderately tolerate drought. Essential oil 3.0%.	
3.	Gujarat Ajwain- 1	2250	Non shattering type, late maturity (180das)	
4.	Lam Sel.-1	1000	Early maturity (145-150das)	
5.	Lam Sel.-2	1000	Spreading type matures in 160 days.	
6.	Ajmer Ajwain-93	874.30	Early maturing (123 days), lodging resistant.	[26]
7.	Azad ajwain	1174.00	Resistant to *Sclerotinia sclerotiorum*	[27]
8.	Pant Ruchika	600-800	Suitable for both irrigated and rainfed condition Matures in 160 DAS. Essential oil 3.4%.	[25]
9.	Rajendra Mani	-	Adopted for cultivation in Bihar	
10.	Pratap Ajwain-1	800-1000	Moderately resistant to leaf blight and powdery mildew, volatile oil 3.9%.	[28]

5. DATES OF SOWING

Among the different agronomic practices, optimum sowing time plays an important role in fully exploiting a variety's genetic potential as it provides optimum crop growing environment such as temperature, humidity, light etc. Sowing time is one of the most important nonmonetary inputs which influences the productivity of seed and oil to a great extent.

"Plant height, number of primary and secondary branches per plant, plant spread, stem diameter, number of umbels per plant, number of umbellets per umbel, number of seeds per plant, and seed yield per plant and ha were significantly higher when the crop was sown on 30th October compared to 15th October and 14th November. The probable reason for these results might be due to the suitability of climatic factors" [29]. Sowing of Ajwain on 1st September recorded a higher yield (11.96q/ha), followed by sowing on 10th September and 20th August in the Southern Telangana zone of Andhra Pradesh. Reduction in yield was observed with delay in sowing [30].

6. SPACING STUDIES

“Plant spacing is importantin the growth and yield of any crop. Indeed, optimum plant density ensures the plant grows properly withits aerial and underground parts by utilizing more solar radiation and soil nutrients” [38]. Closer spacing hampers intercultural operations. Also, in a densely populated crop, the inter-plant competition is very high for nutrients, air, and light, which usually results in mutual shading, lodging and thus favors more straw yield than grain yield. On the other hand, under wider plant spacing desired population per unit area cannot be obtained, which ultimately reduces yield per unit area. An optimum number of plants is required per unit area to utilize the available production factors such as water, nutrient, light and CO2 efficiently.

“Sowing ajwain seeds at broader spacing (30 cm x 20 cm) exhibited significant differences in plant height, number of primary and secondary branches per plant, plant spread, stem diameter, number of umbels per plant, number of umbellets per umbel, number of seeds per plant and seed yield per plant and ha. Significant parameter increases at wider spacing might be due to less competition among plants for solar energy, water, nutrients, and other growth factors. The closest spacing (30 cm x 10 cm) recorded maximum seed yield; maximum seed yield (q ha^{-1}) at closer spacing is due to higher plant population” [29].

“Crop geometry of 50 × 25 cm resulted in 10 percent higher seed yield over 40 × 25 cm. Thus, 50 × 25 cm crop geometry is better for realizing higher yield, net return, and profitability in Ajwain production. Raised bed cultivation of ajwain by 75 cm raised beds with paired row planting coupled with one drip line for fertigation gave maximum seed yield of 1639.8 kg/ha” [31]. Muvel *et al*. [32] reported that “spacing at 45 x 30 cm significantly increased the plant height, fresh weight per plant, dry weight per plant, number of umbels per plant, number of umbellets per umbel, 1000 seed weight, yield per plant, seed yield, straw yield, biological yield, leaf chlorophyll content, carotenoids content and essential oil content in seed. However, closer 30 x 30 cm spacing significantly increased the days to 50% flowering”.

7. NUTRIENT REQUIREMENT STUDIES

Crop nutrient management techniques include chemical fertilization, organic manuring, and mixtures of both inorganic and organic fertilizers which in combination improve soil health and ecosystem sustainability [4]. Ajwain is a seed spice crop; its yield and quality are important, and both can be achieved only by maintaining soil fertility through proper nutrient management practices. The level of nutrient supply at which the maximum yield of the plant is obtained reflects the optimum requirement of a particular plant species.

The fertility and productivity of the soil cannot be maintained solely by applying inorganic fertilizers. Restoration of soil health may also be aided by the incorporation of organic sources such as FYM and biofertilizers [33]. Further, an increase in nutrient supply does not affect plant growth but reflects luxury consumption without significantly contributing to either yield or quality.

Asangi *et al*.[34] studied that, out of varying nitrogen levels, i**.**e**.**, 0, 30, 60, and 90 kg N per ha**.** Maximum biomass was recorded at 60 kg N per ha, whereas maximum seed yield was recorded at 60 and 90 kg N per ha**.** "The experiment plot received 60 kg N ha^{-1} exhibited maximum values for plant height, number of primary and secondary branches per plant, plant spread, stem diameter, number of umbels per plant, number of umbellets per umbel, number of seeds per plant and seed yield per plant and ha. Higher doses of nitrogen enhanced protein and chlorophyll synthesis, leading to marked improvement in the plant's vegetative growth and yield attributes of the crop" [29].

Significantly higher yield attributes *viz*., umbel per plant (184.32), seeds per umbellates (16.97), umbellates per umbel (17.64), test weight (2.01 g) seed yield (11.69 q ha^{-1}), net return of Rs. 20320 per ha and BCR (0.97) in ajwain were obtained with application of 50 +25 kg N and P_2O_5 /ha. Mehta *et al*., 2013. Vahidipour *et al*.,[51] studied the effects of nitrogen on growth and yield traits in ajwain**.** The highest grain yield was related to 200 kg N per ha consumption**.** Further, Essential oil yield increased significantly with increasing nitrogen**.** The fertilizers levels did not affect substantially the fresh weight per plant **(**g**)** at 90 DAS and harvest index **(%).** The maximum benefit**:** cost ratio **(**2**.**05**:**1**)** was found 60**:**30**:**30 kg NPK per ha [32].

"Among the various fertilizer levels tried, the 60;30;30 kg NPK per ha significantly increased ajwain's growth, yield, and quality attributes under the Mandsur condition" [32]. "Out of different nutrient levels, 80; 40; 40 kg NPK per ha should form an integral part of ajwain and package of practices for getting a good harvest of the ajwain crop under climatic conditions of Vidharbha region of Karnataka" [49]. "Application of nitrogen up to 60 kg/ha recorded significantly increased plant height, dry matter accumulation, and chlorophyll content and number of umbels per plant (181.0), number of seeds per umbel (207.9), and seed (1081 kg ha^{-1}), straw (3012 kg ha^{-1}) and biological yields (4093 kg/ha) of ajwain over preceding levels but remained at par with 90 kg N per ha" [35]

8. IRRIGATION STUDIES

"Water is precious and scarce input, and its efficient utilization is necessary. Efficient use of irrigation water aims at utilizing available water resources to the maximum possible advantages in crop production. As such, using this costly and scarce input through efficient water management practices is essential. Among the several recognized criteria of irrigation scheduling, the climatological approach (IW/CPE ratio) is beneficial. Evapotranspiration by a full crop cover is closely associated with evaporation from an open pan" [36]. Information on the optimum water requirement of Ajwain is available meager which calls for a need to generate more information on the combined effect of different irrigation scheduling based on IW/CPE ratio for greater yields in Ajwain.

"Application of irrigation at 18 days intervals gave higher yield attributes viz. Umbel per plant (184.32), seeds per umbellate (16.97), umbellate per umbel (17.64), test weight (2.01 g) seed yield (11.69 q ha^{-1}) over-irrigation at 15- and 12-day intervals" [37]. Out of 2 irrigation methods i.e., Gyro net (micro-sprinkler) and mega net (mini sprinkler), mega-net performed better and gave 13.4% higher seed yield in ajwain than the gyro net micro sprinklers [38, 39].

9. WEED MANAGEMENT STUDIES

"Weed control is the section of weed science that most people are familiar with and where the greater part of education and training is focused. The methods employed to manage weeds vary, depending on the situation, available information, tools, economics, and experience. Improved agricultural technology over the centuries has significantly contributed to increased food production and a related increase in our standard of living" [48]. Excessive weed populations reduce the availability of water and nutrients to the crop. Sound agronomy and crop management throughout the growing season, in addition to using effective herbicides at the correct time, are critical to achieving optimum yield and high oil quality. It has been identified that 69 days after sowing is the Critical time for weed competition in ajwain crops [40]. Advances in weed control practices have been an important part of these gains. Some of the recent advances in weed management in Ajwain have been discussed here; Meena *et al.,* 2015 [41]. The pre-emergence application of oxadiargyl @75 g per ha + one hand weeding at 45 days after sowing (DAS) and pendimethalin at 1 kg per ha + one hand weeding at 45 DAS recorded significantly higher plant height, number of primary, secondary branches, number of leaves, number of nodes and dry matter accumulation per plant at (60 DAS, 90 DAS and at harvest). Hand weeding at 20, 40, and 60 DAS recorded

significantly higher plant height and dry matter production of the crop, yield attributes, and yield over the other treatments. Further, among integrated weed control treatments, oxyfluorfen @ 0.12 kg a.i per ha as PE fb quizalfop pethyl @ 0.05 kg a.i per ha as PoE at 20 DAS proved efficient in recording higher weed control efficiency (72.68%), seed (1,019 kg ha^{-1}) and haulm (1,222 kg ha^{-1}) yields with better weed index (11.77)[47]. Further, application of Oxadiargyl 50 g a.i. ha^{-1} and pendimethalin 1 kg a.i ha^{-1} applications led to lower weed intensity and increased weed control efficiency (WCE), respectively, and seed yield in the weed-free plots were statistically comparable to the yields from the application of oxadiargyl 50 g a.i. ha^{-1} [42].

10. INTERCROPPING STUDIES

Higher economic returns per unit area, better solar and land utilization, maintenance of soil fertility, fulfilling the supplementary requirement of the farmers, safety against natural calamities, and conservation of soil moisture are the targets or goals of intercropping or mixed cropping in any farming system**.** Since the area available for agriculture is limited and the demand for food has been increasing considerably, the replacement of traditional crops by seed spices may become unsustainable in the long run due to a reduction in area for cultivation of food and other commercial crops, unrealistic price, fluctuation in demand, supply, long gestation period in certain spice crops etc. Therefore, it is necessary to explore the possibilities of growing seed spices in areas where traditional agriculture is uneconomical or unsustainable. Mirhashemi *et al*., 2009 [43] reported that "the harvest index and dry weight per plant in ajwain were the highest in intercropping compared to pure culture. The most elevated land equivalent ratio (1.47) was obtained in single-row intercropping and the lowest (1.28) in double-row intercropping".

11. PEST

During storage, food grains and products are severely destroyed by insects and other pests. Stored spices are infested by two predominant pests, *viz*., cigarette beetle (*Lasioderm serricorne*) and drugstore beetle (*Stegobium paniceum*), besides numerous minor pests like, Khapra beetle, Lesser grain borer. Among non-chemical methods for managing drug store beetle population in Ajwain seed, diatomaceous earth @ 0.2% showed maximum mortality of bettle, minimum damage to seeds, and low microbial loads. Interestingly, impregnation of 1.0% w/v own seed oil on ajwain seed resulted maximum protection against the beetle population. [39]**.** Modified Atmospheric Packaging (MAP) was found highly effective for the

management of the beetle population in cumin and ajwain seeds using different inert gases [44].

12. DISEASE MANAGEMENT

The crop suffers due to diseases influencing the yield negatively. It is essential to manage the pathogen causing diseases and produce pathogen-free high-quality seeds [45]. The available recent advances in disease management in ajwain crop has cited in Table 2.

Table 2: Diseases and their management in Ajwain

Sl. No.	Disease	Symptoms	Management	Reference
1	Alternaria blight (*Alternaria alternata*)	Typical leaf spot symptoms appear first and later develop blight symptoms. The spots are small irregular, reddish brown with tan to gray in the centre.	Mancozeb 0.25% is the best spray to control the disease.	
2	Collar rot (*Sclerotium rolfsii*)	The stem near the soil gets infected, and a lesion is formed. The white hyphae grow around the stem, which later covers the lower portion of the stem. Mustard like sclerotia is formed by hyphae. The leaves exhibit yellowing starting from the base. The plant dries up.	The disease develops in patches. Turning of soil helps in checking the disease spread.	[45].
3	Powdery mildew (*Eryiphe polygoni*)	All the above ground parts are infected and get covered by a white powdery mass of the conidia of the fungus. When the inflorescence gets infected, all the flowers get aborted with no seed formation.	Spray of wettable sulphur 0.25% or Karathane 0.05% effectively controls the disease.	

The first report of phytoplasma infection affecting Ajwain in India was observed in Lucknow. The symptoms included small chlorotic leaves, highly proliferating shoots, witches broom appearance, shortened internodes, and an overall stunted growth. Poor flower heads and fruit settings caused considerable yield losses for farmers [46].

13. ECONOMICS

In view of the rapid spread of technology in agriculture, farmers are required to face severe competition, particularly when the farm produce is to be exported. One of the ways to

survive in the competition as also to gain better profit is to have a lower cost of production. For this, farm costing, or working out the cost of production of crops/enterprises, is necessary. The farm costing is also useful to the formers to keep watch on the expenditure which is increasing in modern farming. Significantly higher yield attributes, net return (Rs. 20320) per ha, and BCR (0.97) in ajwain were obtained with the application of 75 kg N and 50 kg P_2O_5 per ha.

The maximum net return (Rs. 35692) per ha was recorded with the spacing (45 x 30 cm). Similarly, significant maximum net returns (Rs. 29249) per ha was recorded with 80:40:40 NPK fertilizer application per ha. The highest B:C ratio (1.92:1) was recorded with spacing 45 x 30 cm. Some studies reported m aximum net returns (Rs. 67692 per ha) and highest cost: benefit ratio (1:2.7) was obtained in oxyfluorfen @ 0.12 kg a.i ha-1 as PE fb quizalfop -p-ethyl @ 0.05 kg a.i per ha as PoE at 20 DAS [32] [47].

14. CONCLUSION:

Looking into the importance of this crop, there is an urgent need to enhance the productivity and quality of the crop. Biotechnological interventions are very much required to understand crops genomics and develop desirable varieties for future generations. Focused work on quality analysis and value addition is required to look at this crop's high medicinal value and good agricultural practices standards for organic and non-organic cultivation. Major research is needed on pesticide residue management to earn better foreign exchange.

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