INTRODUCTION
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Spices constitute one of the most important and vibrant agricultural/horticultural commodities which has maintained a high export potential. Since time immemorial, Indian spices have occupied a place of prestige and popularity throughout the world. Today, more than 150 countries import spices from India. Major spices thus produced are black pepper, cardamom, ginger, turmeric, cumin, coriander, fennel, fenugreek, celery besides chilli; also there are items like dill seed, ajwain seed, caraway seed etc. The states of Rajasthan, Gujarat, Andhra Pradesh, Tamilnadu, Bihar, Uttar Pradesh, Haryana, West Bengal and Madhya Pradesh are the major seed spices growing states, and the productivity potential of this group of crops has been influenced by various factors. Government of Gujarat started the Main Spice Research Station, almost three decades ago at Jagudan, which is now under the Gujarat Agricultural University (Edison 2001). Seed spices are extensively cultivated in North Gujarat.

Fenugreek (*Trigonella foenumgraceum* L. var Guj.1) is an important leafy vegetable crop. Gujarat state grows fenugreek not only as vegetable crop but as the spice also. It is a cool season quick growing crop. The leaves are quite rich in protein, mineral and vitamins. These are used as vegetable and forage. The seeds used as condiments have also some medicinal value. It prevents constipation, removes indigestion, stimulates the spleen and the liver and is appetizing and diuretic (Mehta 1986 and Kochhar 1998). Fenugreek seeds cause a significant lowering in serum total cholesterol, LDL cholesterol, phospholipid level. It also controls liver cholesterol and liver phospholipid whereas it exhibits no significant changes in serum and liver protein (Chakravarty and Mitra 1998).
Coriander (*Coriandrum sativum* L. var Guj.1) is a small aromatic annual herb. In India, coriander is grown in almost all provinces but chiefly in Andhra Pradesh, Maharashtra, Tamilnadu, Punjab, Uttar Pradesh, Himachal Pradesh, Assam, Madhya Pradesh and Gujarat also. The pleasant delicate aroma and taste of the fruits is due to essential oil. The leaves are strong, smelling and are employed for garnishing meat preparations and sausages and for making chutneys. Quite often, they are used for flavoring curries, soups and curd. In a powdered form, the fruits are used as a constituent of curry powders and other spice mixtures. The whole coriander seed is an important ingredient of pickling spice mixture. Coriander oil is used today for flavoring perfumes, candy, cocoa, chocolate, tobacco, baked goods, canned soups, alcoholic beverages and to mask offensive odours in pharmaceutical preparation. Medicinally, coriander oil is used as a carminative, tonic and diuratic. The residue, left after the extraction of the volatile oil is used locally as cattle feed (Kochhar 1998).

Cumin (*Cuminum cyminum* L var Guj.3) is an annual herb, having much-branched angular stem. The dried fruit, commonly called cumin seed has a strong distinctive pleasant odour and somewhat bitter taste due to the presence of volatile oil. The cumin seed is an important ingredient in curry powder and is mainly for flavoring soups, sausages, cheese, meat dishes, bread and cakes. In indigenous medicine cumin seeds have long been considered as stimulant and carminative. They are stomachic, astringent and useful in dyspepsia. The seeds are also used in veterinary medicine. The residue left after the extraction of volatile oil can be used as cattle feed. Cumin is a source of valuable foreign exchange for the country (Kochhar 1998). Cumin seeds are very rich in an essential oil. It is an anthelmentic against hook-worm infections and also antiseptic.
Ajwain (Carum copticum Hiern. var. Guj-1) known as "Ajmo" in Gujarat, is a minor spice crop and cultivated on a large scale in Gujarat. It is an annual herb. Seeds are largely employed in medicine to relieve pain in bronchitis and other diseases of chest in children. Seeds are also used as a spice in vegetable preparation. Thymol, an antiseptic, is manufactured from seeds (Sundararaj and Thulasidas 1976, Kochhar 1998).

Dill (Anethum graveolens M. var. Local) is an annual and has a tap root like a carrot plant. Dill is cultivated through seed. It is an antispasmodic and carminative. Dill tea or water is a popular remedy for an upset stomach, hiccups, or insomnia. For a nursing mother it promotes the flow of milk. It is also an appetite stimulant. It is a constituent of gripe water and other children's medicines because of its ability to ease flatulence and colic. Dill is used in herbal butter and herb vinegars. It can be used for flavor, fish, lamb, pork, poultry, cheese, cream, eggs, vegetables, avocados, apples, popcorn, salad, soups, sauces and spreads. The plant is used to make green dye. The foliage and flowers dry nicely and add an airy touch to plant arrangements (Sundararaj and Thulasidas 1976, Kochhar 1998).

Fluoride (F) is a natural component of the earth's crust with concentration in soil commonly exceeding 0.1% and occasionally 1%. Plants accumulate very small amounts of F, larger quantities may be absorbed from acid soils rich in F. Polluted atmosphere is the main source of F to plants accumulating high concentration. Fluoride bearing minerals like fluorite (CaF₂), apatite [Ca₁₀ (PO₄)₆ F₂] and cryolite (Na₆ Al F₆) are also found in different rocks and contribute F to soil through weathering, apart from natural resources, considerable amount of F may also be contributed by the activities of man. Fluoride salts are commonly used in steel, aluminum, brick and tile industries and released from the burning of coal.
Phosphatic fertilizers like rock phosphates and super phosphate, which are extensively used, contain F as an impurity leading to high level of accumulation in soils. Accumulation of F in soil leads to F toxicity to plants and animals and also causes health problems in humans (Palaniappan et al 1995). Patel (1991) reported that fluoride is generated by Gujarat State Fertilizer Corporation. Phosphate fertilizer industry carries a hazard of exposure to gaseous and particulate fluoride, in addition to other phosphate dust components (AbuDhaise and AbuOmar 1998).

Fluorosis caused by fluoride is an important public health problem in India and some countries of the world. In India occurrence of this disease is endemic to many states like Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Rajasthan, Panjab, Haryana, Utter pradesh and even peripheral parts of Delhi (Khoshoo 1988, Wodeyar and Sreenivasan 1996, Chakma et al 1997, Sarma and Rao 1997). Fluoride taken up by plant from soil or air is transferred to animals by ingestion of plants and their parts i.e. nectar, pollen or whole organs. As the concentration of fluoride varies greatly in different parts of plants, the amount ingested by animal depends mainly on its feeding strategy (Bunce 1983). Chronic osteo-dental fluorosis was diagnosed in cattle, buffaloes, sheep and goats from 21 villages of Banswara, Dungarpur and Udaipur districts of Southern Rajasthan where the mean fluoride concentration in drinking water varied from 1.5 to 4.0 ppm (Choubisa 1999). In Gujarat among the 19 districts, 18 districts have been reported to have excessive fluoride. Out of a total of 18569 villages in the state, 2413 are facing the problem of excessive fluoride. Fluoride content in the district of Amreli, Mehsana, Banaskantha, Panchmahal and Baroda ranges between 2.0 and 7.0 mg/l. whereas the safe limit according to ISI is about 1.5 ppm (Khoshoo 1988). Araya et al (1993) discussed the pressure of fluoride in cattle and grass
following a volcanic eruption. Dental fluorosis was clear in cows, hay fluoride content was high i.e. 48.2 ppm during this season. Serum fluoride levels increased markedly in the bulls during the spring. Fluorosis problem is very acute in Mehsana district. Out of 309 villages where house-to-house survey was done, 236 villages were found to be affected with the disease of fluorosis (Vasavada 1998). The various health problems caused by water-borne fluoride in the fluorosis endemic villages of Mehsana and Banaskantha districts of Gujarat, India were studied. The study revealed high levels of F in serum samples of 500 subjects. Mottling of teeth and skeletal complications were common. Intake of F caused a decrease in haemoglobin content and in serum protein levels. Serum cholesterol levels were normal. Circulating levels of testosterone were decreased, but not significantly enough to indicate an effect on reproductive functions. The enhanced levels of serum transaminases, which are markers for liver function, indicated structural and functional changes in liver due to F intake. Changes in the serum calcium, sodium and potassium levels revealed electrolyte imbalance in fluorotic subjects. While levels of thyroid stimulating hormone and triiodothyronine did not vary, a significant increase in thyroxine levels suggested alteration in thyroid function. Thus the study revealed some harmful effects of F in the soft tissue functions of this endemic population (Michael et al 1996).

The status of fluoride in ground water of Gujarat is reviewed by Mariappan et al (2000) A malady – remedy analysis of the problem of fluorosis has to be holistic in character, as the disease not only affects human beings but also plants and animals. Therefore, we need to have, as far as possible, an idea of the sources of fluoride and its dispersion in the environment including land, water and air. Based on such study an integrated approach has to be evolved to grow up a strategy
for the control of this disease. Fluoride is highly soluble and therefore would be expected to be widely distributed within the cell mainly through drinking water and vegetation, fluoride finds its way to the human body and to livestock. Similarly fluoride may accumulate in food and vegetation grown on fluoride rich soil. Fluoride has damaged plants either as a pollutant or by accumulation from the soil (Treshow 1970).

Assays of fluoride concentration in groundwater samples near the aluminium industry in Hirakund, of India showed that fluoride levels exceed the permissible limit in limited residential areas. The reasons for the high fluoride contents may be due to haphazard disposal of rejected pot linings, and seepage of waste water from the company drain connected to the river Mahanadi (Sahu et al 1998).

The fluoride content of drinking water, human urine and hen egg shells was measured in the Gdansk region of Poland. A positive correlation was found between the concentration of fluoride in drinking water and urine of the inhabitants. High fluoride levels were found in egg shells collected close to a phosphate fertilizer plant (Czarnowski et al 1994). The elevated water fluoride was of natural (due to high fluoride content of soil, Malbork) as well as industrial (Wislinka) origin, which suggests that the elevated fluoride level in urine may be caused not only by the water fluoride, but also by the inhalation of dust particles containing fluoride, and by the diet (Czarnowski et al 1997).

In Delhi almost 50% of the area is affected by fluoride contamination beyond the maximum permissible limit. The wide range (0.10-16.5 ppm) in fluoride concentration suggests contributions from both point and non-point sources. Very high fluoride levels in groundwater are mostly found in the vicinity of brick kilns. Issues related to harmful effects of
The effect of filtration on water fluoride level was investigated in a study using commercially available filters. Testing was carried out in London. Water filtration systems tested did not affect the advantage offered by optimum water fluoride levels. Fluoride dietary supplements should not be prescribed for children living in optimal fluoride areas, irrespective of whether they use household filters (Ong et al. 1996).

Water samples were collected from 40 households in four sublocations of the Molo division of the Rift Valley in Nakuru District of Kenya. The mean fluoride concentration was 0.28 ± 0.03 ppm. The highest fluoride encountered in this study was 2.0 ppm while the lowest was 0.06 ppm (Gikunju et al. 1995).

A total of 104 brands from different regions of Brazil, were analysed using an Orion 96-09 ion specific electrode and an Orion EA 940 ion analyser, previously calibrated with standard fluoride solutions. It was discovered that specific bottled waters contained significant concentrations of fluoride. Fluoride concentrations were high enough to cause dental fluorosis (Villena et al. 1996).

Regional patterns of fluoride concentrations in groundwater in Texas, USA were compiled, mapped, and evaluated. County-median fluoride levels were calculated from nearly 7,000 wells distributed among 237 Texas counties. Four regions with high fluoride levels were identified. Several factors contributed to elevated fluoride levels in Texas aquifers, including seepage from nearby saline formations, sparse recharge and dilution, and native mineral constituents of the aquifers. Results of this study suggest that: (1) regional geology
influenced fluoride concentrations in Texas, (2) state wise, the pattern was not random, (3) fluoride levels were generally higher in the western part of the state, and (4) regions which require further monitoring included west- and north-central Texas (Hudak 1999).

Fluoride contents of water and food, collected from subjects in 5 selected areas of Tamilnadu in South India, were estimated. A direct correlation was also confirmed between the mean fluoride level in drinking water and the percentage incidence of dental fluorosis. The dominant role of fluoride from drinking water, when compared with that from food, was established (Karthikeyan et al 1996).

Zohouri and Rugg-Gunn (2000) reported that intake of water (as a drink) and a tea water by children aged 4, an age when many permanent teeth are formed, are the most important contributors to dietary fluoride intake, substantial increases in fluoride intake was associated with increasing water fluoride concentrations, and fluoride intake was higher in summer than in the winter.

Endemic skeletal fluorosis is a public health problem in India where drinking water contains high concentrations of fluoride. Silicon has been shown to aggravate the risk of fluorosis in experimental animals. F and Si concentrations were determined in food samples i.e. rice, sorgham, bajra and ragi. Foods grown in fluorotic areas generally contain higher concentrations of F and Si than normal areas (Anasuya et al 1997).

The fluoride content of 30 commonly consumed foods from an endemic fluorosis area were determined with special reference to the feeding habits of 200 adult men and women from 8 villages of Faridkot district, Punjab, India. The average
daily fluoride intake from all the sources was 19 mg in men and 13 mg in women, which was very high compared to recommended allowances of ICMR and WHO (Sangha et al 1996).

In several endemic fluorotic zones of rural India, home-made parboiled rice is the main staple. Studies were conducted to investigate whether any relationship exists between the concentration of fluoride in the water used for parboiling paddy, and in the parboiled rice. Parboiled rice (PBR) was prepared in the laboratory using water from different origins (rivers, open wells, tube wells and ponds) collected from normal and fluorosis affected regions. PBR had significantly more F than raw rice (Anasuya and Paranjape 1996).

Plants take up fluorides both from the soil and air. From the soil, it is transmitted through root hair into stem and finally reaches the leaves. It has been conclusively found that plants absorb more fluoride from sand than from clayey soil and more from wet and acid soils than from dry and alkaline ones. Since phosphate fertilizer contain between 1 to 3 percent fluorides, fertilized tuber crops such as potato, beet, radish etc. assimilate more fluoride from soil than from atmosphere. Turgid plants are more susceptible to fluoride accumulation than wilted ones, leafy vegetables such as lettuce, cabbage and celery are especially prone to deposition of air borne fluoride mainly at their exposed areas, which contain more fluoride as compared to their inner plants. Fluoride injury to vegetation commonly results from gradual accumulation of fluoride in the plant tissues over a period of time. Therefore, the duration of exposure as well as its concentration is important in determining the severity of injury (Khoshoo 1988).

Fluoride from the air enters the plant primarily through the leaf stomata, passes into intercellular spaces, contacts the
mesophyll and is either directly absorbed into the cell or dissolved in water and transported through the vascular tissue to the leaf tips and margin where it accumulates. Several studies have been demonstrated the accumulation of fluoride at the extremities. Zimmerman and Hitchcock (1956) showed that the tips of gladiolus leaves might contain 25 to 100 times as much fluoride as the basal section. Chang and Thompson (1966) at the University of California determined the distribution of fluoride in the cells of citrus leaves. Leaves rich in fluoride were fractionated into the subcellular components and the fluoride content of each fraction was determined. Chloroplast was found to contain about 60% of the total fluoride and was presumed to be the major site of accumulation.

The effects of fluoride on plant growth are not always negative. Aso (1906) concluded that sodium fluoride stimulated vegetative growth of barley and pea plants. Apparently fluoride at sublethal concentration may affect plant growth. Growth may be stimulated or inhibited depending on the fluoride concentrations, the sensitivity of the plants and environmental factors such as nutrient and other soil conditions.

McCune (1969) and Treshow (1971) divided the negative effect of fluoride on plants into following categories:
1. Visible injury
2. Changes in physiological processes
3. A decreasing/increasing rate of growth, development and reproduction
4. An accumulation of fluoride in the tissue
5. Cytogenetically change.

Looking to the status of fluoride in Gujarat it was thought of interest to study the response of spice crops to fluoride
application through root (soil), leaf (foliar spray) and seed (pretreatment). Fenugreek, Coriander, Cumin, Ajwain and Dill were selected for the study. The experiments were carried out with following aims:

❖ To study the growth response of spice crops grown on fluoride contaminated soil.
❖ To study the level of selected metabolites in spice crops grown on fluoride contaminated soil.
❖ To study the fluoride uptake by spice crops grown on fluoride contaminated soil.
❖ To study the chemical properties of soil contaminated with NaF.
❖ To study the growth response of spice crops receiving foliar application with fluoride.
❖ To study the level of selected metabolites in spice crops receiving foliar application with fluoride.
❖ To study the fluoride uptake by spice crops receiving foliar application with fluoride.
❖ To study the growth response of spice crops raised from fluoride pretreated seeds.
❖ To study the level of selected metabolites in spice crops raised from fluoride pretreated seeds.
❖ To study the fluoride uptake by spice crops raised from fluoride pretreated seeds.