International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182 Print ISSN: 2349-5979
www.allsubjectjournal.com
Volume 2; Issue 11; November 2015; Page No. 16-21

Bioaccumulation of sodium fluoride toxicity in plant parts at different phases and its impact on crop *Hordeum vulgare* (Barley) Variety RD 2052

[1] Rinku Agarwal, [2] Surendra Singh Chauhan

[1, 2] Indira Gandhi Centre for HEEPS, University of Rajasthan, Jaipur.

Abstract
The objective of the present study was to study the effects of different concentration of sodium fluoride on different yield and its bioaccumulation in barley (*Hordeum vulgare)*.In a pot experiment and field observation, a barley was irrigated with Double distilled water (Control) and different levels of sodium fluoride (3, 6, 9, 12, 15 and 18ppm). The experiment was carried out for the entire life cycle of 105 days of this barley variety. Plants were harvested after 35 days (pre-flowering), 75 days (peak-flowering) and 105 days (post-flowering) of sowing of seeds. Bioaccumulation studies of fluoride in plant parts revealed maximum accumulation in leaves parts (9.948mg/kg) and minimum in Grain (6.302mg/kg) in plants treated with 18ppm NaF in pot experiment. But field observation of sodium fluoride in crop plant parts revealed maximum (16.758mg/kg) accumulation in leaves and minimum in Grain (9.351mg/kg) in plants treated well, tube well water in field experiment. Results showed that the use of groundwater containing high fluoride content for irrigating Barley crop plant may be tolerating to its biological accumulation in different plant parts.

Keywords: Barley, High fluoride, Bioaccumulation, Ground water.

Introduction
Fluoride contamination in water, soil, and vegetation is a major concern because of its toxicity and threat to human life and the environment. Fluoride is a persistent, non-biodegradable oligoelement that accumulates in soil, plants, wildlife, and humans and is probably the most phytotoxic among pollutants (Fornasiero 2001) [6]. Ingestion of plants with a high Fluoride concentration can cause chronic Fluoride toxicity in grazing animals, and humans and lead to bone damage or tooth wear (Clark and Stewart 1983) [2]. Even at fairly low ambient concentrations fluoride (F) can cause a number of physiological and biochemical changes in plants without visible signs of injury. Fluoride is absorbed by plant roots and is then transported via xylematic flow of the transpiratory and storage organs, mainly the leaves, where it can accumulate with adverse effects (Davison and Weinstein 1998) [3, 15]. Bioaccumulation of fluoride in different plant parts vary depending on its transfer from soil solution to roots and translocation from root to shoot. Hence, periodic measurement and control of the concentration of fluorine is very important to avoid both biological and environmental damage (Edward 1975) [5]. Tonk district of Rajasthan is one of the fluorosis endemic areas with high fluoride concentrations in the aquifers and soil. The Devli Tehsil of Tonk district people have health risk due to the excess of fluoride present in the drinking water and dietary materials.

The area is highly dependent on groundwater, for both Irrigation and drinking water purposes. During the last century, large scale utilization of groundwater for irrigation, so that groundwater source getting low rate. As a result, Devli region face the problems like dissolution of Fluorides and other dissolved salts in drinking water. Irrigation of agricultural lands with high fluoride content has lead to rise in accumulation of fluoride in crops. The present work was based on the study to determind the accumulation of fluoride in crops of certain endemic fluoride villages.

Study Area
Devli Tehsil is located in the south of Tonk district and is surrounded by Ajmer, Bhilwara, Bundi, districts. The tehsil head quarter Devli is connected by NH-12 and is situated at 167 km from the Jaipur. Devli located between 25°35’ to 25°58’N latitude and 73°37’ to 73°62’E longitude. It has an average elevation of 296 metres (971feet) above mean sea level. The total area of the Tehsil is 153969 hectares (Map).The terrain is marked by mostly flat hills in between near the Bisalpur dam. The climate of the Devli tehsil is hot and dry. As majority of water for drinking and irrigation in this semi-arid region comes from aquifers, such high levels of exposure to fluoride are of great concern. In major regions of Rajasthan lying in semi-arid zones.

Materials and Methods

Pot experiment were conducted on *Hordeum vulgare* Variety RD 2052 is a popular barley Variety grown in the state of Rajasthan. Barley is a monocotyledonous plants and belongs to Graminae family sown in *Rabi* season. The effect of different concentration of Sodium fluoride, certified seeds of Barley were procured from Agricultural Research Station, Durgapura, Jaipur. Its maturity period ranges between 98 & 105 days. The experiments were conducted in the Department of Environment, University of Rajasthan, Jaipur from Nov. 2011 to March 2012 during winter season. The mean ambient temperature of certified seeds during experimental study was 20^{o}C. Seeds were sown in the earthen pots filled with sandy-loamy soil. These seeds were also sowing in different fields and the same procedure were followed for field plants. In the experiment 5 replicates of each pot set viz. control (Double distilled water), 3 mg/L, 6 mg/L, 9 mg/L, 12 mg/L, 15 mg/L, 18 mg/L, were taken 70% of water was poured into the pot and 30% of Fluorinated water was sprayed on plant. The plants were irrigated with the respective concentration of sodium fluoride in alternative days throughout the experimental period (10 November 2011 to 05 March 2012). Stock solution of 100 mg/L NaF concentration was prepared by dissolving 0.221 g NaF in 1000 ml of distilled water. Serial dilution to stock solution was done to get the desired concentration. Serial dilution of stock solution made of NaF was used for irrigation at regular intervals and in equal quantity with double distilled water as the control.

For each concentration, 7 pots were used and 5 replicates. To ensure germination seeds were sown in each pot equally spaced from each other. After emergence seedling were selected to remain to each pot and allowed to grow. The experiment was conducted during winter season.

After pre-flowering stage (35 days after sowing the seed), peak flowering stage (75 days) and post flowering stage (105 days)from the date of sowing. Treatments of three pots from each stage were taken for the studies. The plants were harvested and washed gently with distilled water to remove soil particles adhering to them.

Determination of Bioaccumulation of fluoride *Hordeum vulgare* in various plants parts

For the bioaccumulation study and determination of fluoride contents. All the plant parts were separately packed and oven dried for 24 hrs at 80ºC. Then the samples were powdered and digested with perchloric acid, followed by neutralization with aqueous KOH and analysis for fluoride by the potentiometric method with a fluoride ion selective electrode. Same procedure were also used for the field observation of plants.

Results and Discussion

At pre-flowering stage (pot experiment and field experiment)

In plants Fluoride concentration of Barley was estimated 0.237mg/kg in leaves, 0.181mg/kg in Shoot and 0.102mg/kg in Root samples of plant grown under (distilled water) condition and treatment level 18ppm, fluoride concentration was estimated 11.572mg/kg in leaves, 8.179mg/kg in shoot and 7.342 mg/kg in Root (Table 1). While in field experiment Site 1 (below in 3ppm) was 0.482mg/kg in leaves, 0.407mg/kg in shoot and 0.316mg/kg in Root samples of plants and Site 2 (NaF approximately 18ppm) fluoride concentrations was estimated 11.124mg/kg in leaves, 7.709mg/kg in shoot and 7.017mg/kg in Root(Table 2). NaF increased as the concentration of Fluoride in the treatment increased.

Table 1: Effects on Growth of different Sodium fluoride treatment levels through Pot Experiment on Hordeum *vulgare*, variety RD 2052. At Pre-Flowering Stage (35 days after sowing the seeds)

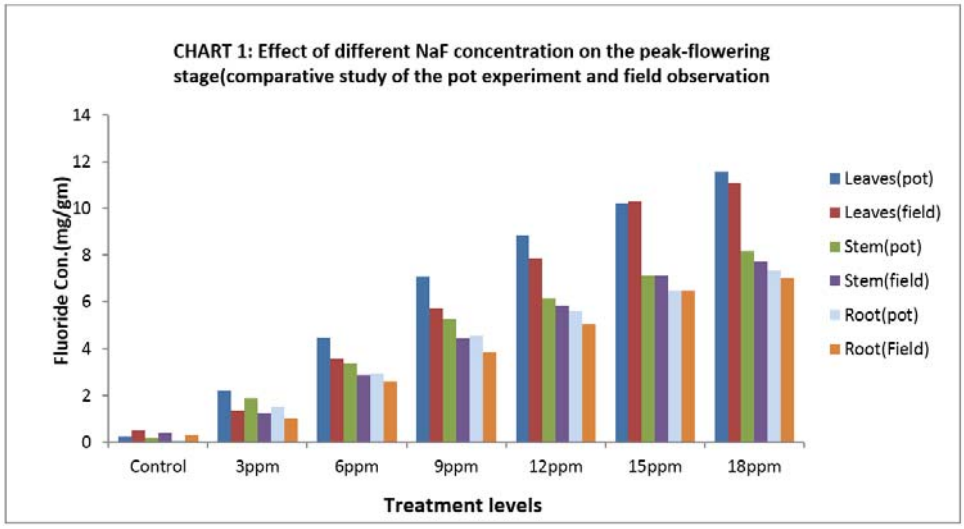
S. No.	Treatment Levels	Pre Stage Fluoride (Mg/Kg)		
		Leaves	Stem	Root
1.	Control(Double distilled water)	0.237±0.007	0.181±0.005	0.102±0.008
2.	3ppm	2.205±0.006 (9.034)	1.872±0.004 (10.343)	1.533±0.009 (15.029)
3.	6ppm	4.476±0.008 (18.886)	3.383±0.007 (18.691)	2.967±0.007 (29.088)
4.	9ppm	7.082±0.012 (29.882)	5.285±0.006 (29.199)	4.544±0.009 (44.549)
5.	12ppm	8.854±0.008 (37.359)	6.144±0.010 (33.945)	5.642±0.008 (55.314)
6.	15ppm	10.213±0.007 (43.093)	7.113±0.009 (39.298)	6.491±0.005 (63.637)
7.	18ppm	11.572±0.005 (48.827)	8.179±0.007 (45.188)	7.342±0.003 (71.980)

All values of mean ± S.D. and (%)

Table 2: Agriculture fields with *Hordeum vulgare*, variety RD 2052 in Devli Tehsil, Tonk district At Peak-Flowering Stages.

S. No.	Treatment Levels	Pre Stage Fluoride (Mg/Kg)		
		Leaves	Shoot	Root
1.	S1(kanwarpura)	0.482±0.0161	0.407±0.094	0.316±0.157
2.	S2(Heerapura)	1.356±0.174	1.261±0.169	1.032±0.143
3.	S3(Bhanwarthala)	3.558±0.135	2.878±0.097	2.589±0.158
4.	S4(Ramthala)	5.734±0.172	4.452±0.157	3.853±0.137
5.	S5(Sangrampura)	7.872±0.103	5.824±0.123	5.058±0.141
6.	S6(Rajmahal)	10.289±0.148	7.115±0.083	6.482±0.134
7.	S7(Dabarkala)	11.124±0.074	7.709±0.119	7.017±0.160

All values of mean ± S.D.



At peak-flowering stage
(pot experiment and field experiment)

In plants Fluoride concentration of Barley was estimated 0.362mg/kg in leaves, 0.284mg/kg in shoot and 0.02mg/kg in Root samples of plants grown under (distilled water) condition and treatment level 18ppm, fluoride concentration was estimated 12.987mg/kg in leaves, 9.556mg/kg in shoot and 8.619mg/kg in Root (Table 3). While in field experiment Site 1 (below in 3ppm) was 0.829mg/kg in leaves, 0.627mg/kg in shoot and 0.498mg/kg in Root samples of plants grown condition and Site 2 (NaF approximately 18ppm) fluoride concentrations was observed 12.778mg/kg in leaves, 9.372mg/kg in shoot and 8.461mg/kg in Root(Table 4). NaF concentration increased as the concentration of fluoride in the treatment increased.

Table 3: Effects on Growth of different Sodium fluoride treatment levels through Pot Experiment on *Hordeum vulgare*, variety RD 2052. At Peak-Flowering Stage (75 days after sowing the seeds).

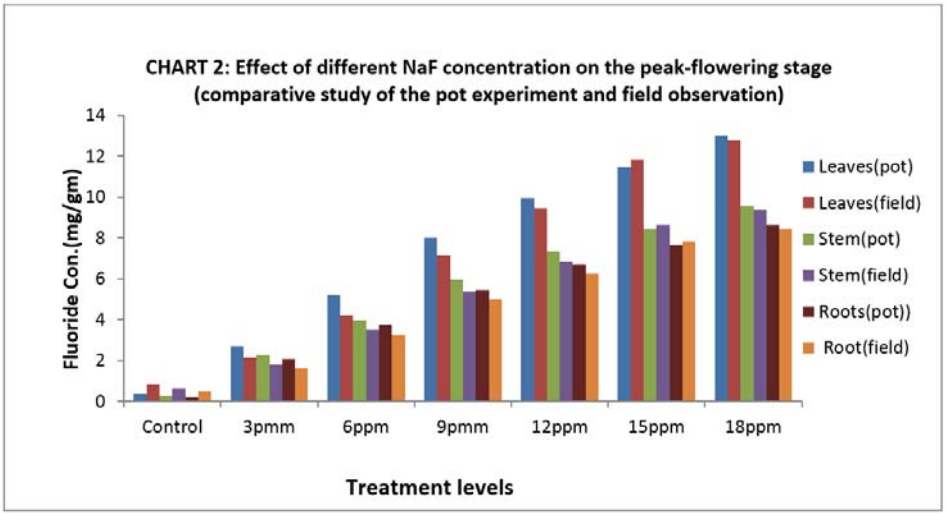
S. No.	Treatment Levels	Peak Stage Fluoride (Mg/Kg)		
		Leaves	Stem	Root
1.	Control(Double distilled water)	0.362±0.009	0.284±0.008	0.197±0.007
2.	3ppm	2.684±0.008 (7.414)	2.267±0.007 (7.982)	2.057±0.009 (10.442)
3.	6ppm	5.227±0.004 (14.439)	3.996±0.009 (14.070)	3.742±0.006 (18.995)
4.	9ppm	8.031±0.006 (22.185)	5.958±0.008 (20.979)	5.473±0.004 (27.782)
5.	12ppm	9.972±0.004 (27.547)	7.347±0.007 (25.870)	6.691±0.006 (33.964)
6.	15ppm	11.480±0.007 (31.713)	8.452±0.006 (29.761)	7.655±0.007 (38.858)
7.	18ppm	12.987±0.005 (35.876)	9.556±0.003 (33.648)	8.619±0.004 (43.751)

All values of mean ± S.D. and (%)

Table 4: Agriculture fields with *Hordeum* vulgare, variety RD 2052 in Devli Tehsil, Tonk district At Peak-Flowering Stages.

S. No.	Treatment Levels	Peak Stage Fluoride (mg/kg)		
		Leaves	Stem	Root
1.	S1(kanwarpura)	0.829±0.085	0.627±0.163	0.498±0.122
2.	S2(Heerapura)	2.147±0.164	1.786±0.157	1.592±0.147
3.	S3(Bhanwarthala)	4.203±0.157	3.513±0.161	3.252±0.088
4.	S4(Ramthala)	7.161±0.159	5.389±0.089	4.971±0.173
5.	S5(Sangrampura)	9.438±0.154	6.851±0.147	6.257±0.156
6.	S6(Rajmahal)	11.803±0.160	8.648±0.153	7.839±0.135
7.	S7(Dabarkala)	12.778±0.107	9.372±0.139	8.461±0.163

All values of mean ± S.D.



At post-flowering stage
(pot experiment and field experiment)

In plants Fluoride concentration of Barley was estimated 0.553mg/kg in leaves, 0.496mg/kg in shoot, 0.402mg/kg in Root and 0.357mg/kg in Grain samples of plants grown under (distilled water) condition and treatment level 18ppm, fluoride concentration was estimated 16.288mg/kg in leaves, 13.693mg/kg in shoot, 12.967mg/kg in Root and 9.115mg/kg in Grain (Table 5). While in field experiment Site 1 (below in 3ppm) was 1.227mg/kg in leaves, 0.991mg/kg in shoot, 0.958mg/kg in Root and 0.874mg/kg in Grain samples of plants grown condition and Site 2 (NaF approximately 18ppm) fluoride concentrations was observed 16.758mg/kg in leaves, 14.059mg/kg in shoot, 13.244mg/kg in Root and 9.351mg/kg in Grain (Table 6). Fluoride concentration increased as the concentration of NaF in the treatment increased.

Bioaccumulation of fluoride was highest in leaves and lowest in grain. In 18ppm NaF treated plants, mean fluoride content in the leaves and grain was 16.288mg/kg and 9.115mg/kg respectively and field observation of Site **2** was highest fluoride

in leaves and lowest fluoride in grain. In comparison to leaves, Grain accumulated least fluoride which was 7.407mg/kg. Owing to its low mobility, fluoride accumulated more in plant root than in other plant parts. However, such correlative findings have also been reported by Gautam and Bhardwaj (2010) [7] and Bhargava and Bhardwaj (2011) [1]. Bioaccumulation studies of fluoride in Barley grain showed an average fluoride content (9.351mg/kg). The study significance that fluoride is a part of food chain in which it is transmitted from vegetation to herbivores and hence to the carnivores (Murray G., 1981) [14]. Result reported in the study that fluoride treatment is detrimental to growth and yield of Barley especially at higher concentrations (18mg/L) sodium fluoride concentration. The accumulation rate of fluoride in the leaves were higher than the accumulation rate in the other parts of plant fluoride level of leaves increased with the concentration of sodium fluoride spray applied on the leaves (Leonard, CD and Graves HH Jr, 1972) [13] Due to this high concentration of fluoride, it result in the necrosis and chlorosis in the plant, reduction in growth of shoot and root and ultimately reduced the yield of *Hordeum vulgare* Variety RD 2052. It was determined that concentration of fluoride was higher in field experiment in comparison to pot experiment. It may be increased due to use of fluoride contaminated soil and water in field while we are using only fluoride contaminated water in pot. Bioaccumulation of fluoride in Barley grains creates secondary source of fluoride to human population resulting in food-borne fluorosis, primary source being water.

Table 5: Effects on Growth of different Sodium fluoride treatment levels through Pot Experiment on Hordeum vulgare, variety RD 2052. At Post-Flowering Stage (105 days after sowing the seeds).

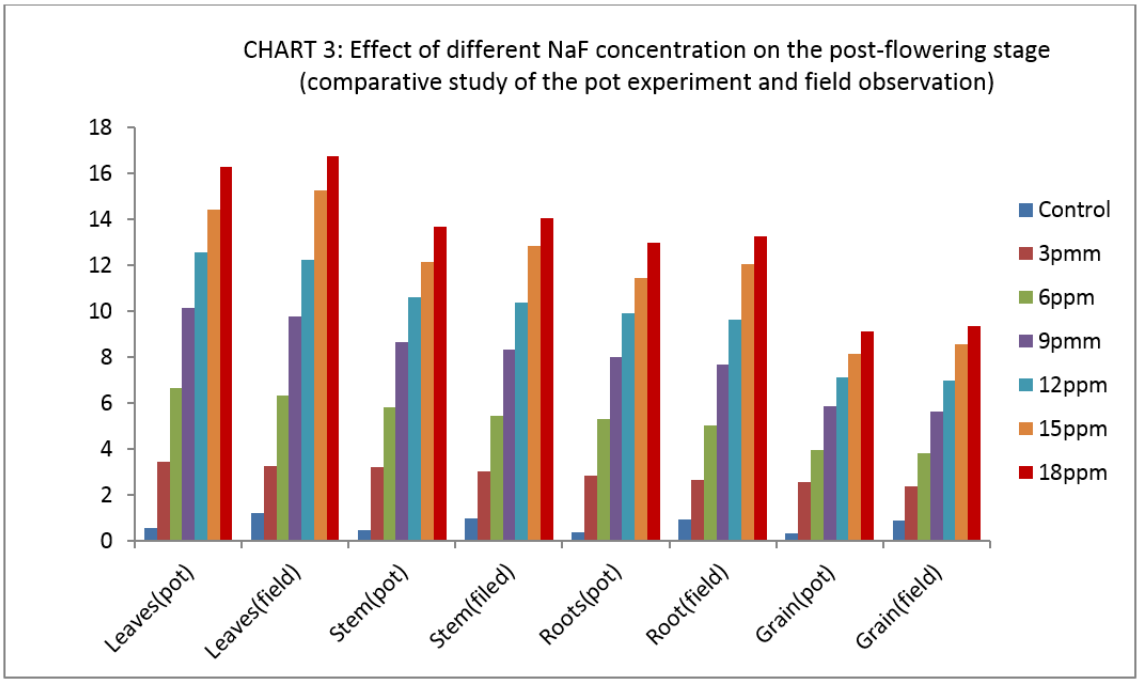
S. No.	Treatment Levels	Post Stage Fluoride (Mg/Kg)			
		Leaves	Stem	Root	Grain
1.	Control(Double distilled water)	0.553±0.006	0.496±0.005	0.402±0.006	0.357±0.004
2.	3ppm	3.457±0.007 (6.251)	3.214±0.008 (6.480)	2.836±0.005 (7.055)	2.554±0.007 (7.154)
3.	6ppm	6.676±0.009 (12.072)	5.811±0.006 (11.716)	5.317±0.007 (13.226)	3.952±0.006 (11.070)
4.	9ppm	10.145±0.008 (18.345)	8.663±0.007 (17.466)	8.001±0.004 (19.903)	5.854±0.005 (16.398)
5.	12ppm	12.548±0.007 (22.691)	10.634±0.005 (21.440)	9.913±0.006 (24.659)	7.138±0.007 (19.994)
6.	15ppm	14.421±0.005 (26.078)	12.162±0.007 (24.520)	11.439±0.003 (28.455)	8.126±0.005 (22.762)
7.	18ppm	16.288±0.006 (29.454)	13.693±0.005 (27.607)	12.967±0.007 (32.256)	9.115±0.008 (25.532)

All values of mean ± S.D. and (%)

Table 6: Agriculture fields with *Hordeum* vulgare, variety RD 2052 in Devli Tehsil, Tonk district At Post-Flowering Stages.

S. No.	Treatment Levels	Post Stage Fluoride (Mg/Kg)			
		Leaves	Stem	Root	Grain
1.	S1(kanwarpura)	1.227±0.138	0.991±0.163	0.985±0.119	0.874±0.159
2.	S2(Heerapura)	3.265±0.152	3.032±0.145	2.664±0.102	2.381±0.150
3.	S3(Bhanwarthala)	6.329±0.243	5.468±0.138	5.032±0.092	3.842±0.143
4.	S4(Ramthala)	9.775±0.170	8.352±0.156	7.683±0.151	5.635±0.135
5.	S5(Sangrampura)	12.218±0.159	10.391±0.163	9.628±0.109	6.976±0.147
6.	S6(Rajmahal)	15.264±0.106	12.838±0.172	12.031±0.095	8.563±0.176
7.	S7(Dabarkala)	16.758±0.152	14.059±0.149	13.244±0.103	9.351±0.163

All values of mean ± S.D.



Acknowledgement
The authors are grateful to the Director, Indira Gandhi Centre for HEEPS and the Dean, Faculty of Sciences, University of Rajasthan, for providing necessary facilities. I am also thanksful to Dr. Surendra Singh Chauhan for his guidance.

References

1. Bhargava D, Bhardwaj N. Phytotoxicity of Fluoride on a Wheat Variety *Triticum aestivum* var. Raj.4083 and its Bioaccumulation at the Reproductive Phase. Asian J. 2011; 25(1):37-40.
2. Clark RG, Stewart DJ. Fluorine. In: Grace, N.E. (Ed.). The mineral requirements of grazing ruminants. New Zealand Society of Animal Production, Occasional Publication 1983; 9:129-134.
3. Davison A, Weinstein LW. The effects of fluorides on plants. Earth Island 1998; 13:257-64.
4. Deshmukh AN, Wadasker PM, Malle DB. Fluorine in environment: A review Gondwana Geol Mag 1995; 9(3):1-20.
5. Edward G. Fluoride pollution. Environment 1975; 17:29-38.
6. Fornasiero RB. Phytotoxic effects of fluorides. Plant Sci 2001; 161:979-985.
7. Gautam R, Bhardwaj N. Bioaccumulation of fluoride in different plant parts of *Hordeum vulgare* Barley var. RD-2683 from irrigation water. Fluoride 2010; 43:57-60.
8. Gritsan NP. Phytotoxic effects of gasous fluorides on grain crops in the southeast Ukraine. Fluoride 1992; 25(3):115-122.
9. Gupta S, Banerjee S, Mondal S. Phytotoxicity of fluoride in the germination of Paddy (*Oryza sativa*) and its effect on the physiology and biochemistry of germinated seedling. Fluoride, 42(2), 142-6.
10. Joshi M, Bhardwaj N. Impact of high fluoride content on flora and fauna in Bilwa Kanwarpura village of Jaipur District. Indian J Ecol. 2007; 34(1):73-5.
11. Kamaluddin M, Zwiasek JJ. Fluoride inhibits root water transport and effect leaf expansion and gas exchanges in aspan (Popular tremuloides) seedlings. Physiologia Plantarum 2003; 117:368-375.
12. Kumari J, Ashlesha P, Kodate J, Vali S. Fluoride partition between coexisting soil and food stuffs : a case study of selected fluorosis endemic villages of Korpana and Rajura tehsils, district Chandrapur (M.S.) Gondwana Geol. Mag 1995; 9(3):91-100.
13. Leonard CD, Grraves HH Jr. Effect of fluoride air pollution on *Florida citrous*. Fluoride 1972; 5:145-165.
14. Murray G. Fluoride cycles I a estuarine ecosystem. Sci Total Environment 1981; 17:233-241.
15. Weinstein LH, Davison AW, Arndt U. Fluoride. In: Flagler RB, editor. Recognition of air pollution injury to vegetation: a pictorial atlas. 2nd ed. Pittsburgh: Air and Waste Management Association 1998, 4-1-4-27.