*International J. Seed Spices 7(2), July 2017:19-25*

# Nutrients uptake pattern in some important cultivars of fennel under typic haplustepts for their management precisely and farmgate budgeting

**O.P. Aishwath**

ICAR - National Research Centre on Seed Spices, Tabiji-305 206, Ajmer, Rajasthan, India

**Abstract**

Characterizing varietal nutrient uptake pattern, ratio and removal at a particular location is an utmost important for the establishment of crop cultivation techniques aiming high production under precision agriculture including production and usage of compound fertilizers or integrated nutrient management. Therefore, present investigation was carried out to assess the nutrient uptake pattern, uptake ratio and recyclable/consumable percentage of nutrients for their budgeting in fennel (*Foeniculum vulgare* Mill.) cultivars. There were seven cultivars/genotypes ie AF-1, GF-1, GF-2, RF-101, PF. 35, AF-1-87, AF-S-01 evaluated in the study under lower fertile soil belongs to semi-arid region of Rajasthan. Results revealed that uptake/removal of N, P, K, Zn and Mn was highest in GF-2. However, Fe uptake was the highest in RF-101 and Cu in GF-1 among all the cultivars. N, P and Fe uptake was least in AF-S-01, however K, Zn and Cu in AF-1-87. Mn uptake alone was least in GF-1 as compared to other cultivars and genotypes. Uptake ratio indicates that K requirement of crop was the highest among the macro nutrients which was about 2 times to N and 5 times to P. Fe requirement was the highest among the micronutrients, which was 6.8 times to Zn and Mn, 35 times to Cu. Mean value of nutrient partitioning for farm gate budgeting indicated that more than 75 per cent nitrogen and >50% of P went off from the farm and rest of N and P could be recycled by the crop residues. However, more than 50% K could be recycled on the farm and rest went out from the farm. In case of micronutrients, >60% of Zn and Mn went out of farm and rest can be recycled, whereas >50% Fe and Cu can be recycled at the farm and rest amount may go out from the farm.

**Key words :** Fennel cultivars, macro-nutrients, micronutrients, nutrient uptake, nutrient budgeting, uptake ratio.

## Introduction

Nutrient uptake is the mechanism by which plants capture essential nutrient elements for their growth and development. A series of chemical and biochemical processes occur within a plant govern by these elements directly or indirectly for synthesis and breakdown of organic compounds. Nutrient uptake depends on a number of factors, including plant species and their varieties, environmental conditions, nutrient supply and interrelationship among nutrients and soil microorganisms their association with plant roots, etc. Uptake ratio of nutrients is very important with respect to crop specific compound fertilizer production and their usage for site and crop/cultivar specific nutrient management precisely. For a sustainable crop production, inputs and outputs budget should be equal. A nutrient budget quantifies the amount of nutrients imported to and exported from a system. Nutrient budgeting can be done at various scales, ie a farm, village, state, or a country. There are three types of nutrient budgeting ie. A farm-gate nutrient budgeting, A soil surface nutrient budgeting and a soil system budget is the most comprehensive type. The goal of nutrient budgeting is to help farmers for choosing and implementing best management practices (BMPs) to economize crop production and reducing the surplus of nutrients (Shober *et al.*, 2011). The purpose of nutrient budgeting is also to educate extension workers, environmental management advisors, and governmental agency staff responsible for precision agriculture. Most importantly reduction in fertilizer inputs and judicious use of resources, to reduce potential nutrient losses from agricultural ecosystem and also to understand nutrients transformation and cycle within, and transport out to urban from agricultural systems (Onema *et al.*, 2003; Smaling and Fresco, 1993).

Fennel *(Foeniculum vulgare* Mill.) is an important seed spice crop in India. It is widely cultivated throughout the temperate and subtropical region of the world, mainly in Rumania, Russia, Germany, France, Italy, India, Argentina and USA. It accumulates huge biomass demands more nutrients than any other seed spices with a very long crop duration (210-240 days). Stover is not palatable to



*Corresponding author email: opa_scn@yahoo.co.in

use as a fodder could be recycled by composting. Being a very important crop, there is no information on nutrient uptake pattern and their budgeting. However, studies available on mineral content in fennel with respect to biological, medical and dietary purpose, particularly for functions in living organisms (Singh and Garg 2006; Divrikli *et al.*, 2006; Demirel *et al.*, 2008; Barros 2010). Relationship in change in location and Ethiopian fennel seed content was reported by Endalamaw and Chandravanshi (2015). Besides that only few reports (Khattak and Khattak 2011; Chowdhary *et al.*, 2014; Ozcan and Akbulut 2007; Kumar *et al.*, 2005; Harisha *et al.*, 2017a, Demissie *et al.*, 2015) are available worldwide on total elemental content/uptake of fennel fruit. However, nutrient uptake pattern and budgeting was done in other seed spices (Aishwath and Anwer, 2016; Aishwath and Malhotra, 2013; Harisha *et al.*, 2017b). Therefore, present study was carried out to calculate nutrient requirement as well as budgeting for judicious use of fertilizers and manures to avoid over and under use.

## Material and methods

### *Location and climate*

Field experiments were carried out under the Typic Haplustepts during *Rabi* season of 2007-2008 and 2008-2009 at ICAR-National Research Centre on Seed Spices, Tabiji, Ajmer, Rajasthan, India. This was laid between 74° 35'39" to 74° 36' 01"E longitude and 26° 22'12" to 26° 22' 31" N latitude. Climate of the Ajmer area characterized as semi-arid. The average annual rainfall of the area is 536 mm and most of it (85-90%) receives from June to September. July and August are most rainy months contributing 60.0% of the average rainfall. Soil moisture control section remains dry for more than 90 cumulative days and hence moisture regime classified as Ustic. Mean annual temperature is 24.5 to 25.0°C. January is the coolest month of the season and temperature remain around 7.0°C. Sometimes, frost is also occurring in this month (Singh and Shyampura, 2004).

### *Treatments and cultural practices*

The treatments consisted of five varieties of fennel viz AF-1, GF-1, GF-2, RF-101, PF 35 and two elite genotypes AF-1-87 and AF-S-01 were arranged in a Randomized Block Design (RBD) with three replications. Seeds of the crop varieties were sown in the 50 cm line to line apart and distance from plant to plant was maintained at 15 cm. Cultural practices were uniformly followed during the growing seasons in both the years. The cultivars were harvested as and when matured as these belong to bit different maturity groups. After harvest, seeds were separated from the straw by beating bundles thereafter winnowing.

### *Soil analysis*

Soil samples were collected from the surface (0-15 cm depth) before sowing of seeds during both years. Samples were air dried and powdered with wooden mortar and pestle and passed through a 2 mm stainless steel sieve. Experimental soil was analyzed for texture (International Pipette Method), EC and pH (Richards, 1954), organic carbon content by rapid chromic titration (Walkley and Black, 1934), available N by alkaline permanganate (Subbiah and Asija, 1956), available P by 0.5 M $NaHCO_3$ extractable P (Olsen, *et al.*, 1954), available K by 1N $NH_4OAc$ extracts method (Jackson, 1973).

Texture of experimental soil was sandy loam. Soil EC, pH and organic carbon were 0.31 $dSm^{-1}$, 8.6 and 0.21%, respectively. However, soil available N, P and K were 97.8, 7.9 and 258 kg $ha^{-1}$, respectively. Micronutrient status like iron, zinc, manganese and copper of the soil was 7.5, 3.5, 25.5, 1.8 kg $ha^{-1}$, respectively. Soil calcium content was 8.5 per cent.

### *Plant analysis*

The plant samples were collected after the harvest of all the crop cultivars and their replications. Plant samples were successively washed with tape water, 0.1 M HCl and distilled water and dried at 70°C. After proper drying samples were powdered in wily mill and passed through the 20 mesh stainless steel sieve. Nitrogen was estimated by Kjeldahl method (Piper, 1966). The samples were digested in nitric and perchloric acid (10:4) for the estimation of P by Venado-molybdo yellow colour method (Chapman, and Pratt, 1962) and K by flame photometer. Micronutrients were analysed by using Atomic Absorption Spectrophotometer from the same aliquot used for P estimation.

### *Statistical Analysis*

The data of both the years were pooled and analyzed by ANOVA and treatment differences were expressed for Least Significant Differences (LSD) at 5% probability to determine the significance among the treatment means (Cochran and Cox, 1987).

## Results and discussion

### *Removal and uptake pattern of macro-nutrient by the crop cultivars*

For the soil surface nutrient budgeting, total removal by the aerial part of the crop has to be assessed for surface application of nutrients to meet out the requirement of crop. It can be inferred from the fig-1, 2 and 3 that highest N, P and K removal was in GF-2, however second highest removal of macronutrients was AF-1, RF-101 and RF-101, respectively. Least uptake of N, P and K was in GF-1, AF-S-01 and AF-S-87, respectively. It indicates that GF-1 requires highest macronutrient than any other

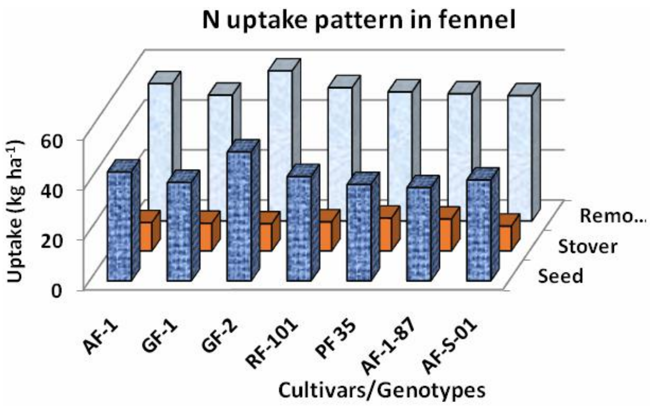


**Fig. 1. Nitrogen uptake pattern in fennel cultivars/ genotypes**

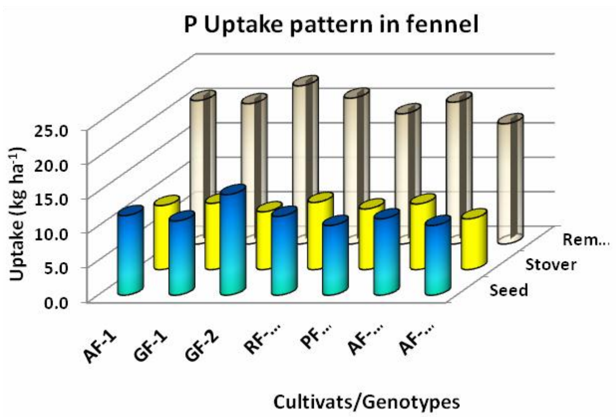


**Fig. 2. Phosphorus uptake pattern in fennel cultivars/genotypes**

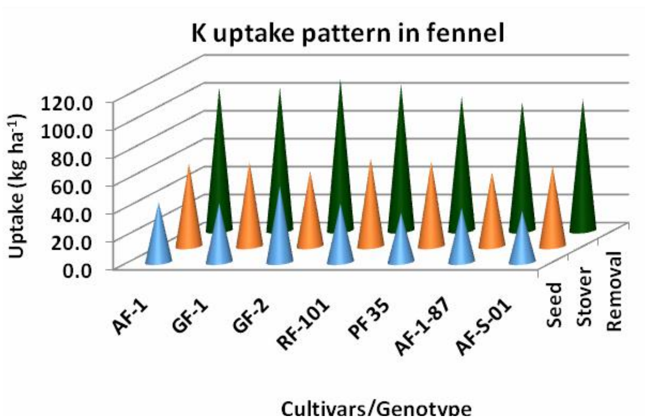


**Fig. 3. Potassium uptake pattern in fennel cultivars/ genotypes**

cultivars. Such variable requirement of NPK in cumin cultivars was reported by Aishwath and Malhotra (2013). Irrespective of cultivars/genotypes, mean value for uptake in seed and stover, reflected that N and P uptake was more in seed than stover, while N was about four time higher in seed than stover. In contrast to it K accumulation was more in stover than seed. This is because of N and P content was more in seed than stover, which was reverse in case of K. Highest N accumulation in seed and straw was in GF-2 and AF-187, respectively. P accumulation in seed was highest in GF-2 and in stover it was highest in RF-101 which was at par with GF-1, PF-35 and AF-S-01. Highest accumulation of K in seed and stover was recorded in GF-2 and RF-101.

***Removal and uptake pattern of micro-nutrient by the crop cultivars***

Fennel cultivars- RF-101, GF-2, GF-2 and GF-1 removed highest Fe, Zn, Mn and Cu, respectively, while it was least in AF-S-01, AF-S-01, GF-1 and AF-1-87 (Fig 4, 5, 6 and 7). Micronutrient removal variability in coriander cultivars was reported earlier by Aishwath and Anwer (2016). Irrespective of cultivars, based on the mean value of micronutrient uptake in seed and stover, it could be inferred that uptake of Fe was more in stover was more than seed. This might be due to the fact that content in stover more than seed resultant, it is difficult to separate seed from stover by usual thresher. In case of Zn and Mn, uptake was more in seed than stover might be due to the content was more in seed. Cu accumulation in both seed and stover was almost similar. For the cultivar/ genotypic variability in uptake of micronutrients in seed and stover showed that Fe uptake was highest in GF-2 and RF-101, respectively. Accumulation of Zn, Mn and Cu in seed was highest only in GF-2, while in stover these were higher in RF-101, AF-1-87 and GF-1, respectively. The highest uptake of Fe among the micronutrients may also be attributed by high lime content in experimental soil along with higher pH, iron turns into physiological inactive which create hunger even at higher accumulation in plant tissue (Aishwath and Anwer, 2010). Pathak *et al.* (2010) calculated the budgets of N, P, and K at national level for 2000–2001 taking into consideration the inputs through inorganic fertilizer, animal manure, compost, green manure, leguminous fixation, non-leguminous fixation, crop residues, rain and irrigation water and outputs through crop uptake and losses through leaching, volatilization and denitrification.

***Nutrient uptake ratio among the macronutrients***

It is very much essential to assess the proportion of different nutrients taken up by the crop for input budgeting and equally important to the compound fertilizers manufacturers and consumer. Data on uptake ratio of nutrients given in fig 8 indicated that N required about 2.5 times higher than P and about 2.0 times lower than K. However, K uptake was about five times higher than P.

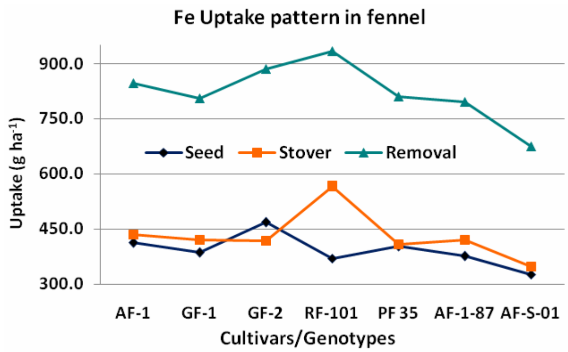


**Fig. 4. Iron uptake pattern in fennel cultivars/ genotypes**

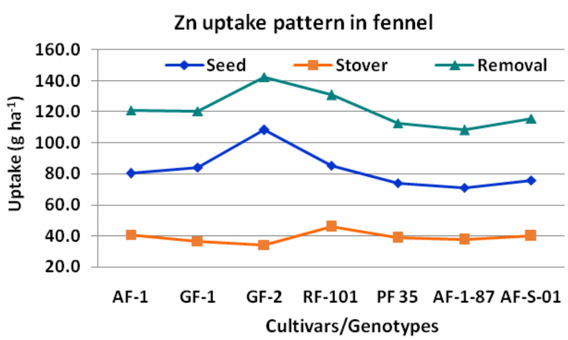


**Fig. 5. Zinc uptake pattern in fennel cultivars/ genotypes**

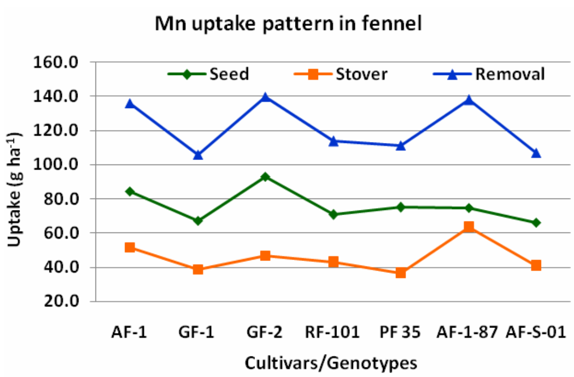


**Fig. 6. Manganese uptake pattern in fennel cultivars/ genotypes**

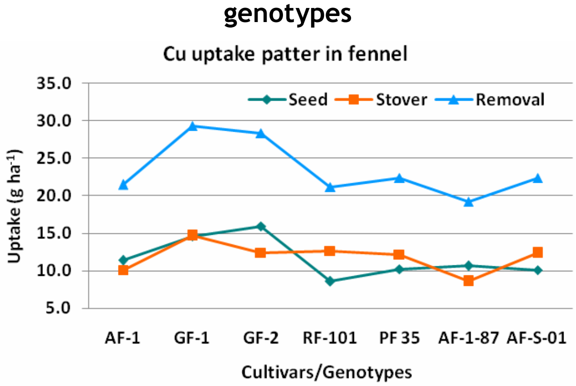


**Fig. 7. Copper uptake pattern in fennel cultivars/ genotypes**

The widest ratio for N/P, N/K and K/P was in PF-35, GF-2 and AF-S-01, respectively. Among the macronutrients K requirement was highest than N and P as evidenced by uptake ratio. For N and P budgeting, Panda *et al.* (2007) observed positive balance of P in the long-term experiments in rice-rice systems in the treatments with N and P application. For the budget of nutrient application ratio in major states have N: K wider than 4:1, which is accepted as balanced nutrient use ratio in the country. For Haryana this value is about 80:1 and for Punjab it was 40:1 (FAI, 2007). It is also very important for manufacturing of crop specific compound fertilizers.

***Nutrient uptake ratio among the micronutrients***

Based on uptake ratio, Fe requirement of fennel was 6-7 times more than Zn and Mn and about 35 times to Cu among the micronutrients (Fig 9 &10). Mn required equally to Zn and more than 5 times to Cu. likewise, Zn also required about five times more than the Cu. This indicated that Fe requirement of fennel is highest and Cu is least among the micronutrients. In case of varietal variability, uptake ratio of Fe/Zn, Fe/Mn, Fe/Cu, Mn/Zn, Mn/Cu and Zn Cu was highest in AF-1-87, RF-101, RF-101, AF-1-87, AF-1-87 and RF-101, respectively. Benbi and Biswas

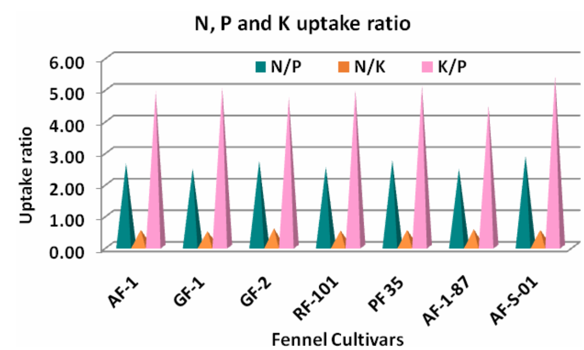


**Fig. 8. Uptake ratio of N, P and K in fennel cultivars/ genotypes**

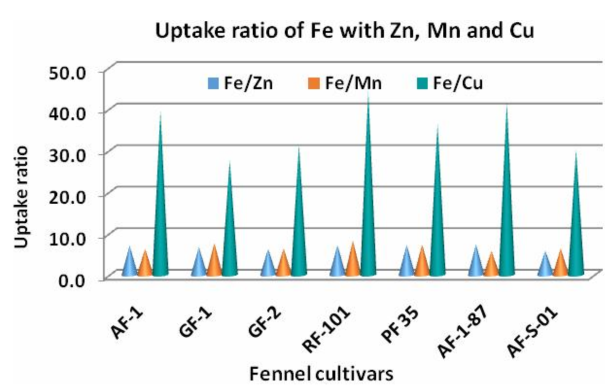


**Fig. 9. Uptake ratio of Fe with Zn, Mn and Cu in fennel cultivars/genotypes**

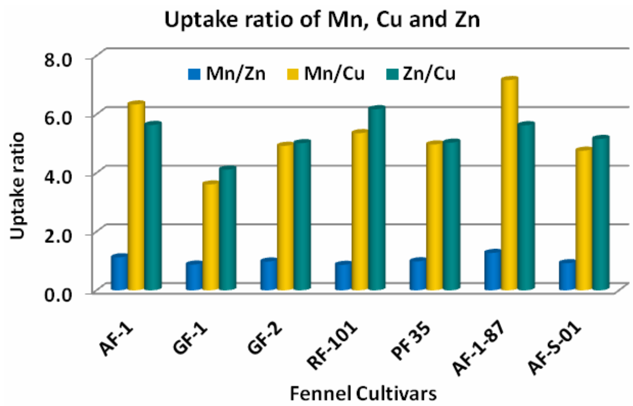


**Fig. 10. Uptake ratio of Mn, Cu, and Zn in fennel cultivars/genotypes**

(1999) studied the P and K balance in maize-wheat cropping system and they found that P uptake by wheat was about 1.5 times to that of maize, whereas K uptake by wheat was only 1.1 times to that of maize. Hence, there is a need for modifying the existing K fertilizer recommendations to compensate for gradual loss of native soil K fertility at Ludhiana (Punjab). Nutrient uptake ratio was also studied in coriander and cumin by Aishwath and Anwer (2016) and Aishwath and Malhotra (2013) could be useful for fertilizer input in seed spice growing areas.

***Per cent removal of macro nutrients for farm gate budgeting***

Mean value of N uptake per cent given in table 1 indicated that about 80 per cent of nitrogen went off from the farm and rest could be recycled through the crop residues. It was because of higher N content in seed than the stover. However, more than 44% and about 60%, P and K could be recycled on the farm and rest went out from the farm. This might be due to the fact that higher content of K in stover and also stover produced more than seed in fennel.

High yielding trait/higher harvest index cultivars removes more of nutrients and exportable from the farm, hence this should be supplied in the ratio exported or retained (Pathak *et al.*, 2010). Therefore, nutrient use efficiency is required to improve by various means (Ladha *et al.*, 2005). Among the cultivars, the highest recyclable N, P, and K were in AF-1-87, GF-1 and PF-35. Maximum amount of N, P and K went off from the farm by the cultivar GF-2 among all the cultivars/genotypes. Aishwath and Anwer (2016) reported that high yielding coriander cultivars removed higher N, P and K and uptake partitioning could be decided by the exportable part of crop for farm gate budgeting. Kikon *et al* (2012) did the nutrient budgeting with the combine use of organic and inorganic fertilizers under inter cropping of patchouli in coconut based farming system. They have calculated the nutrient balance, based on the input (by fertilizers and manures) output (uptake by the crops) ratio of N, P and K via organic and inorganic means.

***Per cent removal of micronutrients for farm gate budgeting***

Irrespective of cultivars, mean value for farm gate budgeting indicated that >60% of Fe and Mn went out and rest could be recycled by the fennel, whereas >50% Cu and Fe can be recycled at the farm and rest of amount went out from the farm (Table 2). This might be the fact that fennel seeds have more Zn and Mn content and accumulation in seed and obviously went it out from the farm as a consumable part. However, highest amount of Fe could be recycled by the fennel cultivars/genotypes. This is because of higher content and uptake of Fe in stover. Likewise more than 50% of Cu could be recycled at farm due to higher accumulation in stover.

Among the cultivars, highest Fe, Zn, Mn and Cu exported

**Table 1.** Per cent macro nutrients removal/recyclable for a farm-gate nutrient budgeting

| Cultivars | N | | P | | K | |
|---|---|---|---|---|---|---|
| | C | R | C | R | C | R |
| AF-1 | 79.3 | 20.7 | 55.3 | 44.7 | 42.2 | 57.8 |
| GF-1 | 77.9 | 22.1 | 52.8 | 47.2 | 41.2 | 58.8 |
| GF-2 | 82.7 | 17.3 | 63.5 | 36.5 | 50.4 | 49.6 |
| RF-101 | 78.2 | 21.8 | 54.0 | 46.0 | 40.0 | 60.0 |
| PF 35 | 74.6 | 25.4 | 53.4 | 46.6 | 37.0 | 63.0 |
| AF-1-87 | 73.2 | 26.8 | 53.7 | 46.3 | 41.9 | 58.1 |
| AF-S-01 | 80.3 | 19.7 | 57.9 | 42.1 | 39.0 | 61.0 |
| Mean | 78.0 | 22.0 | 55.8 | 44.2 | 41.7 | 58.3 |
| CD at 5% | 3.1 | 3.1 | 4.8 | 4.8 | 4.4 | 4.4 |

C = Consumable, R = Recyclable

**Table 2.** Per cent micronutrients removal/recyclable for a farm-gate nutrient budgeting

| Cultivars | Fe | | Zn | | Mn | | Cu | |
|---|---|---|---|---|---|---|---|---|
| | C | R | C | R | C | R | C | R |
| AF-1 | 48.6 | 51.4 | 66.4 | 33.6 | 61.9 | 38.1 | 53.0 | 47.0 |
| GF-1 | 47.8 | 52.2 | 69.8 | 30.2 | 63.3 | 36.7 | 50.3 | 49.7 |
| GF-2 | 52.9 | 47.1 | 76.0 | 24.0 | 66.5 | 33.5 | 56.3 | 43.7 |
| RF-101 | 39.8 | 60.2 | 65.2 | 34.8 | 62.3 | 37.7 | 40.4 | 59.6 |
| PF 35 | 49.7 | 50.3 | 65.9 | 34.1 | 67.2 | 32.8 | 46.0 | 54.0 |
| AF-1-87 | 47.1 | 52.9 | 65.5 | 34.5 | 54.2 | 45.8 | 55.1 | 44.9 |
| AF-S-01 | 48.5 | 51.5 | 65.6 | 34.4 | 61.9 | 38.1 | 44.9 | 55.1 |
| Mean | 47.8 | 52.2 | 67.8 | 32.2 | 62.5 | 37.5 | 49.4 | 50.6 |
| CD at 5% | 5.3 | 5.3 | 4.9 | 4.9 | 4.0 | 4.0 | 5.2 | 5.2 |

C = Consumable, R = Recyclable

out by the cultivars GF-2, GF-2, PF-35 and GF-2, respectively, as these cultivars have more content and uptake of these nutrients in their seed. However, highest Fe, Zn, Mn and Cu could be recycled by the genotype/ cultivars RF-101, RF-101, AF-187 and RF-101, respectively. This indicates that these cultivars have more content and accumulation of these nutrients in their vegetative part resultant more of recyclable micronutrients. Surendran *et al* (2005) carried out the nutrient budgeting at micro (plot/field) and meso (farm) level via nutrient mining and enrichment using NUTrient MONitoring (NUTMON) model. They revealed that nutrient balance (inflow and outflow) in Coimbatore district of Tamil Nadu was negative for farm gate budgeting, either application of manures or chemical fertilizers leading to soil fatigue. Therefore, nutrient budgeting and integrated use of fertilizers and manures is essential for soil health and sustainability in crop production.

## Conclusions

Fennel variety GF-2 found most feeder cultivar as it utilized the highest amount of nutrients particularly N, P, K, Zn and Mn, however, RF-101 was found the most loving for Fe and GF-1 for copper. Least N, P and Fe required by AF-S-01, however K, Zn and Cu by AF-1-87, while Mn required least by GF-1 among the other cultivars and genotypes. K requirement of crop cultivar was highest followed by N among the macro nutrients. Likewise Fe requirement was highest among the micronutrients followed by Mn and Zn. For farm gate budgeting, >75 per cent N and > 50% of P went off from the farm and >50% K could be recycled. Whereas, >60% of Zn and Mn went out of the farm and >50% Fe and Cu could be recycled. The highest and least removal of nutrients is an indicator of nutrient requirement of these crop cultivars or genotypes.

## References


Aishwath, O. P. and Anwer, M. M. 2016. Macro-nutrient requirement and uptake distribution in some important cultivars of coriander for nutritional budgeting. International J. Seed Spices, 6(1): 11-16.

Aishwath, O. P. and Anwer, M. M. 2010. Lime induced chlorosis in *Coriandrum sativum*: First report in the world. NRCSS E-Newsletter, 2 (5): 3-6.

Aishwath, O. P. and Malhotra, S. K. 2013. Nutrient uptake pattern in some important cultivars of cumin for nutritional budgeting. International J. Seed Spices, 3(2) 74-80.

Barros, L., Carvalho, A. M. and Ferreira, I. C. F. R. 2010. The nutritional composition of fennel (*Foeniculum vulgare*): Shoots, leaves, stems and inflorescences. LWT - Food Sci. and Tech.. 43: 814-818 (doi:10.1016/j.lwt.2010.01.010)

Benbi, D. K. and Biswas, C. R. 1999. Nutrient budgeting for phosphorus and potassium in a long-term fertilizer Trial. Nutr. Cycling in Agroecosystems, 54: 125-132.

Chapman, H. D. and Pratt, P. F. 1962. Methods of analysis for soil, plant and water. Div. of Agril. Sci., Univ. of California, California.

Chowdhary, F., Bukhsh, A., Chaman, S. and Naeem, M. 2014. Detection and measurement of zinc concentrations in selected indigenous medicinal plants of Pakistan. Adv. Pharm Ethnomed., 2:10-13

Cocharn, W. G. and Cox, G. M. 1987. Experimental designs, Second Edition. John Wiley and Sons, New York.

Demirel, S., Tuzen, M., Saracoglu, S., Soylak, M. 2008. Evaluation of various digestion procedures for trace element contents of some food materials. J. Hazard Mater 152:1020–1026

Demissie, F., Endalamaw, D. F. and Chandravanshi, B. S. 2015. Levels of major and trace elements in fennel (*Foeniculum vulgare* Mill.) fruits cultivated in Ethiopia. Springer Plus pp 4(5): 1-10 (doi:10.1186/2193-1801-4-5)

Divrikli, U., Horzum, N., Soylak, M. and Elci, L. 2006. Trace heavy metal contents of some spices and herbal plants from western Anatolia, Turkey. Int. J. Food Sci. Technol. 41:712–716.

FAI. 2000–2007. Fertilizer statistics. Fertilizer Association of India, New Delhi

Harisha, C. B., Diwakar, Y., Aishwath, O. P., Singh, R. and Asangi, H. 2017a. Soil Fertility and Micronutrient Uptake by Fennel (*Foeniculum vulgare* Mill.) as Influenced by Micronutrients Fertilization. Environment & Ecology, 35 (1B): 514-518.

Harisha, C. B., Diwakar, Y., Aishwath, O. P., Singh, R. and Asangi, H. 2017b. Response of *Cuminum cyminum* for various modes of micronutrients application including uptake and their availability in soil. International J. Seed Spices, 7(1) 48-51.

Jackson, M. L. 1973. Soil Chemical Analysis, Prentice-Hall of India, Pvt. Ltd., New Delhi.

Khattak, M. I., and Khattak, M. I. 2011. Study of heavy trace metals in some medicinal-herbal plants of Pakistan. Pakistan J. Bot., 43: 2003–2009.

Kikon, Y. Y., Singh, A. K. and Singh, V. B. 2012. Nutrient budgeting under coconut-based patchouli farming system on Hapludalf. J. Pl. Nutr., 35: 975–989.

Kumar, A., Nair, A. G. C., Reddy, A. V. R. and Garg, A. N. 2005. Analysis of essential elements in Pragya-peya a herbal drink and its constituents by neutron activation. J. Pharm. Biomed. Anal., 37:631–638.

Ladha, J. K., Pathak H., Krupnik, T. J., Six, J. and van Kessel, C. 2005. Efficiency of fertilizer nitrogen in cereal production: retrospect and prospects. Adv. Agron., 87: 85–156.

Oenema, O., Kros, H. and de Vries, W. 2003. Approaches and uncertainties in nutrient budgets: Implications for nutrient management and environmental policies. Eur. J. Agron. 20: 3-16.

Olsen, S. R. I., Cole, C. V., Wantanable, F. S. and Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Deptt. of Agric. Circular, 10: 939.

Ozcan, M. M., Akbulut, M. 2007. Estimation of minerals, nitrate and nitrite contents of medicinal and aromatic plants used as spices, condiments and herbal tea. Food Chem., 106:852–858.

Panda, D., Samantaray, R. N., Misra, A. K. and Senapati, H. K. 2007. Nutrient balance in rice. Indian J. Fertil., 3: 33–38

Pathak, H., Mohanty, S., Jain, N. and Bhatia, A. 2010. Nitrogen, phosphorus and potassium budgets in Indian agriculture. Nutr. Cycl. Agroecosyst., 86: 287–299.

Piper, C. S. 1966. Soil and plant analysis, Asia Publishing House, Bombay.

Richards, L. A. 1954. Diagnosis and improvement of saline-alkali soils. Agric. Hand book, U.S. Department of Agric., 60: 160-200.

Shober, A. L., Hochmuth, G. and Wiese, C. 2011. An overview of nutrient budgets for use in nutrient management planning. SL361, of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. (at http://edis.ifas.ufl.edu.) pp 1-4.

Singh, V. and Garg, A. N. 2006. Availability of essential trace elements in Indian cereals, vegetables and spices using INAA and the contribution of spices to daily dietary intake. Food Chem., 94: 81–89.

Singh, R. S. and Shyampura, R. L. 2004. Soil resource appraisal, research farm of NRCSS, Ajmer. NBSS Tech. Bull. pp. 3-9.

Smaling, E. M. A. and Fresco, L. O. 1993. A decision support model for monitoring nutrient balances under agricultural land use, NUTMON. Geoderma, 60: 235–256

Subbiah, B. V. and Asija, G. L. 1956. A rapid procedure for the estimation of available nitrogen in soil. Current Sci., 25: 259 - 260.

Surendran, U., Murugappan, V. Bhaskaran, A. and Jagadeeswaran, R. 2005. Nutrient Budgeting Using NUTMON - Toolbox in an Irrigated Farm of Semi-Arid Tropical Region in India - A Micro and Meso Level Modeling Study. World J. Agril. Sci., 1 (1): 89-97.

Walkley, A. and Black, I. A. 1934. Estimation of soil organic carbon by the chromic acid titration method. Soil Sci., 37: 29-38.

Received : April 2017; Revised : June 2017; Accepted : June 2017.