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Studies on nutritional disorders of gerbera through solution culture (Hydroponics)

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Abstract
The present investigation was carried out for developing visual symptoms of macro and micro nutrient deficiencies in Gerbera through solution culture. Plants of Gerbera var. Savannah were treated with complete Hoagland solution and individual macro and micro nutrient deficiencies were incorporated with a complete nutrient formula minus one of the nutrients. Withholding of different nutrients from the nutrient medium resulted in characteristic visual symptoms on foliage and growth of Gerbera plants. Among macro nutrients, nitrogen deficiency appeared first which resulted in yellowing of older leaves. Phosphorous deficiency resulted in dark green leaves, potassium deficiency appeared as tannish brown necrosis all along the margins of older leaves, calcium deficiency appeared as leathery, brittle and pale green younger leaves, magnesium deficiency exhibited as intervienal chlorosis on older leaves and sulphur deficiency was expressed as uniform chlorosis. Among micronutrients, copper deficiency was first to appear as distorted young leaves, boron deficiency resulted in marginal necrosis of leaf apex on newly emerging leaves, iron deficiency appeared as interveinal chlorosis on younger leaves and zinc deficient plants expressed symptoms as interveinal chlorosis on older leaves. Manganese was the only nutrient which did not express any visual deficiency symptom but content was reduced when compared with plants grown in complete nutrient solution.

Keywords: gerbera, hoagland solutions, solution culture, symptoms, nutrition

Introduction
Gerbera is one among the top ten cut flowers which are in demand and traded in the world market. It occupies fourth place among cut flowers as per global trends in floriculture (Sujatha *et al*., 2002) [16]. They are commonly called as 'Transvaal daisy', 'Barberton daisy' or 'African daisy'. Daisies are ideal for beds, borders, pots, rock gardens and well suited for floral arrangements. Cut flowers have long vase life, attractive colours and shapes. It is botanically called as *Gerbera jamesonii*. It belongs to the family Asteraceae and is native to South African and Asiatic region and is mostly inhabited in temperate and mountainous regions. It is a diploid species with chromosome number 2n=50. In India, it is cultivated in an area of 900 ha with a production of 4000 MT loose flowers and 23.84 lakhs cut flowers. Assam, Haryana, Himachal Pradesh, Maharastra, Manipur, Meghalaya, Mizoram, odisa, Sikkim, Telangana and Uttarakhand are the major states of cultivation. Assam is having largest area under cultivation (600 ha) and Telangana being the major cut flower producer (6.01 lakhs) (Anonymous, 2015-16) [1].

Excellent quality Gerbera flowers are commercially produced under low cost protected structures. Due to it's continuous feeding habit Gerbera finds many deficiency symptoms. 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. Balancing the needs of plant and periodic monitoring will help in assured implementation of nutritional requirements.

Information about symptomology of nutrient disorders of Gerbera and critical nutrient levels were under progress. Hence this experiment is aimed to elucidate the symptomology of Gerbera nutritional disorders and to study content of both macro and micronutrients in leaves of Gerbera.

Materials and Methods

An experiment was conducted in AICRIP on Floriculture, Rajendranagar of Telangana state during 2015-16 using tissue cultured Gerbera variety Savannah. Twelve treatments *viz.* Complete 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) [9]. The nutrient treatments (Table 1) 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. Plants were monitored daily to document and photograph the symptoms of individual nutrient deficiencies. Artificial aeration was been provided by using aerators, to supply air for plants growing in Solution (Fig 1). At the end of the experiment leaves were collected and analyzed for content of Nitrogen by employing KELPLUS digestion and distillation system (Subbaiah and Asija 1956) [15], Phosphorous by Vanado-molybdo phosphoric yellow colour method (Jackson 1973) [10], Potassium by Flame photometer (Tandon 1993) [18], Cacium and Magnesium by Versenate titration method (Tandon 1993) [18], Sulphur by Turbidity method (Chesnin and Yien 1950) [3], Boron by hot water extraction method (Berger and Troug 1939) [2], Mn, Zn, Fe, Cu by feeding extract to atomic absorption spectrophotometer (Tandon 1993) [18]. The data were subjected to Completely Randomized Block Design (CRD) as per procedure outlined by Panse and Sukhatme (1985) [12].

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

Stock solution (1M)	Complete	-N	-P	-K	-Ca	-Mg	-S	-Mn	-B	-Fe	-Zn	-Cu
KNO_3	6	_	6	_	6	6	6	6	6	6	6	6
$Ca(NO_3)_2.4H_2O$	4	_	4	4	_	4	4	4	4	4	4	4
$NH_4H_2PO_4$	2	_	_	2	2	2	2	2	2	2	2	2
$MgSO_4.7H_2O$	1	1	1	1	1	_	_	1	1	1	1	1
Fe-EDTA	1	1	1	1	1	1	1	1(-Mn)	1(-B)	1(-Fe)	1(-Zn)	1(-Cu)
Micronutrients	1	1	1	1	1	1	1	_	_	_	_	_
$NaNO_3$	_	_	_	6	8	_	_	_	_	_	_	_
$MgCl_2.6H_2O$	_	_	_	_	_	_	1	_	_	_	_	_
Na_2SO_4	_	_	_	_	_	1	_	_	_	_	_	_
$CaCl_2.2H_2O$	_	4	_	_	_	_	_	_	_	_	_	_
KCl	_	6	_	_	_	_	_	_	_	_	_	_
$NaH_2PO_4.2H_2O$	_	2	_	_	_	_	_	_	_	_	_	_
NH_4Cl	_	_	2	_	_	_	_	_	_	_	_	_

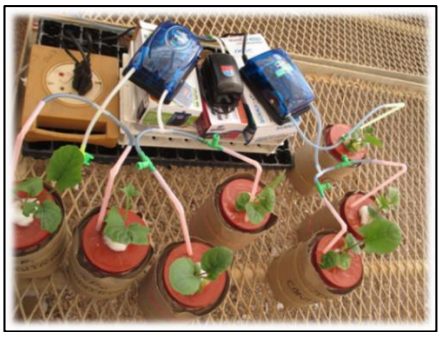

Fig 1: Gerbera plants aerated with Aspirator

Results

Macronutrents

Nitrogen deficiency

The N deficiency symptoms started appearing on Gerbera plants at 21 days after transferring into nutrient solution lacking 'N' element. The first symptom of N deficiency was reduced plant growth with stunted appearance. Leaves were reduced both in number and size, appeared chlorotic. Symptoms first appeared on older leaves as pale green discolouration which later changed to uniform yellow (fig 2b). The pattern of chlorosis extended to younger leaves as the days progressed. Senescence of leaves in the advanced stages was visualised. In the absence of N supply, root development was poor, with reduced root length compared to plants that received complete nutrient solution (fig 2 c). The roots were thin, filamentous with linear elongation. A period of 40 days was taken for the complete manifestation of visual deficiency symptoms of N. Growth almost ceased and plants failed to initiate leaves. Leaf tissue N concentrations for deficient and control plants were 1.1 per cent and 3.12 per cent, respectively.

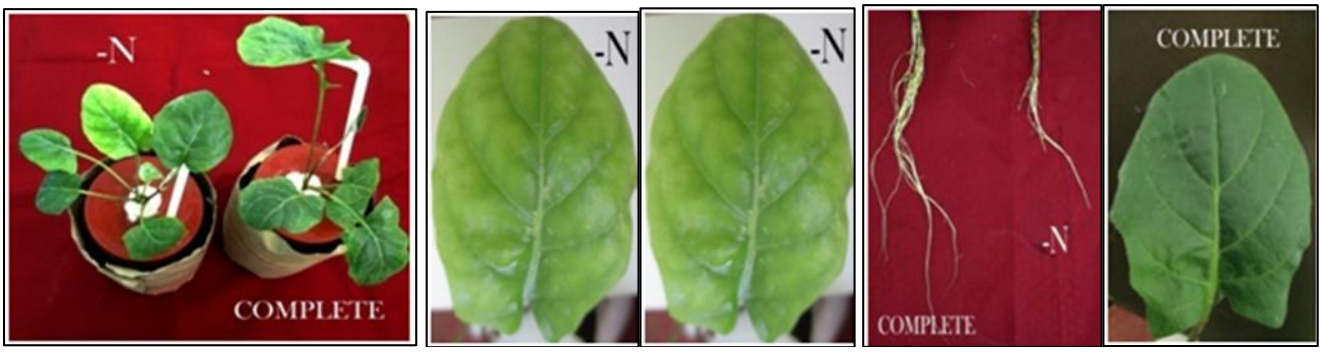

Fig 2a: Effect of N deficiency on shoot **Fig 2b:** Effect of N deficiency on leaves **Fig 2c:** Effect of N deficiency on roots

Fig 2: Gerbera plants showing nitrogen (N) deficiency

Phosphorous deficiency

The P deficiency symptoms started appearing within 30 days after transferring Gerbera plants into nutrient solution lacking 'P' element. Plants were reduced in height. Leaf number was

highly reduced. No specific visual symptoms were occurred on leaves. Older leaves were dark green when compared to plants grown in complete nutrient solution (fig 3a). Roots of P deficient plants were poorly developed with highly elongated and less branched tap root (fig 3b). Laterals were very few and filamentous. Leaf tissue P concentrations for deficient and control plants were 0.11 per cent and 0.6 per cent, respectively.

Fig 3a: Effect of P deficiency on leaves **Fig 3b:** Effect of P deficiency on roots

Fig 3: Gerbera plants showing phosphorous (P) deficiency

Potassium deficiency

The 'K' deficiency symptoms started appearing within 30 days after transferring Gerbera plants into nutrient solution lacking 'K' element. Plants showed reduction in growth. Potassium deficient plants initially developed symptoms as a light tannish-brown necrosis along the margin of the older leaves. The necrosis started from the tip of the leaves, and the center of leaves remained green (fig 4b). Younger leaves showed chlorosis. Root system of K deficient plants, although reduced, was fairly developed with relatively thicker roots (fig 4c). Laterals had developed at the basal region and throughout the length of the tap root. Leaf tissue K concentrations for deficient and control plants were 1.46 per cent and 2.97 per cent, respectively.

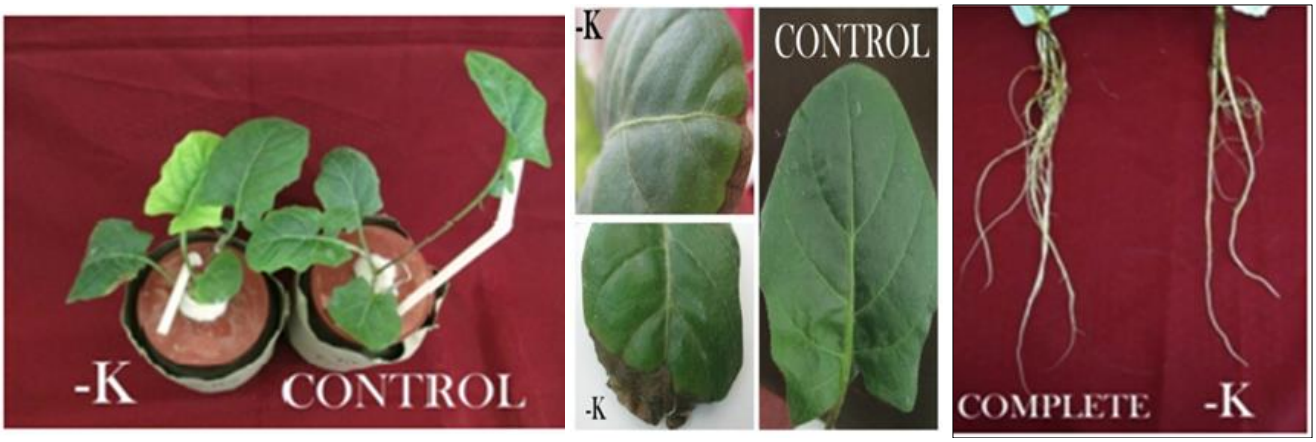

Fig 4a: Effect of K deficiency on shoot **Fig 4b:** Effect of K deficiency on leaves **Fig 4c:** Effect of K deficiency on roots

Fig 4: Gerbera plants showing potassium (K) deficiency

Calcium deficiency

The 'Ca' deficiency symptoms started appearing within 25 days after transferring Gerbera plants into nutrient solution lacking 'Ca' element. The Ca starved plants showed distinctive abnormalities in growth (fig 5a). Plants showed stunted growth and had very little number of leaves. Calcium deficiency first appeared on younger leaves with inward curved margins (fig 5b). Leaves were pale green, leathery and brittle with white spots on lamina (fig 5b). Calcium deficient plants developed poor root system with short, stubby and brownish blunt tips (fig 5c). Leaf tissue Ca concentrations for deficient and control plants were 0.33 per cent and 1.43 per cent, respectively.

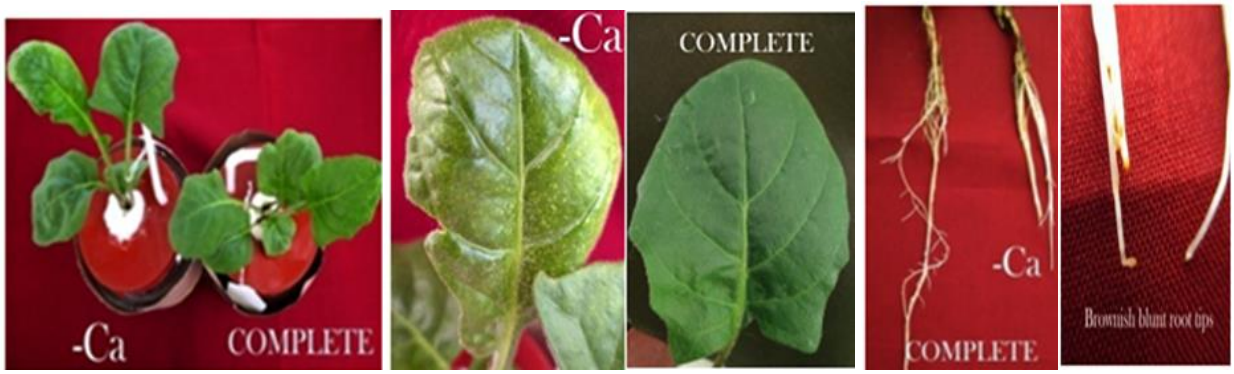

Fig 5a: Effect of Ca deficiency on shoot **Fig 5b:** Effect of Ca deficiency on leaves **Fig 5c:** Effect of Ca deficiency on roots

Fig 5: Gerbera plants showing calcium (Ca) deficiency

Fig 6a: Effect of Mg deficiency on shoot **Fig 6b:** Effect of Mg deficiency on leaves **Fig 6c:** Effect of Mg deficiency on roots

Fig 6: Gerbera plants showing magnesium (Mg) deficiency

Magnesium deficiency

The 'Mg' deficiency symptoms started appearing within 32 days after transferring Gerbera plants into nutrient solution lacking 'Mg' element. The plants were stunted in growth with few numbers of leaves (fig 6a). Leaves of Mg deficient plants showed interveinal chlorosis on older leaves (fig 6b). Initial symptoms were observed as pale green leaves, later as the deficiency progressed, interveinal chlorosis was observed. Roots of Mg deficient plants were not much affected, but the root length is reduced when compared to complete nutrient treatment (fig 6c). Leaf tissue Mg concentrations for deficient and control plants were 0.13 per cent and 0.6 per cent, respectively.

Sulphur deficiency

The 'S' deficiency symptoms started appearing within 40 days after transferring Gerbera plants into nutrient solution lacking 'S' element. Symptoms first appeared on younger leaves due to immobile nature of 'S' (Taiz and Zeigar 2003) [17]. Initial symptoms of deficiency includes pale green leaves which later turned to uniform yellowish green (fig 7b) as the days progressed. There was a reduction in plant growth (fig 7a). Leaves were reduced both in size and number. Root system of S deficient plants were moderately developed with laterals over the entire tap root (fig 7c), but root length was reduced when compared with complete treatment (control). Leaf tissue S concentrations for deficient and control plants were 0.08 per cent and 0.38 per cent, respectively.

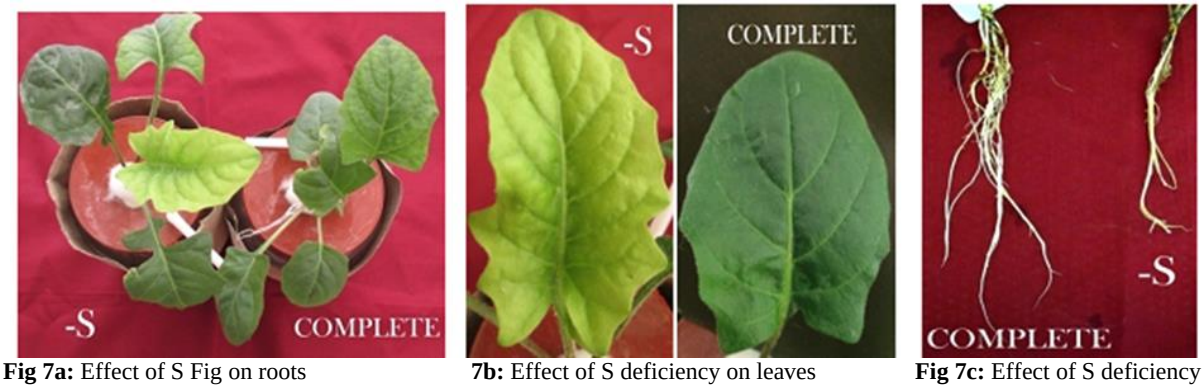

Fig 7a: Effect of S Fig on roots **7b:** Effect of S deficiency on leaves **Fig 7c:** Effect of S deficiency Deficiency on shoot

Fig 7: Gerbera plants showing sulphur (S) deficiency

Micronutrients

Boron deficiency

The 'B' deficiency symptoms started appearing within 21 days after transferring Gerbera plants into nutrient solution lacking 'B' element and the plants observed with stunted growth and reduced leaf number. Symptoms of B deficiency first occurred on growing point and younger leaves, since B is not translocated from older to younger leaves as it is immobile (Taiz and Zeigar, 2003) [17]. There was marginal necrosis on leaf apex of young leaves (fig 8b). The affected leaves were thick and brittle. Root system was poorly developed with reduced root length compared to plants grown in complete nutrient solution (fig 8c). Leaf tissue B concentrations for deficient and control plants were 14.6 and 44.5 ppm, respectively.

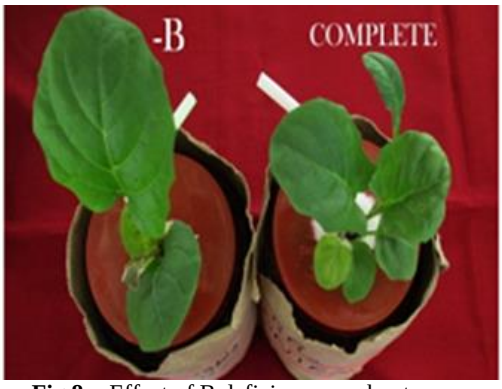

Fig 8a: Effect of B deficiency on shoot

Fig 8b: Effect of B deficiency on leaves

Fig 8c: Effect of B deficiency on roots

Fig 8: Gerbera plants showing boron (B) deficiency

Fig 9a: Effect of Fe deficiency on shoot

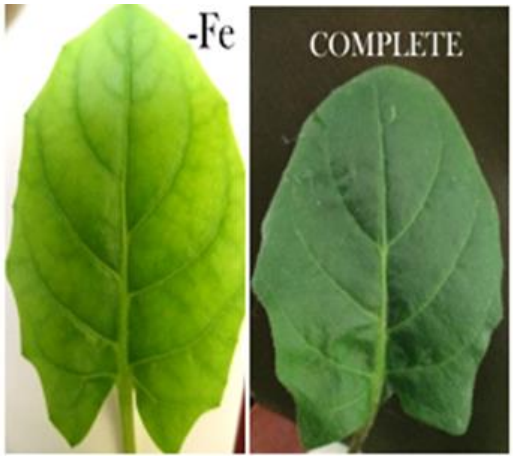

Fig 9b: Effect of Fe deficiency on leaves

Fig 9c: Effect of Fe deficiencyon roots

Fig 9: Gerbera plants showing iron (Fe) deficiency

Fig 10a: Effect of Zn deficiency on

Fig 10b: Effect of Zn deficiency on

Fig 10c: Effect of Zn Deficiency on

Fig 10: Gerbera plants showing zinc (Zn) deficiency

Fig 11a: Effect of Cu deficiency on shoot **Fig 11b:** Effect of Cu deficiency on leaves **Fig 11c:** Effect of Cu deficiency on roots

Fig 11: Gerbera plants showing Copper (Cu) deficiency

Iron deficiency

The 'Fe' deficiency symptoms started appearing within 30 days after transferring Gerbera plants into nutrient solution lacking 'Fe' element. Plant growth was reduced (fig 9a). Iron deficiency symptoms first occurred as interveinal chlorosis on younger leaves. In advanced stage, affected leaves developed uniform chlorosis (fig 9b).The root system in Fe deficient plants was highly reduced with few number of laterals (fig 9c). Leaf tissue Fe concentrations for deficient and control plants were 36.58 and 169.55 ppm, respectively.

Zinc deficiency

The 'Zn' deficiency symptoms started appearing within 35 days after transferring Gerbera plants into nutrient solution lacking 'Zn' element. Foliar deficiency symptoms expressed as interveinal chlorosis of older leaves (fig 10 b). Plant height was moderately reduced (fig 10 a). Lateral root growth of Zn deficient plants was reduced (fig 10 c) when compared with plants receiving complete nutrient solution. Leaf tissue Zn concentrations for deficient and control plants were 12.4 and 57.53 ppm, respectively.

Copper deficiency

The 'Cu' deficiency symptoms started appearing within 20 days after transferring Gerbera plants into nutrient solution lacking 'Cu' element. Deficiency symptoms expressed as distorted young leaves (fig 11 b). Plant growth was reduced when compared with plants receiving complete nutrient solution (fig 11 a). Root system was moderately developed with reduced laterals (fig 11 c). Leaf tissue Cu concentrations for deficient and control plants were 3.21 and 13.3 ppm, respectively.

Manganese deficiency

No visual Mn deficiency was observed during the period of study. Leaf tissue Mn concentrations for deficient and control plants were 28.4 and 72.93 ppm, respectively.

Discussion

Nitrogen, phosphorous, potassium, magnesium and zinc are mobile, first symptom of their deficiency symptoms occurred on older leaves due to translocation of these elements from older to younger leaves (Taiz and Zeigar 2003) [17]. Whereas, Ca, Fe, S and Cu are mobile their deficiency symptoms occurred on younger leaves (Taiz and Zeigar 2003) [17].

Nitrogen is required for chlorophyll synthesis. Hence, in it's absence, the leaves have shown yellow colour (chlorosis). It is important constituent of protoplasm and is needed for increase in size and growth of the plants. Therefore, the plants grown in N deficient conditions observed stunted growth with reduced leaf size and chlorotic leaves (Uchida 2000) [19].

Phosphorous deficiency can reduce both respiration and photosynthesis, but if respiration is reduced more than photosynthesis then carbohydrates will accumulate, leading to dark green leaves (Grant *et al.*, 2001) [9]. Under P stress, roots had undergone several adaptive changes *i.e.*, root elongation due to diversion of photosynthates towards root in search of phosphorous (Fredeen, Rao and Terry 1989) [6].

Potassium is needed in photosynthesis and the synthesis of proteins. Plants lacking K will have slow and stunted growth (Uchida 2000) [19]. The appearance of chlorosis on younger leaves (Fig 4 a) may be due to depressed translocation of iron due to suppression of K, since K has direct synergistic effect on iron (Ujwala 2011) [20].

Calcium is a key element in the structure of primary cell wall (David and Philip, 2006) [5] its deficiency resulted in leathery and brittle leaves. Calcium is very essential in the shoot and root tips for the meristematic activity and formation of new tissues, absence of Ca had caused death of growing tips. Magnesium is an important component of chlorophyll molecule, it's deficiency had resulted in chlorosis (Maathuis 2009) [11]. Sulphur is found in the amino acids *ie.*, Cysteine and Methionine and it is required for formation of sulfolipids (small proportion in chloroplast thylakoids) (Maathuis 2009) [11], the deficiency of S resulted in chlorosis of younger leaves (Uchida 2000) [19].

Functions of boron are fundamental to meristematic tissues, boron deficiency is predominantly resulted in damaging actively growing organs such as shoot and root tips (Hansch and Mendel, 8). Iron is required for chlorophyll biosynthesis (Romheld and Nicolic, 13) and is immobile (Taiz and Zeigar 2003) [17] it's deficiency resulted in interveinal chlorosis of younger leaves. Many enzymes require zinc ions for their activity and Zn may be required for chlorophyll biosynthesis (Storey 2006) [14]. Hence deficiency of Zn resulted in chlorosis on older leaves as it is mobile (Taiz and Zeigar 2003) [17]. Copper deficiency depresses carbondioxide fixation, electron transport, and thylakoid prenyl lipid synthesis relative to plants receiving full nutrition (David and Dean 2006) [4]. Hence, deficiency resulted in distortion of young leaves.

Conclusion

It can be concluded that among the macronutrients, N deficiency was early (21 DAT) to manifest whereas, in micronutrients, Cu deficiency was early to manifest (20 DAT) in Gerbera var. Savannah. Manganese has not much affected plant growth during period of study in Gerbera var. Savannah. In deficiency situation, content of individual mineral element

was reduced when compared to plants grown in complete nutrient solution.

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