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Advances in cultivation of fennel

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Abstract

Fennel (*Foeniculum vulgare* Mill), wild or cultivated, is cosmopolitan throughout the world and belongs to the *Apiaceae* family. It is one of the major seed spices in India which has been ordinarily used as a conventional food and medicine. Fennel seeds are commonly used for their antispasmodic, anti-inflammatory, antimicrobial properties and oestrogen-promoting action. Recent studies has known fennel as a valuable medicinal plant with potential for varied uses, in addition to provide raw materials of pharmaceutical business, particularly steroidal hormones. A significant increase in quantity and quality yields through the suitable practices and chemical constituents could build a necessary contribution to farm and pharmaceutical trade. To achieve these goals with reference to sustainable production, we tend to review an outline of biology and cultivation of fennel in this paper.

Keywords: Fennel, medicinal uses, botany, crop improvement, cultivation, commercial products, quality specifications

1. Introduction

Foeniculum vulgare is the oldest valid name inside the genus *Foeniculum* for the plant selected by Karsten as *Foeniculum Foeniculutn*. In 1768 Philip Miller, who first legally published as *Foeniculum vulgare* in his eighth edition of "Gardeners Dictionary" on accordance with the international rules as adopted at Cambridge. From then on, the name of this plant is written as *Foeniculum vulgare* Mill. It is a medicinal plant belonging to the family Umbelliferae (*Apiaceae*), used by humans from ancient past because of its flavour. It is globally known as Fennel. In India it has many local names. Some of them are mentioned here - Hindi: Moti saunf, Manipuri: Hop, Tamil: Sompu, Malayalam: Preumjirakam, Telugu: Peddajilakarra, Kannada: Dodda sompu, Bengali: Mauri, Sanskrit: Misreya, Madhurika.

In Greece, fennel was considered as symbol of success. In Rome, tender fennel shoots were used as food. Though details about its introduction are obscure, it has occurred in California for the past 120 years and is presumed to have escaped from cultivation repeatedly. As an important economic crop, fennel has been used and traded internationally for centuries due to its therapeutic and culinary utilisation.

1.1 Culinary Uses

It is an extremely aromatic and flavourful herb with cookery and medicative uses. Fennel seeds have anise like aroma and are mainly used as flavourings in food, meat and fish dishes, ice cream, alcoholic beverages and herb mixtures (Diaaz-Maroto *et al.*, 2005) [10]. The bulb, foliage and seeds of the fennel plant are widely employed in various culinary cuisines across the world. It is chiefly used in Mediterranean cuisine, where bulbs and leaves are used, both as raw and cooked, in side dishes, salads, pastas, vegetable dishes. Many cultures in the Indian subcontinent and the Middle East use fennel seeds in their cooking. Fennel is one among the foremost vital spices in Kashmiri Pandit and Gujarati cookery. (Grieve, 1931) [13].

1.2. Medicinal and Therapeutic Uses

Fennel has antioxidant, antitumor, chemopreventive, cytoprotective, hepatoprotective, hypoglycemic, and oestrogenic activities (Singh, 2008). Apart from its carminative properties, fennel is mainly used as purgatives along with liquorice powder. Fennel water has properties just like those of anise and dill water that is mixed with sodium bicarbonate and sweeteners, which are readily consumed as domestic 'gripe water', to cure flatulence in infants. Fennel tea, extensively utilized as a carminative, is made by pouring boiling water on a teaspoonful of bruised fennel seeds. In the Indian Subcontinent, fennel seeds are eaten raw, sometimes with some sweetener to improve digestion. Studies indicated that the presence of phytoestrogens in fennel helps to promote growth of breast tissue, thereby helps in milk secretion. (Agarwal *et al.*, 2008) [1].

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1.3 Origin and distribution

Fennel is an extensive species that is naturalised principally in the coastal and sub-coastal districts all through the southern and south-eastern parts of Australia. Broadly established in the UK, Southern Africa, New Zealand and Pacific Islands (i.e., Hawaii, Fiji, New Caledonia, Niue and French

Polynesia), USA, Mexico, Central America and South America. Punjab, Haryana, Bihar, Maharashtra and Karnataka. Gujarat is the leading state in Fennel production, which contributes about 85-90% of the total Indian production. The area, production and export for fennel are given in Table 1 and 2.

Table 1: State wise area and production of fennel in India

| Major state | 2016-17 | | 2017-18 | | 2018-19 | |
|----------------------|-----------|-------------------|-----------|-------------------|-----------|-------------------|
| | Area (ha) | Production (tons) | Area (ha) | Production (tons) | Area (ha) | Production (tons) |
| Gujarat | 40910 | 87820 | 38130 | 79240 | 56416 | 117340 |
| Rajasthan | 45200 | 56240 | 24370 | 19950 | 30678 | 35290 |
| Madhya Pradesh | 1430 | 2520 | 1480 | 2720 | 1488 | 2760 |
| West Bengal | 1020 | 1020 | 1030 | 1050 | 1025 | 1050 |
| Uttar Pradesh | 690 | 760 | 730 | 800 | 708 | 790 |
| Total (incl. others) | 89540 | 148560 | 65810 | 103830 | 90392 | 157347 |

(Source: otherspices - State Agri/Horti Departments/DASD Kozhikkode)

Table 2: Major importers of fennel from India (2017-18)

| Country | Quantity (MT) | Value (Rs. Lakhs) |
|----------------------|---------------|-------------------|
| Vietnam | 18975.62 | 12245.42 |
| U.S.A | 2314.59 | 2556.10 |
| Malaysia | 2298.54 | 1679.94 |
| Saudi Arabia | 1570.04 | 1193.80 |
| U.K | 766.91 | 996.33 |
| U.A.E | 1183.52 | 967.62 |
| Total (incl. others) | 34550.00 | 25906.35 |

(Source: DGCI&S Kolkata/Exporters' Returns/DLE from Customs)

1.4 Botany

Fennel is a highly aromatic annual, biennial or perennial herb. It is erect, shining green and grows to heights of 2.5 m tall, with hollow stems. The leaf matures to 40 cm long and finely compound, with the ultimate segments filament-like, about 0.5 mm wide. The leaves are similar to those of dill, yet slightly thinner in comparison. The flowers are produced terminally in compound umbels which are 5–15 cm wide.

Each umbellate have 20–50 tiny yellow flowers on short stalks. The fruit could be a dry seed from 4–10 mm long, half as wide or less, and grooved. It is brownish or greenish grey, ovate, ribbed with 1.5-2 mm broad (Grover, 2013). The fruit has stylopodium and pericarp with oil canals contain an essential oil. The seed contains 0.7-1.2% volatile oil, which majorly constitutes anethole, fenchone and trace amount of pinene, camphene, diphetene *etc.*

2. Crop Improvement

Crop improvement in fennel has mainly focused on following objectives like wider adaptability, high yield with good aroma, taste, colour and uniformity in size and shape of the seeds, high essential oil content, disease (powdery mildew) and pest resistance varieties.

There are many varieties released commercially for cultivation in different areas of the country through AICRP on seed spice. A brief description of each variety is given in Table 3.

Table 3: Improved varieties/ cultivars of fennel released in India

| S. No | Variety | Pedigree /parentage | Duration (days) | Av. Yield (kg/ha) | Salient features |
|-------|-------------------|---|-----------------|-------------------|---|
| 1 | PF-35 | Selection from local germplasm | 225 | 1280 | Moderately tolerant to leaf spot, leaf blight and sugary disease |
| 2 | CO 1 | Reselection from PF 35 | 220 | 570 | Suitable for intercropping and border cropping with chilli and turmeric. Suitable for drought prone, water logged, saline and alkaline conditions |
| 3 | Gujarat Fennel 1 | Pure line selection from Vijaypur local | 225 | 1695 | Suitable for early sowing, tolerant to drought |
| 4 | Gujarat Fennel 2 | Pedigree selection from local germplasm | 225 | 1940 | Suitable for both rain fed and irrigated condition |
| 5 | Gujarat Fennel 11 | Selection based on individual plant progeny performance from local germplasm | 148 | 2489 | A medium maturity type adapted to <i>rabi</i> season under irrigation; seeds medium bold. |
| 6 | RF 101 | Recurrent half sib selection | 150-160 | 1400 | Medium maturity type with long bold grains, most suitable for loamy and black cotton soil. |
| 7 | S-7-9 | Selection | 210 | 1100 | A bushy plant with big umbel, moderately tolerant to blight. |
| 8 | RF 125 | Recurrent half sib selection on EC 243380 from Italy | 110-130 | 1700 | Plants are short statured with compact umbels and long bold seeds when presence, denser view of plants green. |
| 9 | RF 143 | Recurrent selection | 130 | 1200 | Medium tall and recommended for loamy and black cotton soils |
| 10 | RF 205 | Recurrent selection based on individual plant progeny (half sib) from F2 generation of a cross between JF-25 x RF-125 | 140-150 | 1600 | Medium maturity, erect and medium tall plant with long and attractive seeds |
| 11 | Hisar Sawrup | Mass selection from indigenous germplasm of Haryana | 175-185 | 1600 | Plants grow up right, spreading, gives a bushy appearance. A late maturity type grain long and |

| | | | | | |
|----|----------------|---|---------|------|---|
| | | | | | bold, resistant to lodging, no shattering of grains. |
| 12 | HF 143 | - | 150 | 1779 | This variety has out yielded other varieties, GF-II (National check) and local checks under coordinated varietal trials of AICRPS |
| 13 | Azad Sanuf 1 | Selection from germplasm | 160-170 | 1500 | Medium plants, resistant to blight and root rot diseases. Escapes attack of aphids due to early maturity, seeds are bold green. |
| 14 | Pant Madhurika | Pure line selection from local germplasm | 180 | - | Tall robust erect plant with big umbels having bold seeds with green fine ridges sweet in taste, medium maturity. |
| 15 | Ajmer Fennel 1 | Recurrent selection from individual plant progeny | - | 1950 | Medium maturity seed, bold, tolerant to blight |
| 16 | Ajmer Fennel 2 | Recurrent selection from individual plant progeny | - | 1790 | Moderately resistant to <i>Ramularia</i> blight diseases. Superior in quality as seed contains 1.9% essential oil. |

3. Package of Practices

3.1 Soil and Climate

Cool and dry climate is best for the cultivation of fennel crop. Prevalence of dry and cool weather during the seed set increases seed yield as well as the quality of the produce. Fennel can be cultivated in all types of soils which are rich in organic matter. Shallow sandy soils are not suitable for fennel cultivation. Best soils for fennel cultivation are black cotton soil and loamy soil containing lime (soils of Gujarat, Rajasthan, UP). Proper drainage is also an important requisite for commercial cultivation of fennel crop. Fennel is unsuitable in waterlogged and salt-affected lands (Anon., 2014) [3].

The optimum temperature for growth is 15-20° C and high temperature result in premature flowering and low seed yield. It can tolerate a range of annual precipitation from 0.3 to 2.6 mm and soil pH from 5.5 to 7.5.

3.2 Germination improvement

Seed spices belongs to *Apiaceae* family have been reported to exhibit poor crop stand due to slow germination, dormancy and sudden shift in climate from optimum to abnormal. 16-18° C has been considered as preferable temperature for germination and it takes 8-10 days to germination (Malhotra and Vashishtha, 2007) [23].

The seed spice crops have been reported to have less dormancy problem. So, soaking of seeds has helped hastening the germination process in most of the seed spices crops. Soaking of seeds in water for 8-12 hours in coriander, fennel, ajowan have been observed good germination. (Malhotra, 2012) [22].

3.3 Seed rate

Fennel is mainly propagated through seeds. Direct sowing as well as transplanting can be done. Betul (2013) determined the appropriate seeding rate for fennel cultivation without using any chemicals and reported that highest fruit yield was obtained on 15 kg ha⁻¹ seeding rate.

3.4 Sowing

As fennel seeds are small, line sowing is followed majorly. Maximum depth of sowing for fennel seeds is 1.5-2 cm and adopting row – plant spacing of 45-60 X20-25 cm. Main season for fennel sowing is Mid September- First week of October, for early season crop, July (Nursery sowing) August (Transplanting) (Malhotra, 2012) [22].

Sharma and Prasad (1990) [29, 30] made an experiment on effect of seed rate and row spacing in fennel at IARI, New Delhi. They obtained highest seed yield of 2850 kg ha⁻¹ in bold – seeded cultivar when row spacing was maintained as 30 cm with sowing rate of 40 kg ha⁻¹.

Ahmad (2004) [2] has also conducted research on effect of different sowing seasons and row spacing on fennel in NWFP Agricultural University, Pakistan. He recorded highest seed yield (560.5 kg ha⁻¹) in autumn sowing (15th October) crop in 40 cm row spacing.

Yadav *et al.* (2000) [33] studied effect of row spacing and plant population on growth and yield of fennel cultivar PF-35. This study was conducted in CCS Haryana Agricultural University, Hisar. They resulted that the spacing of 40 X 25 cm gave maximum plant height (182.0 cm), number of primary branches/ plant (6.55) and number of umbels/ plant (30.5) but maximum fruit yield (24.16 q ha⁻¹) and biological yield (136.2 q ha⁻¹) were produced at 20 × 15 cm spacing and minimum at 40 × 25cm spacing.

In transplanted fennel, higher yield attributes were recorded in planting density of 27,770 plants ha⁻¹, while seed yield ha⁻¹ was higher with density of 55,550 plants ha⁻¹ (20.89 q ha⁻¹) (Menaria and Maliwal, 2007) [26].

3.5 Manures and Fertilizers

DASD, Calicut has recommended about 15 t ha⁻¹ well decomposed FYM should be applied at least 3-4 weeks before sowing. In addition to this 90 kg N, 40 kg P₂O₅ and 30 kg K₂O/ha should be applied as, 1/3rd N and full dose of P₂O₅ and K₂O should be applied as basal dose at the time of sowing and balance nitrogen should be top dressed in the field at 30 & 60 days after sowing. In the early growth, stage of fennel if plant seems week, then spray 1% urea on the crop 3 weeks after sowing.

Delfieh *et al.* (2016) [29] investigated the effects of different nitrogen nutritional systems including chemical, organic and biological ones on yield and essential oil content of fennel. Results showed that spraying of urea (50% at planting time and 50% at stem elongation) has lead to 13.4 % more seed yield production with 3.28 % essential oil content than control. Moreover, the study showed that replacing 50 % of required nitrogen with cow manure in fennel could lead to a favourable quantitative and qualitative seed production.

Ayub *et al.* (2011) [5] found out application of 90 kg N ha⁻¹ resulted higher seed yield in fennel and this increase in yield is due to greater plant height, umbels per plant, seeds per umbel and 1000- seed weight.

Application of native phosphate solubilizing potential of *Bacillus subtilis* strains PSB-1 and PSB-36 is helpful in increasing the seed yield as well as essential oil content in the fennel seeds. These two PSB isolates are able to enhance the Phosphorus availability significantly in the saline, semi-arid soil commonly found in fennel growing areas of Rajasthan in India. The application of PSB microbial inoculants will not only help in increasing the nutrient use efficiency but also

reduce the dependency of chemical phosphatic fertilizer in fennel cultivation (Mishra *et al.*, 2016) [27].

Zardak *et al.* (2017) [34] revealed that *Arbuscular mycorrhiza* (AM) inoculation remarkably affect quantitative and qualitative yield of fennel. Since it is a mycorrhizal dependent plant, the inoculation with AM fungi is an excellent strategy to enhance the benefits of the symbiosis. Application of *Glomus mosseae* is more efficient under drought stress so that supports fennel plants. The application of these microorganisms could be critical under arid and semi-arid areas, where water is the most important factor in determining plant growth and yield.

Using biofertilizer (combined strains) i.e. *Azotobacter chroococcum*, *Azospirillum lipoferum*, and *Bacillus megatherium* plus half a dose of NPK have resulted in the greatest plant growth and yield in fennel (Mahfouz and Eldin, 2007) [18].

3.6 Irrigation

Kouchaki *et al.* (2006) [17] studied effect of different irrigation intervals and plant density on yield of fennel. They obtained maximum grain yield in the crop when it is irrigated at 10 days interval and plant density of 100 plants per m².

Sharma and Prasad (1990) [29, 30] observed higher yield in fennel crop as it was irrigated at 0.6 IW/CPE.

When irrigation water contains salinity levels up to 1000 ppm, it might be recommended to add 5 ton/ ha organic manures to fennel plants in order to reduce or overcome toxicity and to get relatively good plant growth and yield (El-Magd *et al.*, 2008) [11].

3.7 Intercultural Operation

Mubeen *et al.* (2009) [28] studied critical period of weed- crop competition in fennel and concluded that weeds control in fennel crop should be done before 50 days of emergence as it was the critical period of competition.

Meena and Mehta (2009) [24] revealed pre- emergence application of oxadiargyl at the rate of 75g ha⁻¹ along with one hand weeding at 45 DAS recorded significantly highest plant height at all growth stages and yield attributes.

3.8 Plant protection

Khare *et al.* (2014) [16] have studied the various diseases affecting fennel genotypes and their management practices. They found that crop is attacked by pathogens causing diseases viz. Damping off of seedlings (*Pythium aphanidermatum*), Ramularia blight (*Ramularia foeniculi*), Cercospora blight (*Cercospora foeniculi* Magn), Alternaria blight (*Alternaria alternata*), Rhizoctonia root rot (*Rhizoctonia solani*), Ascochyta blight (*Ascochyta foeniculum* Mc Alpine), Downy mildew (*Plasmophara nivea* (Casparg) Schroeter), and Powdery mildew (*Leveillula taurica*).

Ramularia blight of fennel is a constraint to get potential yield. To manage it, field trials were conducted by Jaiman *et al.* (2013) [15] and they found out better control of disease with higher yield on three sprays of Emcab @ 0.2 % or mancozeb @ 0.2 % or carbendazim @ 0.05 %

Organic based IPM modules were evaluated for the management of thrips on fennel under field conditions. Results showed that the maximum reduction (63.22%) in thrips population on the plants treated with IPM module M-3 (Garlic extract @10 ml lit⁻¹ + azadirachtin 0.03% EC @ 5ml lit⁻¹+ tumba fruit extract @10ml lit⁻¹) (Meena *et al.* 2019) [25]

3.9 Harvesting and Yield

Time of harvesting depends upon the type of the products marketed. For green saunf used for chewing purpose, umbels are harvested about 30-40 days after flowering when these are still green and have attained half length size. Since not all the fruits mature at a time, therefore harvesting of umbels has to be done 4-5 times as and when they become ready. Umbels are plucked when fruits have changed their colour from green to yellow and are fully mature. Under scientific management conditions of the crop, an average yields of 20-25 q/ha can be harvested.

Bhati (1990) [7] studied the effect of stages of umbel picking on fennel and found out better quality seeds can be obtained when umbels are harvested at half –length seed stage i.e., bright green, of uniform shape and size, and with good fragrance.

3.10 Post harvest handling

3.10.1 Whole seeds

Harvested umbels 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 to remove dirt and dust. The moisture content of seed has to be maintained at 9%, as higher moisture content leads to the development of fungal growth on surface of the seeds. The dried seeds are packed in gunny bags lined with eco- friendly plastic films. The bags are sealed and stored in dry, ventilated rooms. (Malhotra and Vashishtha, 2008) [21]. Fennel seeds are used both as spice and condiment all along the world. It acts as a major ingredient in the Bengali spice mixture *panch phoron* and in the Chinese five-spice powder. Fennel seeds are common ingredient in Italian sausages and European breads. In India, fennel seeds are usually chewed alone after meals or with betel leaves. The seeds are also used in flavouring liquors and in the pickle preparations.

3.10.2 Essential oil

Fennel essential oil is extracted from grounded seeds, either by hydro or steam distillation. In recent times, supercritical CO₂ is also used. The optimum condition for SC-CO₂ was found to be pressure (100 bars), temperature (40°C), extraction time (120 min.), which gave high content of *trans*-anethole with reduced methylchavicol content (Damjanovic *et al.* 2004) [8]. The amount of essential oil varies with variety as well as type of fennel used. The volatile oil content in Indian fennel (0.7-2.5%) which is lower compared to European fennel (2-6%). The essential oil possesses antimicrobial and antioxidant properties, mainly used in beverages and bakery preparations. Essential oil should be stored in air- tight aluminium containers and stored in cool, dark place.

3.10.3 Oleoresin

Fennel oleoresin is prepared by solvent extraction using dried, grounded seeds. Commonly used solvents are food grade hexane ethanol, ethyl acetate or ethylene dichloride. Oleoresin extraction is followed by filtration and desolventization under vacuum condition. Fennel oleoresin is mainly used in processed foods, snacks and sauces preparation.

3.10.4 Fennel powder

Fennel powder is produced by grinding dried seeds; pre-chilling and reduced temperature grinding can also be done in order to reduce the loss of volatiles. Finely grinded powders are used for seasoning purpose whereas coarsely grinded are

used for extraction of oils and oleoresins. (Malhotra, 2010) [20].

3.10.5 Fennel-based commercial blends

Various fennel-based commercial blends are available (Malhotra, 2012) [22], including:

- **Fennel tea:** Fennel tea is prepared by making infusions with fresh leaves or dried herbs. Seeds and herbs are often used in blends or mixes with other herbs for organic herbal tea preparations containing catnip, spearmint, lemongrass, calendula flowers, skullcap, rosemary and sage leaf.
- **Cough syrups:** Produced from mixtures of fennel with honey and other ingredients such as marshmallow root, horehound and mullein. Syrups containing 10 % alcohol by volume are also available.
- **Absinthe:** Absinthe is an alcoholic mixture which originated as a medicinal elixir in Switzerland. Florence fennel is one of three main ingredient used.
- **Indian panch phoran (five spices):** This spice mixture is very popular in West Bengal, Sikkim and Bangladesh. It is mainly used for meat dishes. It contains equal parts of nigella, fenugreek, cumin, black mustard seed and fennel.

- **Chinese five spice blend:** Popularly used to flavour several kinds of foods and made from organic products including anise, black pepper, fennel seeds, cinnamon and cloves.

3.11 Quality specifications for export

3.11.1 Whole seed

Quality specifications for fennel seed can be classified as commercial specification, cleanliness and health specifications as explained by Tamilselvan (2007) [32] and Malhotra (2005) [19].

3.11.1.1 Commercial specifications: For seed spices, it mainly depends on colour, appearance, taste, flavour, shape, volatile oil and packaging. Commercial requirements for fennel are light brownish green, sweet or bitter, small or large seeds, aromatic with high volatile oil (min. 3%- Netherlands, 2%- UK, 1%- Germany).

3.11.1.2 Cleanliness specifications: As per ASTA, ESA and ISO, the permissible cleanliness specifications are given below

ASTA cleanliness specifications for fennel

| Whole insect dead (by count) | Excretes mammalian (mb/lb) | Excreta other (mg/lb) | Mould (% wt) | Insect defiled/ infected (%wt) | Extraneous matter (% wt) |
|------------------------------|----------------------------|-----------------------|--------------|--------------------------------|--------------------------|
| 2 | 2 | 2 | 2 | 1 | 0.5 |

Other quality standards of fennel as per ESA and ISO

| Ash level % w/w (min.) | Acid insoluble ash % w/w (max.) | Moisture content % (max.) | Volatile oil % (min.) |
|------------------------|---------------------------------|---------------------------|-----------------------|
| 9 | 2 | 12 | 1.5 |

Health specifications: Pesticide residues, microbial loads, aflatoxin level, heavy metal contamination *etc.* are considered as health specification. The importing countries have its own specification as maximum permitted level of these contaminants. Limits are:

Maximum pesticide residue level – 0.05 to 0.2%

Microbial counts (i.e. *Salmonella*, *E. coli*, yeast, moulds) - 1×10^2 / g to 1×10^6 /g

Aflatoxin – 5 ppb to 10 ppb (max.)

Heavy metals – arsenic (5mb/kg), copper (20mg/ kg), lead (10mg/ kg) and zinc (50mg/kg).

3.11.2 Essential oil

The specifications for fennel oil are:

- Colourless or pale yellow
- Specific gravity- 0.965 to 0.977
- Optical rotation- +11 to +24
- Refractive index- 1.528 to 1.539
- Solubility (80% ethanol), 5-8 vols
- Congealing point, not below 5° and as high as 10° in good oils
- Anethol content 50-80% (Singhal *et al.* 1997)

3.11.3 Fennel powder

It should be produced hygienically and should have at least 95% of grounded product that it passes through U.S. Standard No. 30 sieve (Farrell, 1999) [12].

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