Int. J. Chem. Sci.: 12(1), 2014, 73-82
ISSN 0972-768X
www.sadgurupublications.com

EVALUATION OF PLANT YIELD, MACRO AND MICRONUTRIENTS CONCENTRATION IN SPINACH (*SPINACIA OLERACEA L.*) PLANT TISSUE AS WELL AS IN SOIL AMENDED WITH HAIR AS FERTILIZER

SURUCHI GUPTA and ANSHUMALA SHARMA*

P.G. Department of Chemistry, Govt. Dungar College, BIKANER (Raj.) INDIA

ABSTRACT

To meet the requirement of ever increasing population, modern agricultural practices rely heavily on artificial or chemical fertilizers, which later on creates critical pollution problems. To avoid the use of these chemical fertilizers, number of waste material and by products (such as animal manure, municipal solid waste compost and sewage sludge) are used currently in agricultural crop production. An attempt is made in this work by the use of uncomposted hair waste as nutrient source for high value plants and to evaluate the effect of these waste materials on soil microbial community. In the Pot experiment, the addition of uncomposted hair waste to soil increased yield in Spinach. Addition of hair waste also increased NH_4-N and NO_3-N in soil, increased total N concentration in plant tissue and stimulated soil microbial biomass. It`s addition also increased conc. of N, S, Ca, Na, Fe, Cu, Zn and Mn in soil as well as in plant tissue. Our result suggest that the addition of 13.33 g/Kg or 29866.66 Kg/ha of hair is sufficient for Spinach crop and can support at least 2-3 harvest of crops, without the addition of other fertilizers.

Key words: Uncomposted hair waste, Microbial Biomass, Spinach, Mineral elements.

INTRODUCTION

Barber shops situated at every corner of the city generate a significant amount of human hair waste, that is usually put to garbage and ultimately end up in land fill, which are creating severe environmental problem as nitrate leaching from hair can contaminate the ground water (Nitrogen is one of the component of hair composition). Hair is made up of protein, which originates in the hair follicle. As the cells mature, they fill up with the fibrous protein called keratin. These cells lose their nucleus and die as they travel up the hair follicle. Approximately 91% of the hair is protein made up of long chain of amino acids, joined to each other with the help of chemical bond, which are called polypeptide. There are various

*Author for correspondence; E-mail: anshumalabkn@gmail.com

elements found in the hair and they are used to make amino acids, keratin, melanin and protein. The average composition of normal hair is composed of 45.2% carbon, 27.9% oxygen, 15% nitrogen and 5.2% sulphur. The keratin found in the hair is called 'Hard Keratin'. This type of keratin does not dissolve in water and is quite resilient. So keratin is an important insoluble protein and is made from 18 amino acids. The most abundant of these amino acids is Cystine which gives hair much of its strength. Property of hair as a source of slow releasing organic nitrogen is a valuable soil conditioner.

It has been proposed that body stores of minerals may be estimated from hair analysis because growing hair is metabolically active and is a sequestering tissue[1]. It has been also found that sweat secreated by sebaceous glands may be an important source of minerals in hair and that fatty secretion of apocrine glands may provide physical or chemical means by which exogenous mineral may bind to hair. Hair is made up of Keratin and Keratin contains disulphide bonds that may be major binding sites of minerals in hair[2].

As the protein of hair will prove to be a natural fertilizer and farmers are escaped from using expensive and harmful chemical fertilizers. With the use of composted hair as fertilizer there is considerable loss of nitrogen[3], so in our study we have utilized uncomposted hair waste as a nutrient source for high value plants.

The objective of this study was to examine the effect of uncomposted hair waste as nutrient source for Spinach plant. Spinach is an edible plant in the family of *Amaranthaceae*. It is an annual plant, which grows to a height of upto 30 cm. Spinach can be grown successfully on a variety of soils, but a fertile sandy loam high in organic matter is preferred. The use of cover crops and green manure crops is recommended to maintain the soil organic matter. Spinach is greatly responsive to nitrogen fertilizer[4] and in this study, we have provided nitrogen by means of hair waste.

EXPERIMENTAL

Material and methods

The samples of hair waste were collected from two local shops of Mukta Prasad Colony, Bikaner. These wastes were cleaned by hand picking the polythenes, matchsticks and other types of wastes.

Experimental pots were prepared by adding 6 Kg of soil to each pot along with 300 g of cow dung compost. Treatment consisted of 0 g, 20 g, 40 g and 80 g of hair waste addition to the prepared pots. Spinach seeds were sown in these pots. The experiment had a control with same treatment but with no plant to evaluate the effect of nutrient availability on plant.

Spinach was fully developed in 25 days with a 14 hr. day and 10 hr. night photoperiod, with an average day temperature of 28^{o}C. These were irrigated carefully and evenly once a day with sufficient water. The plant species were harvested when they were fully grown.

After the harvest, the plant species were washed under running tap water to remove soil particles and then spread on newspaper for drying. After sun drying the plants were weighed and oven dried at 70^{o}C for 72 hrs. The herbage was ground using a Wiley Mill to pass through a 1.0 mm screen. The powdered form was kept for mineral and trace element analysis. Fresh soil samples from all experiments were taken at harvest and kept in a cooler at 4^{o}C for microbial biomass and NH_4-N and NO_3-N analysis. Additional soil samples for nutrient and trace element analysis were taken at harvest, air dried (at 20^{o}C), and ground with a mortar and pestle to pass through 2.0 mm screen.

For tissue and soil trace element analysis, plant tissues were digested in the diacid mixture of 20 mL conc. HNO_3 + 2-3 mL conc. $HClO_4$ and extract was prepared.[5] For soil sample extract, DTPA method was used[6]. Parameters like pH is determined by pH meter, EC is determined by electroconductivity meter, organic carbon by Walkley and Black titration method, phosphorus in soil by Olsen's method and in plant tissue by titrametric method, K and Na by flame photometer, Ca & Mg in soil by Versenate (EDTA) titration method and in plant tissue by AAS, sulphur estimation in soil and plant tissue in $CaCl_2$-extractable S by Williams and Steinbergs method using spectrophotometer, Fe, Mn, Cu and Zn in soil and plant tissue by AAS and microbial biomass of soil by fumigation-incubation method.

RESULTS AND DISCUSSION

Result from this study suggests that hair waste is an excellent soil amendment and nutrient sources for high value crops. The soil used in the pot was sandy soil with very low nitrogen content and other minerals as shown in Table 1. Analysis of hair showed that it contain good amount of all nutrients required by plants (Table 2) and almost all nutrients showed their positive effect except few like phosphorus and potassium. It also introduces a significant amount of Na into the soil.

Table 1: The initial physical and chemical characteristics and the concentration of plant available nutrients of soil used in the pot experiments

Parameter	pH	O C (%)	EC millim-hos/cm	P Kg/ha	K ppm	Ca & Mg me/L	S ppm	Na ppm	Fe ppm	Mn ppm	Cu ppm	Zn ppm
Conc. in soil	8.72	0.13	0.17	24	187	8.5	0.055	750.2	0.638	1.6	0.788	2.036

Table 2: The elemental concentration of hair waste used in the pot experiment with Spinach

Parameter	This study ^	Literature		
		Hair $	Hair #	Hair @
C	395 g/Kg	413 g/Kg	-	-
N	1.2 g /Kg	1.3 g/Kg	-	-
Ca	2.1 g/Kg	2.45 g/Kg	1022 micro g/g	1090 ppm
Mg	70 mL/Kg	78 ppm	94 ppm	105 micro g/g
K	22 ppm	72 ppm	5.3 micro g/g	11.8 micro g/g
Na	143 ppm	187 ppm	261 micro g/g	266 micro g/g
Fe	4.43 ppm	39 ppm	-	-
Cu	14.77 ppm	19 ppm	22 ppm	23 ppm
Mn	1.1 ppm	2 ppm	2.5 ppm	2.94 ppm
Zn	117 ppm	217 ppm	192 ppm	189 ppm
P	92 mL/Kg	104 ppm	207 micro g/g	184 micro g/g
S	50.6 g/Kg	89.6 g/Kg	42300 ppm	46900 micro g/g

^ Elemental concentration of hair in this study was measured on AAS and various techniques described in material and methods following digestion in conc. HNO_3.

$ Hair mineral content as reported by V. D. Zheljazkov, J. Environ. Qual., **34**, 2310-2317 (2005).

Hair mineral content as reported by D. A. Bass et al., Altern. Med. Rev., **6**, 472-481 (2001).

@ Certified value of hair mineral content as suggested by Shanghai Institute of Nuclear Reasearch Academia Sinica (SINRAS).

Physico-chemical and biological parameters of soil

NH_4-N and NO_3-N of Spinach increased with increase in conc. of doses in control as well as with plant experiment (Table 3). NH_4-N ranges between 0.512-18.02 ppm in control and between 0.20-25.43 ppm in with plant soil. NO_3-N ranges between 0.054-32.5 ppm in control and 0.56-46.75 ppm in with plant soil. The increase in NH_4-N and NO_3-N in soil is due to mineralization of N in wool rather than mineralization of soil N.

pH of soil decreases with the addition of high doses of hair in soil and this is good for arid and semi arid regions where soil is mostly alkaline in nature. The optimum range of pH for plants is between 5.5-7.0.[7] pH decreased from 8.85 to 8.52 (Table 3) in control experiment. The decrease in pH helps in the availability of nutrients in soil to plants. Organic carbon is a measure of organic matter, which is the seat of nitrogen in soil and the permissible limit is between 0.20-1%.[8] Our experiment showed an increase with increase in dose i.e. from 0.14-0.18% (Table 3).

Table 3: Spinach yield, NH_4-N, NO_3-N, pH, EC, OC and microbial biomass as affected by hair waste addition to soil with or without Spinach plant and total Nitrogen conc. of Spinach tissue as affected by hair waste addition to soil in pots

Crop	Hai g/pot	Soil NH_4-N ppm	Soil NO_3-N ppm	Tissue N %	DM yield Kg/pot	Microbial biomass/g	pH	EC Millim hos/cm	OC %
No crop	0	0.512	0.054	-	-	1×10^4	8.78	0.18	0.14
	20	0.587	1.20	-	-	20×10^4	8.80	0.21	0.15
	40	1.60	3.24	-	-	23×10^4	8.60	0.28	0.17
	80	18.02	32.5	-	-	255×10^4	8.50	0.40	0.18
Spinach	0	0.20	0.56	1.96	0.047	2×10^4	8.85	0.28	0.14
	20	2.46	6.2	1.96	0.368	4×10^4	8.77	0.29	0.12
	40	10.58	20.46	2.408	0.459	1×10^5	8.80	0.21	0.17
	80	25.43	46.75	3.024	0.536	2×10^5	8.60	0.40	0.20

EC also increased with increase in dose but all values are with in permissible limit which is below 0.75 millimhos/cm[9]. The range found is between 0.17-0.40 millimhos/cm (Table 3). The increase is because of liberation of sodium, which increases the salinity of soil.

Calcium and magnesium content in soil as well as in plant tissue increases with increase in dose. This is because hair contains a good amount of Ca and Mg. The range found of Ca and Mg in soil is 8.9-13.0 me/L (Table 4). In plant tissue the maximum conc. of Ca and Mg is found at 40 g dose after that conc. decreases because excess ammonia induces Ca deficiency[10].

Sulphur content increases in both soils as well as in plant tissue. Sulphur present in our soil is very low i.e. 0.055 ppm and with addition of hair it's conc. increases but still below the permissible limit i.e. 10-20 ppm[11]. The value increases from 0.055 to 0.605 ppm

(Table 4) and in plant tissue it increased from 36.0 to 75.0 ppm and values are below permissible limit of 0.05-1.5%[12]. The increase in S value is due to mineralization of wool.

Experimental soil is rich in sodium content i.e. 750.2 ppm and is not required further and with the addition of hair it's conc. further increases from 750.2-842.6 ppm but not beyond the critical level of 5%[13]. In plant tissue, it also increases from 2365-2948 ppm (Table 4).

Table 4: The phytoavailable nutrient conc. in soil (with or without plant), amended with hair waste and total nutrient content in Spinach tissue grown in pots with 0, 20, 40 and 80 g/pot in the hair waste pot. Only nutrients with conc. affected by the treatment are shown

Crop	Hair g/pot	Na ppm	S ppm	Ca & Mg me/L	Fe ppm	Zn ppm	Mn ppm	Cu ppm
No crop (soil)	0	750.2	0.055	8.9	0.638	2.036	1.60	0.79
	20	838.2	0.119	11.2	0.762	2.790	4.60	0.78
	40	842.6	0.45	12.2	1.134	3.404	9.00	0.81
	80	890.4	0.605	13.0	1.380	3.726	27.74	0.816
Spinach (soil)	0	765.6	0.055	9.0	1.246	1.844	4.306	1.004
	20	695.2	0.35	11.6	1.628	1.094	6.520	1.032
	40	805.2	0.625	12.3	2.494	3.182	12.608	1.086
	80	853.6	0.575	12.2	2.246	4.014	14.376	1.032
Total concentration of nutrients in plant tissue								
Spinach	0	2365	36.0	4159.81 & 300.6	76.19	4.927	14.91	1.72
	20	2783	58.5	4311.61 & 289.82	87.33	4.97	16.47	1.93
	40	2948	66.0	4843.98 & 300.98	90.42	6.916	20.63	2.05
	80	3255	75.0	4425.71 & 300.11	155.4	11.609	28.70	2.99

Soil used in experiment is deficient in iron content i.e.0.638 ppm and is below the permissible limit of 2.5 ppm[14]. So the addition of hair is beneficial as it enrich the soil with iron content from 0.638-1.380 ppm (Table 4). In plant tissue, the maximum value comes at 80 g dose i.e. 155.4 ppm. Values of plant tissue are within permissible limit i.e. from 10-250 ppm[12].

Manganese content in soil is found to be 1.6 ppm (Table 4), which is above the permissible limit of 1.0 ppm[14], hair waste addition further increase it from 1.6-27.74 ppm and it is a good increase. In plant tissue the increase is from 14.91-28.70 ppm but the values are within the permissible limit i.e.10-1000 ppm[12].

Copper conc. increases in both in soil as well as in plant tissue i.e from 0.788-0.816 ppm in soil and 1.72-2.99 ppm in plant tissue (Table 4). All the values are within permissible limit i.e. 0.2-10 ppm in soil[14] and 1-50 ppm in plants[12].

Zinc conc. increases with increase in dose from 2.036-3.726 ppm in soil and values are above the critical level of 0.3 ppm[15] and experimental soil has Zn content as 2.036 ppm. In plant tissue, it also increases from 4.927-11.609 ppm and the values are within the permissible limit i.e. from 1 to 200 ppm[12] (Table 4).

Microbial biomass increased in soil with plant as well as in soil without plant, this is because various chemicals secreated by plants attract myriads of micro organisms. The increase is from 2 x 10^4/g to 8 x 10^4/g in Spinach grown soil and 1 x 10^4/g to 255 x 10^4/g in control experiment (Table 3).

Analysis of plant tissue

Spinach (*Spinacia oleracea*) is an edible plant in the family of Amaranthaceae. Spinach can be grown successfully on a variety of soil, but a fertile sandy loam high in organic matter is preferred. The use of cover crops and green manure crop is recommended to maintain the soil organic matter. Spinach requires a high level of fertility, especially nitrogen. The need of Spinach is fulfilled by addition of hair as fertilizer in the experiment. Hair is a good source of nitrogen and provide sufficient amount for its growth. Our result showed that the numbers of leaves were more and healthy and of maximum quantity in 80 g dose of hair in physical appearance. Chemically the results at 80 g dose are-NO_3-N-32.5 ppm in control and 46.75 ppm in with plant soil, NH_4-N-18.02 ppm in control and 25.43 ppm in with plant soil, plant tissue nitrogen also increases with increase of dose and found to be 3.024% in 80 g dose. Phosphorus content found to be 0.78%, potassium content 3234 ppm, calcium content 4425.71 ppm, magnesium content 300.11 ppm, sulphur content 66 ppm, sodium content 2255 ppm, iron content 155.4 ppm, manganese content 28.70 ppm, copper content 2.99 ppm and zinc content 11.609 ppm. Microbial biomass increases with increase in dose, which is favourable for Spinach and found to be 8 x 10^4/g at 80 g dose. In Spinach plant tissue conc. of N_2, Ca, Na, S, Fe, Cu, Mn and Zn increases with the application of hair.

CONCLUSION

The results from this study suggest that addition of hair waste not only increased macro and micro nutrients in soil and plant tissue but also enrich the soil with microbial biomass. Study concluded that 80 g dose of hair in 6 Kg soil is sufficient in Spinach for their appropriate growth. Following conclusions are drawn from the results –

- We added 0-80 g of hair waste in Spinach and observed that Spinach gave best results with maximum growth at 80 g dose, the reason being it is a leafy vegetable and number of leaves increases with increase in nitrogen content. So yield of Spinach was maximum in 80 g dose.
- If we apply this dose in field, it will be equivalent to 13.33 g/Kg or 29866.66 Kg/ha (or 80 g of hair waste in 6 Kg soil). The use of a large quantity of human hair waste as a nutrient source for crop production used for direct human consumption (e.g. vegetables) may be questioned; these might be point of issue with marketability and social acceptance. As there are specific guidelines and regulations for the use of sewage sludge or industrial waste, similar guidelines should be developed for the use of these waste materials in agricultural crops.
- Our results also demonstrated that the addition of large amount of hair waste to soil would depress soil pH due to mineralization and oxidation of sulphur and nitrogen containing compounds. But this is good for arid and semi-arid regions where soil is mostly alkaline in nature. In acidic soil, the application of higher dose of hair is not recommended.
- Study also showed that there is increase in organic carbon % with the addition of hair waste, which not only help in the increase of organic matter but also increases the water holding capacity of soil.
- S, Fe, Cu, Mn and Zn conc. increases both in soil as well as in plant tissue because of high amount of these nutrients in hair.

So our study will help barbers and farmers as barbers get the better way of disposing waste and in turn get the monetary benefit by selling it. On the other hand, farmers will get a better option for chemical fertilizers as the hair waste is not only inexpensive but also enrich their fields chemically and biologically.

Overall our results suggest that uncomposted hair waste can be an excellent soil amendment and nutrient source for high-value crops.

ACKNOWLEDGEMENT

Author acknowledge the support extended by Dr. Tribhuvan Sharma, Deptt. of Animal Nutrition, Veterinary College, Bikaner (Raj.).

REFERENCES

1. D. K. Combs, R. D. Goodrich and J. C. Meiske, J. Animal Sci., **54(2)**, 391-398 (1982).
2. H. C. Hopps, The Biologic Basis for using Hair and Nail for Analysis of Trace Elements, Sci. Total Environ., **7**, 71-89 (1997).
3. E. Epstein, Trace Elements, Heavy Metals and Micronutrients, in E. Epstein (Ed.) The Science of Composting, Technomic. Publ., Lancaster, PA (1997) pp. 137-170.
4. S. Jamal and A. Ronaghi, Int. Res. J. Appl. Basic Sci., **3(4)**, 770-777 (2012).
5. D. Singh, P. K. Chhonkar and B. S. Dwivedi, Manual on Soil, Plant and Water Analysis, Westville Publishing House, New Delhi (2005) p. 86.
6. W. L. Lindsay and W. A. Norvell, Development of a DTPA soil test for Zn, Fe, Mn, and Cu, Soil Sci. Soc. Am. J., **42**, 421-28 (1978).
7. Perry Leonard, pH for the Gardens, (http://pss.uvm.edu/ppp/pubs/oh 34. htm). Retrived 11 December (2012).
8. H. L. S. Tandon, Methods of Analysis of Soils, Plants, Waters, Fertilisers and Organic Manures, Fertiliser Development and Consultation Organisation (2013) p. 50.
9. Solanki S. Ajay, Ph.D. Thesis- Physico-chemical and Toxicological Studies and Treatment of Industrial Effluent of Dying and Printing Units in Bikaner City of Raj. (2009) p. 263.
10. Nutrient Deficiency: www.ces.nscu.edu / dept/hort / Consumer / quickref / fertilizer / nutri.def.html.
11. Shivanand Tolanur, Practical Soil Science and Agricultural Chemistry, International Book Distributing, Lucknow (2004) p. 55.
12. T. C. Baruah and H. P. Barthakur, A Text Book of Soil Analysis, Vikas Publishing House Pvt. Ltd., New Delhi (1997) p. 297.

13. C. Ken, Plant and Soil Sciences e Library, Sodium Affected Soils (2013). www.fusion fert.com.

14. S. Tolanur, Practical Soil Science and Agricultural Chemistry, International Book Distributing, Lucknow (2004) p. 59.

15. T. C. Baruah and H. P. Barthakur, A Text Book of Soil Analysis, Vikas Publishing House Pvt. Ltd., New Delhi (1997) p. 196.

Revised : 05.01.2014 *Accepted : 08.01.2014*