Plant Archives Vol. 17 No. 2, 2017 pp. 1425-1430 ***ISSN 0972-5210***

INFLUENCE OF NUTRIENT DEFICIENCIES ON NUTRIENT CONTENT, UPTAKE AND THEIR INTERACTIONS IN GERBERA THROUGH SOLUTION CULTURE

Ch. Sai Ratna Sharavani*, B. Neeraja Prabhakar, M. Chandini Patnaik, A. Girwani and Ramesh Thatikunta

College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Rangareddy - 500 030 (Telangana), India.

Abstract

Gerbera is a member of the Asteraceae family and one of the commercial cut flower, India is the best country to produce excellent quality Gerbera flowers under low cost protected structures. It suffers from many deficiency disorders in Green houses because of its continuous feeding habit. Hence, the present investigation was carried out to know the influence of nutrient deficiencies on nutrient content, uptake and their interactions in cut Gerbera var. Savannah through solution culture. Plants were treated with complete modified Hoagland solution and deficiencies were incorporated with a complete nutrient formula minus one of the nutrient. Leaf analysis revealed that plant in deficient solution, content and uptake of individual mineral element was significantly reduced. Some interactions between nutrients has been resulted in increase of N content in K deficient treatment, P content in Zn deficient treatment, K, Ca and Mn content in Mg deficient treatment, Mg content in K deficient treatment, S content in N deficient treatment, B content in Ca deficient treatment, Fe content in Cu deficient treatment, Zn and Cu content in Fe deficient treatment were increased.

Key words : Gerbera, solution culture, Hoagland solutions, nutrient content, nutrient interactions.

Introduction

Gerbera (Asteraceae) is indigenous to South Africa and Asia as a perennial herb, mostly inhabiting temperate and mountainous regions. In India, they are distributed in the temperate Himalayas from Kashmir to Nepal at altitudes from 1,300 to 3,200 m. Gerbera occupies fourth place among cut flowers as per global trends in floriculture (Sujatha *et al*., 2002). It is an important commercial flower grown throughout the world and in India, Assam is having largest area under cultivation (600 ha) and Telangana being the major cut flower producer (6.01 lakhs) (Anonymous, 2015-16). It is ideal for pot, rock gardens, boarders and beds.

For commercial production, Gerberas are considered as moderate feeders. This moderate level of fertility produces a plant with a proportional leaf area to flower ratio. Any increase or decrease in nutrient supply results in abnormal growth and yield loss thereby highlighting the need of balanced nutrition. Knowledge on deficiency symptoms of nutrients would assist the grower in problem identification. Qualitative techniques, as visual diagnosis are very useful to detect an individual problem, but when visual symptom shows up, some reduction in yield has already been caused. For this reason quantitative technique such as foliar analysis is preferred. The critical leaf tissue concentration also highly significant to determine nutritional status of plants. Therefore, the standards for leaf tissue nutrient concentrations are important to determine nutritional status of plants and take up corrective measures.

Information about effect of nutrient deficiencies in Gerbera var. Savannah and critical nutrient levels have not been found in literature. Hence this experiment is aimed to elucidate the influence of different nutrient deficiencies on nutrient content, uptake and their interactions of cut Gerbera var. Savannah.

Materials and Methods

An experiment was conducted in AICRIP on Floriculture, Rajendranagar of Telangana state during 2016

****Author for correspondence :*** E-mail: chnani11@gmail.com

using tissue cultured Gerbera var. Savannah. Plants, which were grown prior to treatment in peat based compost were used in the present investigation. Plants of uniform size with 3-4 leaf stage were selected. Twelve treatments (table 1) *viz.* complete modified Hoagland solution and complete minus N, P, K, Ca, Mg, S, Mn, B, Fe, Zn, Cu were used to incorporate deficiencies (Hoagland and Arnon, 1950). The nutrient treatments were arranged in a completely randomized design with 12 plants each treatment. Nutrient solutions were replaced at weekly intervals and volume is maintained by adding distilled water. Leaves were collected at end of the experiment and analyzed for content of Nitrogen by employing KELPLUS digestion and distillation system (Subbaiah and Asija, 1956), Phosphorous by Vanado-molybdo phosphoric yellow colour method (Jackson, 1973), Potassium by Flame photometer (Tandon, 1993), Cacium and Magnesium by Versenate titration method (Tandon, 1993), Sulphur by Turbidity method (Chesnin and Yien, 1950), Boron by hot water extraction method (Berger and Troug, 1939), Mn, Zn, Fe, Cu by feeding extract to atomic absorption spectrophotometer (Lindsay and Norvell, 1978). The data was analyzed by using software OPSTAT in CRD.

Table 1 : Composition of nutrient solutions for various treatments (ml.l^{-1}).

Treatment	Composition of nutrients (ml/lit)
T_1 (complete)	KNO_3 @ 6ml + $Ca(NO_3)_2.4H_20$ @ 4ml + $NH_4H_2PO_4$ @ 2ml + $MgSO_4.7H_20$ @ 1ml + Fe-EDTA @ 1ml + Micronutrients @ 1ml
T_2 (-N)	$MgSO_4.7H_20$ @ 1ml+ Fe-EDTA @ 1ml + Micronutrients @ 1ml + $CaCl_2$ @ 4ml+ KCl @ 6ml + $NaH_2PO_4.2H_2O$ @ 2ml
T_3 (-P)	KNO_3 @ 6ml + $Ca(NO_3)_2.4H_2O$ @ 4ml + $MgSO_4.7H_20$ @ 1ml + Fe-EDTA @ 1ml+ Micronutrients @ 1ml + NH_4Cl @ 2ml
T_4 (-K)	$Ca(NO_3)_2.4H_20$ @ 4ml + $NH_4H_2PO_4$ @ 2ml+ $MgSO_4.7H_20$ @ 1ml + Fe-EDTA @ 1ml + Micronutrients @ 1ml + $NaNO_3$ @ 6ml
T_5 (-Ca)	KNO_3 @ 6ml + $NH_4H_2PO_4$ @ 2ml + $MgSO_4.7H_20$ @ 1ml + Fe-EDTA @ 1ml + Micronutrients @ 1ml + $NaNO_3$ @ 8ml
T_6 (-Mg)	KNO_3 @ 6ml + $Ca(NO_3)_2.4H_20$ @ 4ml + $NH_4H_2PO_4$ @ 2ml + Fe-EDTA @ 1ml + Micronutrients @ 1ml + Na_2SO_4 @ 1ml
T_7 (-S)	KNO3 @ 6ml + $Ca(NO_3)_2.4H_20$ @ 4ml + $NH_4H_2PO_4$ @ 2ml+ Fe-EDTA @ 1ml + Micronutrients @ 1ml + $MgCl_2.6H_2O$ @ 1ml
T_8 (-Mn)	KNO_3 @ 6ml + $Ca(NO_3)_2.4H_20$ @ 4ml + $NH_4H_2PO_4$ @ 2ml + $MgSO_4.7H_20$ @ 1ml +Fe-EDTA @ 1ml + Micronutrients @ 1ml –Mn
T_9 (-B)	KNO_3 @ 6ml + $Ca(NO_3)_2.4H_20$ @ 4ml + $NH_4H_2PO_4$ @ 2ml + $MgSO_4.7H_20$ @ 1ml + Fe-EDTA @ 1ml + Micronutrients @ 1ml- B
T_{10} (-Fe)	KNO_3 @ 6ml + $Ca(NO_3)_2$.4H20 @ 4ml + $NH_4H_2PO_4$ @ 2ml + $MgSO_4.7H_20$ @1ml + Micronutrients @ 1ml
T_{11} (-Zn)	KNO_3 @ 6ml + $Ca(NO_3)_2.4H_20$ @ 4ml + $NH_4H_2PO_4$ @ 2ml + $MgSO_4.7H_20$ @ 1ml + Fe-EDTA @ 1ml + Micronutrients @ 1ml – Zn
T_{12} (-Cu)	KNO_3 @ 6ml + $Ca(NO_3)_2.4H_20$ @ 4ml + $NH_4H_2PO_4$ @ 2ml + $MgSO_4.7H_20$ @ 1ml + Fe-EDTA @ 1ml + Micronutrients @ 1ml – Cu

Results and Discussion

Nitrogen deficiency

In the present investigation, N content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 3.12 per cent and 17.55 mg plant^{-1}, respectively (tables 2 & 3), while in pot Gerbera it was 2.7-4.1 per cent (Dole and Wilkins, 2005) and in cut Gerbera it was 1.5-3.5 per cent (Ocampo, 2001). In plants grown under N deficiency conditions, N content and uptake of variety Savannah has recorded 1.1 percent and 1.54 mg plant^{-1} respectively, which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3) whereas, threshold level of N in cut Gerbera was 1.2 per cent (Ocampo, 2001). Sulphur content was recorded maximum (0.67%) in N deficient leaves due to antagonism between N and S which resulted in accumulation of more non-protien S compounds in vegetative tissues (Fageria, 2001).

Phosphorous deficiency

In the present investigation, P content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 0.6 per cent and 3.47 mg plant^{-1} respectively (tables 2 & 3) whereas, leaf tissue P content for pot gerbera was 0.3-0.7 per cent (Dole and Wilkins, 2005) and in cut Gerbera, it was 0.2-0.5 per cent (Ocampo, 2001). In plants grown under P deficiency condition, variety Savannah has recorded 0.11 percent P content and 0.28 mg plant^{-1} P uptake which was significantly low when compared to plants grown in complete nutrient solution, whereas, threshold level of P in cut Gerbera was 0.15 per cent (Ocampo, 2001)

Potassium deficiency

In the present investigation, K content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 2.97 per cent and 16.73 mg plant^{-}

^{1} respectively (tables 2 & 3) whereas, leaf tissue K content for pot gerbera was 3.1-3.9 per cent (Dole and Wilkins, 2005) and in cut gerbera, it was 2.5-4.5 per cent (Ocampo, 2001). In plants grown under K deficiency condition, variety Savannah has recorded K content of 1.46 percent and uptake of 4.25 mg plant^{-1} which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3) whereas, threshold level of K in cut Gerbera was 2 per cent (Ocampo, 2001). There was an interaction recorded between K, N and K, Mg due to antagonisms between them which resulted in increased N and Mg contents (3.45% and 0.79%). The increased N and Mg contents was due to the competition of K with N (NH_4) for uptake (Chang *et al*., 2001) and both Mg & K ions are quite similar in size and charge and hence, exchange site cannot distinguish the difference between the ions (Ujwala, 2011), thereby Mg content was increased in K deficient leaves.

Calcium deficiency

In the present investigation, Ca content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 1.43 per cent and 8.00 mg plant^{-1} respectively (tables 2 & 3), whereas, for pot gerbera it was 3.1-3.9 per cent (Dole and Wilkins, 2005) and in cut gerbera was 1.0-3.5 per cent (Ocampo, 2001). In plants grown under Ca deficiency condition, variety Savannah has recorded Ca content of 0.33 percent and uptake of 1.05 mg plant^{-1} which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3), whereas, threshold level of Ca in cut Gerbera was 0.7 per cent (Ocampo, 2001). Boron content was more (71.75 ppm) in Ca deficient leaves due to antagonism between Ca and B which has resulted in localization of Ca in cell wall, which further lead to decreased cell wall boron permeability (Turan *et al.,* 2009).

Magnesium deficiency

In the present investigation, Mg content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 0.6 per cent and 3.37 mg plant^{-1} respectively (tables 2 & 3), whereas, leaf tissue Mg content for pot gerbera was 0.24-0.63 per cent (Mills and Jones, 1996) and in cut gerbera was 0.2-0.7 per cent (Ocampo, 2001). In plants grown under Mg deficiency condition, variety Savannah has recorded Mg content of 0.13 percent and uptake of 0.49 mg plant^{-1} which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3), whereas, threshold level of Mg in cut Gerbera was reported to be 0.15 per cent (Ocampo, 2001). There was an antagonistic interactions recorded among Mg and K, Ca, Mn which resulted in increasedcontents of K (3.51%), Ca (2.09%) and Mn (109.45 ppm) in Mg deficient leaves. Both Mg and K ions are quite similar in size and charge and hence, exchange site cannot distinguish the difference between the ions and binding site of K is much stronger than Mg and it easily out-compete Mg which had resulted in more absorption of K at exchange sites (Ujwala, 2011). High rhizospherecontents of calcium, relative to magnesium are inhibitory to the absorption of magnesium and vice versa (Merhaut, 2006). Manganese, as a divalent cation, can compete with magnesium for binding sites on soil particles as well as biological membranes within plants (Merhaut, 2006).

Sulphur deficiency

In the present investigation, S content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 0.38 per cent and 2.14 mg plant^{-1} respectively (tables 2 & 3), whereas, leaf tissue S content for cut gerbera was 0.25-0.5 per cent (Ocampo, 2001). In plants grown under S deficiency condition, variety Savannah has recorded S content of 0.08 percent and uptake of 0.27 mg plant^{-1} which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3), whereas, threshold level of S in cut Gerbera was reported to be 0.16 per cent (Ocampo, 2001).

Manganese deficiency

In the present investigation, Mn content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 72.93 ppm and 41.1 mg plant^{-1} (tables 2 & 3), whereas, leaf tissue Mn content for pot Gerbera was 30-260 ppm (Dole and Wilkins, 2005) and in cut gerbera, it was 40-250 ppm (Ocampo, 2001). In plants grown under Mn deficiency condition, variety Savannah has recorded Mn content of 28.4 ppm and uptake of 13.50 mg plant^{-1} which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3) whereas, threshold level of Mn in cut Gerbera was reported to be 30 ppm (Ocampo, 2001).

Boron deficiency

In the present investigation, B content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 44.5 ppm and 25.30 mg plant^{-1} respectively (tables 2 & 3) whereas, leaf tissue B content for pot gerbera was 19-50 ppm (Dole and Wilkins, 2005) and in cut gerbera was 20-60 ppm (Ocampo, 2001). In plants grown under B deficiency condition, variety Savannah has recorded B content14.6 ppm and uptake

Table 2 : Leaf tissue concentrations of macro (%) and micro nutrients (ppm) and their interaction levels in leaf tissues of cut Gerbera var. Savannah.

Treatments	Content of macronutrients (%)						Content of micronutrients (ppm)				
	N	P	K	Ca	Mg	S	Mn	B	Fe	Zn	Cu
T_1 (Complete)	3.12	0.61	2.97	1.43	0.60	0.38	72.93	44.50	169.55	57.53	13.30
T_2 (-N)	1.10	0.47	3.20	1.84	0.58	0.67	55.67	59.25	205.5	73.35	11.35
T_3 (-P)	2.75	0.11	3.38	1.59	0.53	0.45	60.70	41.38	210.25	70.30	17.16
T_4(-K)	3.45	0.65	1.46	1.78	0.79	0.38	94.63	60.50	45.00	63.80	18.70
T_5 (-Ca)	2.35	0.39	3.29	0.33	0.65	0.34	55.61	71.75	248.50	65.25	19.14
T_6 (-Mg)	2.68	0.71	3.51	2.09	0.13	0.49	109.45	22.80	121.40	71.55	12.15
T_7 (-S)	2.62	0.64	3.43	1.55	0.72	0.08	54.85	45.75	135.55	41.15	16.40
T_8 (-Mn)	2.63	0.31	3.44	1.44	0.63	0.42	28.40	33.85	225.20	53.50	19.40
T_9 (-B)	2.60	0.41	2.67	1.95	0.60	0.43	55.03	14.60	159.80	68.05	18.10
T_{10} (-Fe)	2.56	0.35	2.71	1.15	0.63	0.41	51.24	68.50	36.58	79.25	28.50
T_{11} (-Zn)	2.75	0.77	3.05	1.5	0.51	0.55	55.52	36.35	197.50	12.40	25.20
T_{12} (-Cu)	2.60	0.70	3.22	1.16	0.65	0.525	52.05	46.61	256.40	67.15	3.21
S Em ±	0.032	0.008	0.008	0.009	0.009	0.004	0.284	0.289	0.446	0.224	0.206
C D (p=0.05)	0.099	0.025	0.026	0.028	0.029	0.011	0.885	0.901	1.39	0.699	0.641

Table 3 : Uptake of macro and micro nutrients (mg plant^{-1}) in cut Gerbera a var. Savannah.

Treatments	Uptake of macronutrients						Uptake of micronutrients				
	N	P	K	Ca	Mg	S	Mn	B	Fe	Zn	Cu
T_1 (Complete)	17.55	3.47	16.73	8.00	3.37	2.14	41.1	25.30	95.47	32.42	7.38
T_2 (-N)	1.54	0.68	4.49	2.59	0.81	0.94	7.85	8.35	28.94	10.29	1.62
T_3 (-P)	7.15	0.28	8.63	4.09	1.35	1.13	15.65	10.70	54.01	18.30	4.43
T_4(-K)	9.75	1.89	4.25	5.10	2.26	1.15	27.18	17.66	13.10	17.88	5.38
T_5 (-Ca)	7.14	1.25	10.20	1.05	2.05	1.075	17.23	22.62	77.07	20.27	6.01
T_6 (-Mg)	9.97	2.65	13.21	7.90	0.49	1.86	41.10	8.65	45.78	26.68	4.56
T_7 (-S)	9.65	2.33	12.57	5.70	2.63	0.27	20.10	16.65	49.87	15.20	6.15
T_8 (-Mn)	12.60	1.44	16.17	6.75	2.95	1.96	13.50	16.00	105.40	25.52	9.02
T_9 (-B)	11.22	1.735	11.58	8.35	2.59	1.87	23.70	6.16	69.60	29.73	7.73
T_{10} (-Fe)	7.60	0.99	8.04	4.70	1.82	1.24	15.11	20.67	10.98	23.52	8.38
T_{11} (-Zn)	13.90	3.85	15.07	7.48	2.52	2.08	27.61	18.10	98.00	6.65	12.42
T_{12} (-Cu)	10.74	2.88	11.93	4.75	2.75	2.10	21.52	19.30	105.60	27.73	1.33
S Em ±	0.037	0.021	0.016	0.03	0.016	0.017	0.027	0.193	0.207	0.216	0.058
C D (p=0.05)	0.116	0.065	0.049	0.094	0.048	0.053	0.083	0.602	0.646	0.673	0.181

of 6.16 mg plant^{-1} which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3) whereas, threshold level of B in cut Gerbera was 15 ppm (Ocampo, 2001).

Iron deficiency

In the present investigation, Fe content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 169.55 ppm and 95.47 mg plant^{-1} respectively (tables 2 & 3), whereas, leaf tissue Fe content for pot gerbera was 60-130 ppm (Dole and Wilkins, 2005) and in cut gerbera was 50-200 ppm (Ocampo, 2001). In plants grown under Fe deficiency condition, variety Savannah has recorded Fe content of 36.58 per cent and uptake of 10.98 mg plant^{-1} which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3) whereas, threshold level of Fe in cut Gerbera 40 ppm (Ocampo, 2001). There were interactions recorded between Fe, Cu and Fe, Zn due to antagonisms between them which resulted in increase in Cu and Zn content (28.5 ppm & 79.25 ppm). Cu and Fe have similar affinity to different enzymatic systems (Cohu and Pilon, 2007). Hence, under Fe deficiency, a metabolic shift occurred to enhance the reduction capacity resulted in a greater uptake of Cu

(Gama *et al*., 2015), where as, Zn and Mn interfere with Fe utilization in the leaves for chlorophyll synthesis (Fageria, 2001).

Zinc deficiency

In the present investigation, Zn content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 57.53 ppm and 32.42 mg plant^{-1} respectively (tables 2 & 3) whereas, leaf tissue Zn content for pot gerbera was 19-80 ppm (Dole and Wilkins, 2005) and in cut gerbera was 25-100 ppm (Ocampo, 2001). In plants grown under Zn deficiency condition, variety Savannah has recorded Zn content of 12.4 ppm and uptake of 6.65 mg plant^{-1} which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3) whereas, threshold level of Zn in cut Gerbera was 20 ppm (Ocampo, 2001). Phosphorous content in Zn deficient leaves was recorded more (0.77%) due to antagonism between them as zinc deficiency enhanced the uptake rate of phosphorus by the roots and translocation to the shoots, which can be part of an expression of higher passive permeability of the plasma membranes of root cells or impaired control of xylem loading (Storey, 2006).

Copper deficiency

In the present investigation, Cu content and uptake for cut Gerbera var. Savannah grown in complete nutrient solution was recorded 13.3 ppm and 7.38 mg plant^{-1} (tables 2 & 3) whereas, leaf tissue Cu content for pot gerbera was 2-10 ppm (Dole and Wilkins, 2005) and in cut gerbera was 6-20 ppm (Ocampo, 2001). In plants grown under Cu deficiency condition, variety Savannah has recorded Cu content of 3.21 ppm and uptake 1.33 mg plant^{-1}, which was significantly low when compared to plants grown in complete nutrient solution (tables 2 & 3) whereas, threshold level of Cu in cut Gerbera was 4 ppm (Ocampo, 2001). Iron content in Cu deficient leaves was recorded more (256.4 ppm) due to antagonism between them as Cu in excess interfered with plant's capacity to absorb and/or translocate other nutrients (Fe) inhibiting root elongation and adversely affecting the permeability of the root cell membrane (Frageria, 2001).

It can be concluded that, plants grown in complete nutrient solution recorded maximum nutrient content and uptake compared to plants grown in individual deficiency treatments. Under deficiency conditions, both content and uptake of individual mineral element has reduced. Some interactions between nutrients has been resulted in increase of N content in K deficient treatment, P content in Zn deficient treatment, K, Ca and Mn content in Mg deficient treatment, Mg content in K deficient treatment, S content in N deficient treatment, B content in Ca deficient treatment, Fe content in Cu deficient treatment, Zn & Cu content in Fe deficient treatment were increased.

References

Anonymous (2014-15). National Horticulture Data Base National Horticulture Board. Ministry of Agriculture, Government of India.

Berger, K. C. and E. Trough (1939). Boron determination in soils and plants. *Ind. Eng. Chem. Anal*., **11** : 540-545.

Chang, D. C., S. Y. Kim, J. C. Jeong and K. Y. Shin (2001). Effects of potassium and Calcium content in nutrient solution on the growth and mineral uptake by Potatoes. *International Society of Horticultural Science*, *Acta Hort*., **548** : 477-483.

Chesnin, L. and C. H. Yien (1950). Turbedimetric determination of available sulphates. *Proc. Soil Sci. Soc. Am*., **14** : 149-151.

Cohu, C. M. and M. Pilon (2007). Regulation of superoxide dismutase expression by copper availability. *Physiologia Plantarum*, **129(4)** : 747-755

Dole, J. M. and H. F. Wilkins (2005). *Floriculture Principles and Species*, 2nd ed., Pearson-Prentice Hall, Upper Saddle River, New Jersey.

Frageria, V. D. (2001). Nutrient interactions in crop plants. *Journal of Plant Nutrition*, **24(8)** : 1269-1290.

Gama, F., T. Saavedra, T. I. Diaz, M. D. C. Campillo, A. D. Varennes and A. Duarte (2015). Fe deficiency induction in *Poncirus trifoliata* rootstock growing in nutrient solution changes its performance after transplant to soil. *Scientia Horticultura*, **182** : 102-109.

Hoagland, R. J. and D. I. Arnon (1950). *The Water-Culture Method for Growing Plants without Soil*, Circ. 347 (Rev. edition). California Agricultural Experimental Station, Berkeley, California.

Jackson, M. L. (1973). *Soil ChemicalAnalysis*, Prentice-Hall of India Pvt. Ltd., New Delhi.

Lindsay, W. L. and W. A. Norvell (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.*, **42** : 421-428.

Maathuis, F. J. M. (2009). Physiological functions of Mineral macronutrients. *Current Opinion in Plant Biology*, **12** : 250-258.

Merhaut, D. J. (2006). Magnesium in A.V. Barker and D. J. Pilbeam (eds). *Hand book of Plant Nutrition*, CRC press, eBook. pp 146-165.

Ocampo, V. D. M. V. (2001). *Gerbera*. Ediciones Hortitecnia Ltd., Bogotá, Colombia.

Storey, J. B. (2006). Zinc in A.V. Barker and D.J Pilbeam (eds) *Hand book of Plant Nutrition*, CRC press, eBook. pp. 411-430

Subbaiah, B. V. and G. L. Asija (1956). A rapid procedure for the determination of available nitrogen in soils. *Current Science*, **25** : 259-260.

Sujatha, K., J. V. N. Gowda and M. M. Khan (2002). Effects of different fertigation levels on gerbera under low cost greenhouse. *J. Orn. Hort. New Series*, **5(1)** : 54-59.

Tandon, H. L. S. (1993). *Methods of Analysis of soils, plants, water and fertilizers* (ed.). Fertilizer Development and Consultation Organization, New Delhi.

Turan, M., A. Nizamettin, G. Adem and O. Taskin (2009). Yield and Chemical Composition of Brussels Sprout (*Brassica oleracea* L. *gemmifera*) as Affected by Boron Management. *Hort. Science*, **44(1)** : 176-182.

Ujwala, R. M. (2011). Interaction of micronutrients with major nutrients with special reference to potassium. *Karnataka J. Agric. Sci.*, **24(1)** : 106-109.