Advance Production Technology of

Fennel

(*Foeniculmn vulgare* Mill)

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Correct Citation: R.S.Mehta, S.S. Meena, M.M.Anwer, G.Lai & Krishna Kant (2009) Advance Production Technology of Fennel

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Published by: Director,

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Printed: November 2009 (500 Copies)

First edition: 2009

Revised in: 2021

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Printed at: Job Offset Printers

Ajmer

98294 72031

PREFACE

India is the world's largest fennel producing country with Syria, Egypt, Turkey, Germany, Spain and Pakistan also making significant contributions to global production.India and Egypt are significant exporters of fennel. In India it is mainly cultivated in Gujarat, Rajasthan, Madhya Pradesh, West Bengal and Uttar Pradesh covering an area of 75260 ha with production of 127790 metric tonnes and productivity 1698 kg per ha (2019-20). Gujarat and Rajasthan are major fennel producing states.The productivity level of fennel in our country is low. The main reason of low productivity are lack of adoption of improved variety, package of practices including weed management and control of insect pests as well as inadequate extension services and laggard attitude of farmer's for adoption of new innovation due to fear of poor performance on farmers field. The technology that have emanated out of research efforts at NRCSS and at different centres located in the different agro climatic regions, under the AICRP on spices at various SAU's and NRC on Seed Spices has been compiled in this book of advance production technology of fennel. We are assured that this publication shall prove highly useful to various stake holders such as field functionaries, growers, exporters, students and others having interest in cultivation of fennel scientifically.

We hope that technical bulletin will provide relevant informations.Suggestion if any for its improvement are welcome for future publication.

Ajmer Authors

1.11.2009

Introduction

Fennel (*Foeniculmn vulgare* Mill) belongs to family Apiaceae is a native of Southern Europe and Mediterranean region and one of popular seed spice in India mainly grown in Rabi season. The most common Indian name is Saunf and there are many popular regional names. It is widely cultivated through out the temperate and subtropical regions of the world and major growing countries are India, Syria, Egypt, Turkey, Germany, Spain and Pakistan. Major fennel producing states in India are Gujarat Rajasthan, Madhya Pradesh, West Bengal and Uttar Pradesh. Gujarat and Rajasthan are major fennel producing states, contributing nearly 96% of national fennel area and production both. In Rajasthan, it is mainly cultivated in Nagaur, Sirohi, Jodhpur, Pali and Swai Madhopur districts and in Gujarat the major fennel growing area are Mehasana, Morbi, Banaskatha, Sabarkantha and Aravalli. Major fennel growing district with higher region in India are given in Table 1.

Table 1: Major fennel producing state with zone/district

State	High productivity zone /district	Agro-climatic regions
Gujarat	Patan, Sabarkantha, Mehasana, Banaskantha	Gujarat plain and hill region
Rajasthan	Jodhpur, Nagaur, Sirohi, Pali	Western dry region

During 2019-20 (Adv. Est.) production of 127790 tonnes of fennel was achieved from 75260 ha area which is 7.61 and 4.3 percent of total seed spice production and area, respectively. The current productivity of fennel is 1698 kg /ha.

Cultural requirements

The important cultural practices for successful cultivation of fennel for realising higher yield are described as under:

Fennel is a cool season crop, mainly grown during winter season in north India, and does not thrive in south India except at higher elevation. A dry and cold weather favours higher seed production. Fennel thrives on long sunny days. A temperature of 15-30° C is the optimum and above 25°C for extended period usually retards development of fennel and in early growth may result premature flowering and very low seed yield. Crop is susceptible to frost injury at flowering stage. The optimum temperatures for seed germination is 20-29° C. High winds at the time of maturity can cause shattering of seed and very hot winds at flowering reduce seed setting. Therefore, climatic conditions are important abiotic factors, which decide expression of genetic potentiality off particular genotype.

Soil

Fennel thrives well on drained sandy loam to loamy soil, which is rich in plant nutrients and lime. However, heavy soils are more desirable than light soils. A neutral to slightly alkaline soil having the pH range 6.5-8.5 is preferable, it is showing good tolerance to salinity. Fennel is low accumulator of heavy metals and thus can be grown on polluted soil. Fennel is poor host of root knot nematodes, thus in soils having problem of root knot nematode, fennel can give reasonably good yield.

Cropping System

Adoption of proper cropping system is the best way to enhance resource use efficiency of land, water and nutrients. In present era of resource crisis, it is important to look for system productivity rather than resource productivity for realising higher resource use efficiency. Fennel is an ideal seed spice crop suited for inclusion of other short duration component crops because its initial growth for 50-60 days is slow, hence short duration vegetable crops like carrot, garlic, onion, chillies etc may successfully be taken along with fennel. Moreover it is desirable to include leguminous crops or other suitable crops which exhibits less competition for light, nutrient water and space. Carrot as component crop with fennel in 1:1 ratio is better for taking higher yield and profit. Care should be taken that inclusion of exhaustive crops should be avoided as it becomes depressive and harmful for realising better system productivity. Likewise, crop rotation should be adopted to keep away soil borne disease and weeds. Some of the crop rotations suitable for fennel under different agro climatic conditions of fennel growing area are as under:

Gujarat/Rajasthan

- Green gram Fennel- Summer fallow
- Black gram-Fennel- Summer fallow
- Cowpea Fennel-Summer fallow

Punjab

- Paddy- Fennel- Summer fallow
- Maize- Fennel- Summer fallow
- Green gram-Fennel-Summer fallow
- Kharif fodder- Fennel- Summer fallow

Recommended improved varieties

Suitability of variety for any agro ecological zones depends on its adaptability to the particular soil and climatic condition and should have resistance and tolerance against biotic and abiotic stresses

prevailing in the respective region. There are many varieties released for cultivation to different areas. A brief description of each variety is given as under:

(A) Rajasthan

Ajmer Fennel-1 (AF-1)

This variety developed through mass selection method and released at institute level in 2005. The variety developed at NRCSS, Ajmer is suitable for growing both for early sowing and as rabi crop. The plants are erect and tall, bearing large size umbels. It produces an average yield of 1950 kg/ha during rabi season and 2510 kg/ha when grown as an early transplanted crop. This variety has tolerance to *Ramularia* and *Alternaria* blight.

Ajmer Fennel-2 (AF-2)

This variety developed through recurrent selection method and released for national level in 2017. The variety developed at NRCSS, Ajmer is suitable for growing both for early sowing and as rabi crop. The plants are erect and tall, bearing large size umbels. Produces average yield of 1790 qkgha during rabi season. Its seed contain 1.9 % essential oil and 57.5% anethole+estyragol . This variety has tolerance to *Ramularia* and *Alternaria* blight.

Ajmer Fennel-3 (AF-3)

This variety developed through recurrent selection method and released for national level in 2018. The variety developed at NRCSS, Ajmer is suitable for growing both for early sowing and as rabi crop. The plants are erect and medium tall, bearing large size umbels. Produces average yield of 2140 kg/ha during rabi season. Its seed contain 1.9 % essential oil and 45% anethole+estyragol . This variety has moderately resistant to *Ramularia* blight.

RF-101

It has been developed by Sri Karan Narendra Agriculture University, Jobner (Rajasthan), through recurrent half sib-selection method from a local collection of Sohela (Tonk) and identified for release in 1995. The plants are tall erect type, with stout stem. It bears large umbel with long bold seeds. It matures in 150-160 days and gives an average seed yield of 1550 kg/ha.

RF-125

It has been developed by Sri Karan Narendra Agriculture University,Jobner (Rajasthan), through recurrent half sib selection method from an exotic collection, EC-243380 from Italy and Identified

for release in 1997. The plants are early, short stature type with compact umbels and long bold. It gives an average seed yield 1730 kg/ha.

RF-143

It has been developed Sri Karan Narendra Agriculture University, Jobner (Rajasthan) through recurrent selection method based on individual plant progeny and recommended for Rajasthan state. This variety is suitable for the loamy and black cotton soil. It is medium duration and medium tall, it gives an average seed yield 1200 kg/ha. Its seed contains essential oil f 1.87 per cent.

PF-35

It had been developed by Gujarat Agriculture University though selection from Pilwai local germ plasm in 1973. The plants are tall and spreading growth habit with medium sized hairless and green seeds. It seed contains 1.9 per cent essential oil. It matures 215-225 days and gives an average yield of 1289 kg/ha. It is moderately tolerant to sugar diseases, leaf spot and leaf blight.

Gujarat Fennel-1

It has been developed at Spice Research Centre, (Gujarat Agriculture University) Jagudan in Sardarkrushinagar Dantiwada Agricultural University, Gujarat. It was developed through pure line selection method from a local germ plasm (VC-14- 3-3) and released in 1984. The plants are tall, bushy type suited for *kharif and rabi* season It has umbels bigger in size, more number of umbel, seeds bold, long dark green colour, do not shatter, Its seed contains 2.2 % essential oil. It matures in 158 days and gives 1695 kg/ha seed yield and.It is tolerant to drought, moderately tolerant to sugary disease.

Gujarat Fennel-2

It is a high yielding variety developed at Spice Research Centre, Jagudan, in Sardarkrushinagar Dantiwada Agricultural University, Gujarat and was released in 1997 through pedigree selection method of local genotype. This variety is suitable for cultivation during rabi season under irrigated condition. Plants are matured within 159 days. It produces seed yield of 1940 kg/ha. The seed contains 2.4 % essential oil.

Gujarat Fennel-11

It is a high yielding variety developed at Spice Research Centre, Jagudan, in Sardarkrushinagar Dantiwada Agricultural University, Gujarat. This variety is suitable for cultivation during *rabi*

season under irrigated condition. Plants are matured within 157 days. It produces seed yield of 2500-2590 kg/ha. The seed contains 1.8 % essential oil.

Gujarat Fennel-12

It is a high yielding variety developed at Spice Research Centre, Jagudan, in Sardarkrushinagar Dantiwada Agricultural University, Gujarat. This variety is suitable for cultivation during *rabi* season under irrigated condition. Plants are matured within 151-160 days. It produces seed yield of 2400 kg/ha. The seed contains 1.9-2.0% essential oil.

Fennel-S, 7-9

This variety was devepoed Gujarat. It is dwarf variety of fennel. Seeds are bolder and it gives an average seed yield about 1200 kg/ha.

Hisar Swarup

It has been developed at Haryana Agricultural University, Hisar. This is a selection from indigenous germplasm and plant has an average height of 132 cm, spreading growth habit, late in maturity, resistant to lodging and shattering of seeds, Seeds are long and bold. It gives an average seed yield 1700 kg/ha. Its seed contains 1.6 per cent essential oil.

Co-1

It has been developed by Tamil Nadu Agriculture University Coimbatore, Tamil Nadu, through reselection method from PF-35 and released in 1985. The plants are medium with profuse branching. It matures in 210-220 days and gives an average yield of 567 kg/ha. It is suited for intercropping with other crops, saline and alkaline soil and hilly area. It also suitable for drought prone and water logged area.

Exotic hybrid varieties

In Italy some hybrid varieties have been developed having higher yield potential compared to other varieties. The important high yielding hybrid varieties are Plinio F_1,Mars F_1, Ronodo F_1, Orion F_1, Vietorio F_1 , Amigo F_1, Bravo F_1, Carmo F_1, Claro F_1, Clio F_1 and Pronto F_1.

Field preparation

The land should be well prepared for ensuring better germination and growth of fennel. The land may the irrigated if the moisture is not sufficient for germination of seed. First ploughing should

be done by soil turning plough and afterward 2-3 ploughing m should be done with harrow. The ploughed field should be made fine and levelled by planking. In order to manage problem of termite apply Endosulfan 4% or Methyl Parathion 2% dust, @ 25kg/ha or Fibronil granule @ 20 kg /ha in soil before planting.

Sowing time

Time of sowing is an important non-monetary agro technique for deciding level of productivity of other resources involved in crop production. Therefore, sowing of fennel at appropriate time is an important aspect in crop production for realising higher yields as well as lowering the incidence of disease and pests. Both, early as well as late, sowing results in reduction in yield and higher incidence of insect pest and diseases. Fennel, being a cool season crop is sown in the month of October to first fortnight of November. However, under North Indian condition, it can be sown in the hills during March-April. Sowing of fennel in October is an ideal period for main season crop. For early fennel, seed is sown in nursery in the month of July and about 45-50 days old seedling should be planted in the main field. Last week of September to first week of October is an appropriate time for transplanting of fennel in the main field. Recommended sowing time for fennel in different state is given in Table.2.

Table 2: Sowing time recommended for different fennel growing state

Name of state	Sowing time
Rajasthan	From 1st fortnight of October to mid November for direct sowing. For transplanted crop, nursery in June and transplanting in August-September.
Gujarat	For transplanted crop, first week of September in nursery and transplanting in 2nd half of October and first fortnight of October for direct sowing.
Bihar	1st week of September in nursery and transplanting in 1st week of October

Seed rate

Seed rate of fennel depends upon the method of sowing and type of variety used. Seed rate of bold seeded dwarf varieties is comparatively higher than normal seeded variety with profuse branching habit. Generally 2.5-3.0 kg/ha seed is required for sowing by transplanting method and 10-12 kg/ha for direct sown fennel. The seed rate recommended for different state is given in Table 3.

Table 3: Seed rate recommended for fennel in different states

Name of state	Direct sowing	Transplanting
Rajasthan	10-12 kg / ha	3-4 kg /ha
Gujarat	9-12 kg /ha	3-5 kg /ha
Bihar	9-12 kg /ha	3-5 kg /ha

Seed treatment

Seed treatment is an important practice for control of seed and soil borne diseases. The seed should be treated with Captan or Thiram 2.5g/kg seed.

Raising seedling in nursery

Select fertile land having good drainage. Raised bed of 1 meter width having connivent length must be prepared during May-June and sowing of about 2.5-3.0 kg seed is done in first week of September in a nursery area of 1000 m^2 for raising seedling for one hectare. Seeds are broadcasted in a well-prepared seedbed. The beds are covered with straw or stalk-mulch to protect against high temperature and strong sunlight and are irrigated. The seeds germinate within 7 to 8 days. The mulch is removed after germination. Irrigation is given as per requirement. Weeds in nursery should be removed manually. The seedlings are ready for transplanting after 45-50 days.

Sowing methods

Depending upon the variety used and availability of field, two methods of sowing *viz*. direct sowing and transplanting method are very popular in fennel growing area.

Direct sowing

In this method fennel is sown either in lines or by broadcasting seeds in a well-prepared flat seedbed and raking the bed surface prudently for mixing the same in upper 1-2 cm surface area. However, sowing in lines is comparatively better than broadcasting since it facilitate inter cultural operations like hoeing and weeding. If moisture is not enough in the field, pre-sowing irrigation is beneficial for facilitating better germination. Depth of sowing depends on soil type, type of seeds and soil moisture at the time of sowing. Normally, seed being of small size in nature should be sown at a depth of 1.5- 2.0 cm. deeper sowing delayed germination. Normally fennel takes 7-8 days for germination.

Transplanting

Transplanting of seedling should be done in evening hours otherwise seedling dies in sunny days. Seedling of 45-50 days old should be removed carefully from nursery after providing irrigation. After transplanting, light irrigation must be provided for establishment of seedling.

Crop geometry

Crop geometry is an important non monitory agro technique which plays an important role for proper interception of sun light which in turn results optimum physiological activities of plants. Maintenance of optimum plant population for fennel is a pre-requisite for better translocation of photosynthates from source to sink. If plant population is more than recommended then there is competition for light, space, water and nutrient resulting in lower dry matter accumulation per plant. Therefore in order to realise higher production of fennel, it is necessary to maintain plant population by adjusting crop geometry. State wise recommended spacing for fennel cultivation is given in Table 4.

Table 4: State wise recommended crop geometry for fennel

Name of state	Crop geometry
Rajasthan	60 x 30 cm between rows and with in rows respectively
Gujarat	60 x 40 cm
Haryana	Direct sown -30 x 20 cm Transplanted 90 x 60 cm

Fertilizer requirement varies from region to region depending upon type and fertility status of the soil, targeted yield of crop and variety to be grown. Therefore, manure and fertilizer should be applied based on soil testing report of fennel as well as targeted yield of fennel. Therefore in order to get good production of fennel about 15 t/ha well-decomposed FYM should be applied at least 3-4 weeks before sowing. In addition to this in the soil of normal fertility status 90 kg N and 40 kg P_2O_5 ha^{-1} should be applied. Fennel has responded positively up to 120 kg N and 50 kg P_2O_5 /ha. 1/3rd of total nitrogen and full dose of P_2O_5 should be applied as basal dose at the time of sowing and balance nitrogen should be applied in two equal splits as top dressing at 60 and 100 days after sowing in the standing crop. The proper soil moisture should be maintained before broadcasting of nitrogenous fertilizer for realising higher nutrient use efficiency. In the early growth, stage of fennel if plant seems week, then spray 1% urea on the crop 3 weeks after sowing. State wise fertilizer recommendation for fennel is given in Table 5.

Table 5: State wise fertilizer recommendation for fennel

Name of state	Recommendation
Gujarat	90 kg N, 45 kg P_2O_5 and 20 kg K_2O per ha. Nitrogen should be applied in three splits i.e. 50 % N as basal 25 % N at 30 DAS, and balance 25 % at 60 DAS. Full dose of P & K should be applied as basal dose at the time of field preparation.
Rajasthan	90 kg N and 50 kg P_2O_5 per ha. Apply 1/3rd N and full dose of P as basal and remaining N at 60 and 100 DAS as top dressing.
Haryana	50 kg N and 30 kg P_2O_5. Nitrogen should be applied in three splits i.e 50 % N as basal dose with full dose of P_2O_5 and balance 50 % N in two equal dose at 30 and 60 DAS as top dressing.
Bihar	60 kg N,40 kg P_2O_5 and 20 kg K_2O
Uttar Pradesh	60 kg N, 50 kg P_2O_5 and 10 kg K_2O

Irrigation

Fennel being a long duration crop, therefore water requirement of the crop is higher as compared to other seed spice crop. Depending upon prevailing temperatures and soil type, 6-10 irrigations should be applied at an interval of 12-18 days in fennel. In direct seeded crop, light irrigation is given immediately after sowing, if initial moisture is low for proper germination and establishment of the crop. At critical stage of fennel like flowering and seed formation, irrigation must be applied for realising higher yield and profit as well as higher water use efficiency and water expanse efficiency. Immediately after transplanting irrigation should be given for establishment of seedling and further irrigation must be given similar to direct sown fennel.

Intercultural operation

Due to slow growth of fennel and wider spacing, weed may pose problem in initial growth stages, however in later stages when the crop canopy is fully developed weeding is not required at all as the crop itself suppress the weeds. Three to four weeding are required for successful cultivation of fennel. Pre-sowing irrigation helps to reduce weed population, improve germination and thus helps the crop to compete with weeds in a better way. Initial weeding is needed after each irrigation till crop cover the ground. Integrated weed management is a cost, effective and appropriate method of weed control. Pre-emergence application of Oxadiargyl @ 75 g / ha or Pendimethalin @ 1.0 kg /ha or Oxyflurofen @ 150 g /ha along with one hand weeding and hoeing at 50 DAS /ha is effective for management of weeds in fennel. At the time of application of weedicide, there must be sufficient moisture otherwise efficiency of weedicide is drastically reduced. During summer season, soil solarisation with polythene has been found effective to

manage weed as well as soil borne disease in fennel. Therefore, in order to harvest good yield it is necessary to keep the crop weed free.

Plant protection

Fennel crop harboured number of insect pests at various stages of crop growth. Important insect pest are seed wasp, thrips, hopper, seed bug and leaf and stem feeding larvae like *Helicoverpa armigera* and *Spodoptera litura*. Among diseases damping off, *Ramularia* blight, *Alternaria* blight, and powdery mildew causing damage to the crop at different stages. Timely application of pesticide is needed to prevent the crop from serious damage from pest and diseases.

Fennel crop also attract large number of pollinator predator and parasite which contribute better quality and yield of crop. Application of selective insecticides and pesticides and spraying at evening hours should be done to conserve natural enemies pollinators population. The plant protection measure should include selection of resistant varieties, crop management practices such as sowing time, balanced nutrition, crop rotation, green manuring etc for reducing the incidence of disease, insects and pests and adoption of control measure.

Frost injury

Sometime fennel is affected with frost injury in the area where there is sudden fall in temperature during cropping season. Fennel is susceptible to frost during initial flowering and seed formation stage. It is better to irrigate the crop in anticipation of frost if atmosphere is clear, wind stop and sudden fall in temperature so that crop can be protected form frost and an arrangement of smoke should also be made in the field. Along with this application of 0.1% commercial H_2SO_4 has been found effective to protect the crop against incidence of frost.

Diseases

Ramularia blight (*Ramularia foenicuii*)

The disease cause considerable loss in yield due to destruction of foliage and poor development of fruits. Brown to black lesions is formed on the leaves, stem, and peduncle and on seeds. This later shows whitish growth. The infection spread to stem, peduncle and fruits and cover whole plant with a fungal growth of ash colour. Severe infection results in shrivelling and drying up of leaves giving a blight appearance. Flower buds of the diseased plants turn yellowish brown and ultimately dry up.

Control

- Avoid excessive irrigation

- Use disease free seed
- Adopt field sanitation measures
- Use tolerant varieties like AF-1
- Spray the crop with 0.2% Mancozeb or Difolatan or Zineb on 60 to 90 days old crop or at the time of diseases appearance and also during cloudy weather. The spraying should be repeated at 15 days interval.

Alternaria blight (*Alternaria teniusi*)

The disease attacks mainly the inflorescence. Initially the infection starts on lower buds, which turn yellowish or brown and whole inflorescence dry up resulting in heavy loss of the yield. Occasionally the disease is also observed on the tips of the leaves of young plants in the form of brown spots, which may check the growth of the plants.

Control

- Avoid excessive irrigation
- Use disease free seed
- Adopt field sanitation measures
- Use resistant/tolerant varieties like AF-1
- Spray with 0.2- 0.3 % Mancozeb or Copper oxychloride or 0.1 % Carbendazim and repeat spray at 15 days interval.

Powdery mildew (*Leveillula taurica*)

Powdery mildew appears generally in the month of February and March in Rajasthan and occasionally causing severe losses. Initially the disease appears on the leaves and then on stem and other parts such as umbels in the form of white powdery spots. The disease appears in the situation of high temperature and humidity.

Control

- Dusting with 300 mesh sulphur @ 20-25 kg/ha or by spraying wettable sulphur 0.2% at 15 to 20 days interval during flowering control the attack of powdery mildew in fennel.
- Foliar spray of onion extract (5%) is effective in reducing the severity

Drooping off (*Sclerotina sclerotinorum* (Lib) de Bary)

This disease was first reported from Tonk, Rajasthan in 1965-66. Drooping off was the first characteristics symptoms of this disease. White colony appeared on the infected portion. Stem

becomes yellowish brown, whole vasculare zone is plugged with black, hard sclerotial bodies of 0.5-1.5 cm in length.

Control

- Soil drenching with Vinclozin, Procymidox, Iprodione and Benomyl @2 g /ha

Nemotade (*Meloidogyne javanica*)

Though fennel being poor host to root knot nematode, generally precautionary measure can take care of crop as given below

Control

- Use disease free seed
- Adopt field sanitation measure
- Apply neem cake @ 1000 kg /ha

Insect /Pests

Fennel is long duration seed spice crops and grown under two sowing times. It grown at mid of August to September and during October months. It is important crop for insect pests management as it attacked by different pests which cause serious loss to yield. It is also attracted very large numbers of predators/ parasitoides and pollinators as it provide nectar and pollen to them for very long duration.

Insect- Pests of fennel

Aphids:

Hyadaphis coriandri is the main aphids species of fennel crop in India. It is the major pests of fennel crop and causing serious damage to the crop resulting in poor quality of seed and reduced yield. Heavy infestation of aphid may cause up to 50 per cent of yield losses in comparison to normal crop. Development of aphid started at vegetative stage of the crop and continues to develop until seed mature. Maximum colonization of aphids develops on umbel. Nymph and adults suck sap from the tender leaves, which make it weak and shrivelled. Aphid attacks at flowering stage results serious damage. It exudes copious quality of honeydew, which favours the growth of sooty mould. As a result the growth of plants retards and quality and quantity of fruits are also affected. When infestation occurs at flowering and fruiting stage, the fruit are not formed and if they are formed they are shrivelled and of poor quality.

Thrips:

Fennel crop attacked by thrips during vegetative stages. Crop colonised by thrips at early vegetative stages causes more damage than its attack at full vegetative stages. Thrips species mostly found on fennel plants are *Thrips tabaci*, *Frankliniella schultzei* and *Scirtothrips sp.* Both adults and nymphs congregate at the leaf sheath or in the flowers and feed on the plant sap by lacerating the leaf tissues causing of drying of leaves and umbels.

Management of Aphids/Thrips/Mites:

- Installation of yellow or blue sticky traps at suitable palce and height should be done at early vegetative stage of plant for aphid management.
- Use botanicals Neem seed kernel extract (NSKE) 5.0%, Neem oil 2.0%, Azadirachtin 10000ppm @2.0ml/lire and bio-pesticides like *Verticillium lacanii*1x10^8 CFU's/gm5.0 g. /litre of water as foliar spray on the crops.
- For mite control use bio pesticide *Hirsutells thompsoni* 1x10^8 CFU's/gm5.0 g. /litre of water as foliar spray on the crops.
- In case of severe infestation need based use of chemical insecticides i.e. Emamectin benzoate @ 10 g ai/ha or Thiacloprid @ 0.24% or Dimethoate 30EC @ 0.03% to prevent losses.

Seed wasp, *Systole albipennis* (Walker)

Systole albipennis is another important pests of Fennel. This pest comes under category of quarantine pests, since its immature stages present inside the seed after the harvest. It causes the damage in field condition but the immature stage present inside the seed emerged at storage. The eggs hatches inside seed and developed larva feeds upon and destroys the embryo and/or endosperm consequently. Adult emerge out by making exit hole in the seed. They complete their life span within 25 days from egg to adult's stage. The immature stages present inside the seed after harvest emerged in storage condition and takes two to three months or even more.

Management of Seed Wasp:

- Apply botanical products i.e. neem products NSKE 5% @ 5ml/lit, neem oil 2% ot karaj oil 2% is effective against this pest.
- Soil application of Karanj meal 500 kg/ha. + Spray of Karanj oil 2%.
- There is no level claim of any insecticides for seed wasp in fennel crop. However in case of severe infestation need based use of chemical insecticides i.e.Abamectin 1.9EC @ 2ml/lit or Thiacloprid @ 0.24% to prevent losses.

Defoliators:

Fennel cropattacked by defoliators from flowering to seed maturation stages. The common species found on seed spice crops are *Spodoptera litura* S. exiqua and *Helicoverpa armigera*.In fennel crop it causes 16 to 20 percent loss when the larval population reached at 2 to 3 larvae/ plant in fennel crop.

Management of Defoliators:

- For managing noctuids moth larvae at field conditions 4-6 inaculative releases egg parasitoids 150,000 like *Trichogramma Chilonus*. *T. Brasielensis* @ 150000 parasitoides/ha or starting at first appearance of the moths at 1-15 days interval is found useful.
- Application of NSKE (Neem Seed Kernal Extract) at 5 per cent or Neem oil 2 per cent or commercial formulation of neem based pesticide gives effective control of early stages of infestation.

Harvesting and yield

Time of harvesting depends upon the type of the products we are interested. Therefore, in order to get green saunf which is used for chewing purpose, umbels are harvested about 30-40 days after flowering when these are still green and have attained half-length size. In order to get mature seeds for spice purpose umbels are plucked, when fruits have changed their colour from green to yellow and are fully mature. All the fruits does not mature at a time, therefore harvesting of umbels has to be done 4-5 times as and when they become ready. Harvested umbles should be dried in shade under well-aerated conditions particularly for green fennel. Umbels should never be piled as it may deteriorate the quality. The dried umbel are separated and cleaned by winnowing.

Under scientific management conditions of the crop, average yields of20-25 q/ha can be harvested.

Cleaning, packaging and storage

Seeds are used to store in gunny bags lined with polythene film. Vacuum gravity separator is used for cleaning ajwain seeds. The properly cleaned ajwain seeds are stored with an initial moisture level of 7-8% and at an equilibrium relative humidity of 40%. Fennel seeds well packed are stored in ventilated dry and cool place under ordinary conditions till sowing of next season crop.

Processing

The fennel seeds are dried in partial shade in the sun and the moisture content of seed should be kept to nine per cent. High seed moisture content may lead to chance of contamination by fungus.

The dried, cleaned and graded produce is packed in the standard sized packs/ container and appropriately labelled. The dried seed is filled in the gunny bags lined with degradable environment friendly plastic films. Waste generating packaging material should be avoided. Each bags is sealed and stored under clean, dry and ventilated place.

Processing method of fennel should be based on mechanised, Care should be taken to maintain the vital quality of ingredient through each step of its processing. Processing method should be selected in such away that it would limit the number and quantity of additives and processing aids. The mature dried seeds are distilled to obtain the essential oil. Hydro or steam distillation method is generally used for extraction of essential oil. On an average, the dried seeds yield 0.7- 2.0% volatile oil. The percentage of volatile oil varies depending upon variety and type of fennel. The volatile oil is lowest in Indian fennel (0.7-1.2%) and highest in European fennel. The oleoresin prepared from fennel have good demand in the international market. The volatile oil should be kept in well sealed bottles or aluminium containers. The essential oil of fennel is used for scenting soap and as flavouring material for cakes. The by-product arks of saunf after extraction of essential oil possess good medicinal properties for curing indigestion problems at home level remedies.

Products

The characteristic odour of fennel oil is due to the high content of anethole. The essential oil of fennel seed is colourless or pale yellow liquid with a characteristic taste and odour. The taste and odour of sweet fennel oil are superior to those of bitter fennel oil. Indian fennel oil contain over 70% anethole and 6% fenchone. The oil of good quality contains 50-70% anethole. The oil of sweet fennel contain high percentage of anethole (upto 90%) and the in the absence of fenchone are responsible for its delicate sweet odour and flavour. Tarpenless fennel oil is obtained by removing terpenes.

Other names of fennel

Fennel is commonly known as Saunf and other name of the fennel are common fennel, Florescence Fennel, Sweet Fennel, Wild Fennel, Large Cumin and Sweet Cumin. In foreign languages fennel is named as below.

- French : Fenouil
- German : Ffenchel
- Greek : Marathon
- Italian : Finocchio

- Spanish : Hinojo
- Chinese : Wooi heung
- Indian : Barisaunf, Mdhurika and ,Sonf
- Indonesian : Adas
- Malaysian : Jintan manis

Uses

Fennel plant is pleasantly aromatic and is used for its seed, which have pleasing fragrance and a pleasant aromatic taste. It is widely used in various Indian dishes for flavouring soups, sauces, pastries, confectioneries, bread rolls liquor, meat dishes and in seasoning pickles. In India, fennel seeds are chewed alone or in beetle leaf. The fennel leaves are used in fish's sauces and for garnishing and the leaf stalk is used in salad as a vegetables. The seeds also have use for flavouring liquors and in the preparation of various types of pickles. The leaves are used in fish sauces and for garnishing while leafstalks are also used both as vegetables and salad. Chinese, Indian and Egyptian have used it as condiments. The thickened leaf stalk of Florescence fennel are branched and used as vegetables. The oil is widely used as flavouring agent in culinary preparation, confectionery, cordials and in liquors.

Medicinal uses

Fennel seeds, leaves and roots all possess medicinal uses. The leaves are used as diuretic, fruits are aromatic, stimulant and carminative and the roots as purgative. The seeds are aromatic, act as stimulants and are carminative they are used in disease like cholera, bile, nervous disorder, cough and cold, constipation, dysentery and diarrhoea and also for disease affecting chest, lung spleen and kidney. A hot infusion of fruit is used in indigestion medicine to increase lacteal secretion. Fennel volatile oil relieves abdominal air, stomach pain and bloating, stimulate appetite, diuretic and anti-inflammatory also used in medicinal preparation like in infantile colic and flatulence. It checks griping and is considered a good vermicide against hookworm. The residue left after extraction of essential oil from fruits is used as feed for cattle. The fennel seeds aids to weight loss and longevity. Chinese, Indian and Egyptians use fennel seeds as a remedy for snakebites and scorpion stings. The essential oil of fennel has been reported to possess oestrogen stimulation properties that make it useful for treating postmenopausal syndrome (PMS) and regulate menstrual period. Owing to antimicrobial properties it is used in cosmetic creams, body lotion and moisturisers. The essential oil of fennel is used for scenting soap and as flavouring material for cakes.

Economics of fennel cultivation:

Cultivation of fennel is highly remunerative to farmers. The cost and returns may vary from farmers to farmers, field to field, district to district and state to state. The average cost and return based on the information provided by the farmers during 2018-19, average input cost of cultivating one hectare of fennel farmers incurred input cost of Rs. 32432 per ha. Average yield harvested at surveyed farmer's field was 14.19 quintal per hectare valued at Rs. 109633. The return after adjusting input cost was arrived at approx 77 thousand rupee per ha. The average return of 3.38 rupee per rupee of cost (A2) was estimated.

S. No.	Particulars	Value in rupees
1	Cost of production per hectare (Cost A2)	32432.00
2	Average yield (Kg per ha)	1419.00
3	Gross return per hectare (@7726 Rs per quintal price)	109633.00
4	Returns over cost A2 per hectare	77201.00
	Return per rupee of cost A2	3.38

Acknowledgement:

This matter has been collated from original research work carried out at NRCSS and from research reports of other centres and also from AICRP on spices. It includes the following references.

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