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Review article

Gerbera: Soil fertility and plant nutrition

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A B S T R A C T

Gerbera (*Gerbera jamesonii* Bolus ex. Hook) belonging to family Asteraceae is an important cut flower, native to tropical Asia and Africa. Thumping success of Gerbera under protected conditions has extensively discouraged growers to raise this crop under open field conditions, with the result, most of the studies have accrued out under protected conditions. The cut flowers like Gerbera is intensively cultivated, and substantial amounts of nutrients are anticipated to be removed with every harvest, The definitive role of soil-climate specific agro-techniques is being increasingly explored to sustain the flower production coupled with quality as an important flower trade attribute. Improvisation in of flower yield alongwith quality makes this maiden but important task, all the more challenging, especially in the context of vagaries associated with open field conditions. Maintaining water-nutrient synergy through an integrated nutrient supply system across crop phenophases is considered as the most important aspect of Gerbera cultivation, and if addressed to their potential, is supposed to bring some discernible changes in the overall scenario of Gerbera cultivation under open field conditions. In this context, DRIS-based nutrient diagnostics have provided some definitive breakthroughs. Unfortunately, soil as a finite source of nutrients has seldom been attempted to engineer through exogenous application of both organic manures (also carries beneficial microbes, and can function as effective bioinoculants) and inorganic fertilizers in such a way that it sustains the crop nutrient demand so effectively, keeping any potential possibility of nutrient mining at no risk. This is where, the concept like integrated nutrient management finds its utmost intervention. The benefits of such technique can only harvest when all other growing conditions are maintained within optimum requirements.

1. Introduction

Floriculture is increasingly regarded as one of the viable options towards diversification from the traditional field crops due to higher returns per unit area, and fast developing habit of “saying it with flowers”. From a symbol of love, flowers have transformed into an industry, which is characterized by constant change, activities and excellence, unique in its character and function. Although the floriculture industry is growing at a faster rate compared to other horticultural based industries. Still there is vast scope to bridge the gap of demand and supply in domestic as well as world market in the field of floriculture (Kundu *et al*., 1997). Floriculture industry of India (Bijay Kumar *et al*., 2010) amount to 167 thousand ha and 9.88 thousand tons (loose flowers) in terms of area and production, respectively. While cut flowers figure to 47942 lakhs (as number) with West Bengal (44.3%), Karnataka (12.2%), Maharashtra (11.9%), Gujarat (10.6%) etc as major partners in cut flowers production, trade and economics.

Gerbera is the latest sensation to Indian Floriculture, commercially grown throughout the world in a wide range of climatic conditions. According to the global trends in floriculture, gerbera occupies the 4th place among cut flowers (Sujatha *et al.,* 2002). Gerbera at present comprises 45 species, native to tropical Asia and Africa. As many as seven species were recorded in India distributed in temperate Himalayas from Kashmir to Nepal at an altitude of 13,00 to 3,200 meters. Gerbera species of Indian origin are : *Gerbera andria, G.kunzeana, G. languinosa, G. macrophylla, G. nivea, G. ovalifolia* and *G.poiloselloides*. The cultivated species in this genus are *Gerbera asplenifolia, G. aurantica, G. kunzeana* and *G. viridifolia.*

Botanically known as *Gerbera jamesonii* Bolus ex Hook, it belongs to the family Asteraceae, and is commonly called as Transvaal daisy, Barbeton daisy or African daisy. The genus *Gerbera* is named in honour of German naturalist Traugott Gerber, while the species *jamesonii* was named for Dr.L.S.Jameson, a British colonial statesman. Gerbera is a herbaceous perennial, native to South Africa only (Brickell and Zuk, 1997). Tourjee *et al*. (1994) revealed that the early development of *Gerbera jamesonii* as a floricultural crop was traced from its collection as a novelty in South Africa to its establishment as a commercial crop in the 1930’s. Loser (1986) grouped gerbera into single, semi-double and double cultivars based on flower heads. The single types have one or two rows of ray florets on the periphery of the disc and the rest are disc florets while in the double types, more than two rows of ray florets are present in the flowers which enhances its attractiveness. They are further divided into 'Standard', `Spider’ and `Mini’ depending on the shape and size of the flowers.

In order to get maximum production of quality flowers, crop phenology vis-à-vis plant nutrition holds a paramount importance. While doing so plants need to be exposed to optimum climatic conditions and nourished with appropriate nutrients during the entire growing period. However, the prime constraint in the fact that still the Gerbera flowers are available in the market for a limited period, without any genuine effort to extend its availability throughout the year. A study on planting time to extend number of harvesting by understanding the crop phenology is one such very promising option. A difference in planting dates often brings about variation in growth, flowering, yield and quality of gerbera. In a 3- year- trial on Gerbera conducted by Parthasarathy and Nagaraju (2003), it was observed and opined that the flower bud initiation, growth, development and flowering were faster during warmer period (April – May and June – July). While the longevity of flower was more during October – November. Similarly, studies conducted at Dharwad to evaluate the best planting time for Gerbera cv. Sath Bata showed a profound influence of staggered planting on vegetative as well as reproductive attributes, with July planting resulted in maximum flower size (Singh, 2001).

Growing media for Gerbera are claimed to be highly porous with abundance in organic matter content and well drained to provide aeration to the root system. The richness of soil in terms of organic matter helps in alteration of physico- chemical (Aishwath *et al*., 2003) and biological properties l (Peterson and Larton, 1982) to suit uninterrupted growth of Gerbera. The improvement in physiochemical properties also aides in promoting the root growth and hastening the nutrient absorption by crop plants (Chandra and Singh, 2010). Greater scope for integration of chemical fertilizers with organic supplements obtained through biological sources is reported Raniperumal *et al*, 1988; Gupta *et al.,* 1996). The recent crisis and hike in the prices of inorganic fertilizers further warranted towards the use of organic of manures in flower crops (Waheeduzzama *et al.*, 2007). In spite of these results, information is highly lacking with regard to changes within rhizosphere soil takes place as a result of either manuring or inorganic fertilization alone, or even when combined application of both organic manures and inorganic fertilizers are practised. The present studies have precisely take note of this issue since soil health as a safeguard mechanism a`gainst ant potential nutrient mining has proclaimed an apex agenda in any crop yield maximisation programme.

Precise diagnosis of nutrient constraints vis-à-vis plant nutrition in Gerbera is highly under doldrum, primarily on account of no plausible crop specific leaf nutrient standards, with very limited efforts made under soilless culture of Gerbera. This has further compounded the entire process of flower yield maximisation. A sincere effort in this regard, has been made to put forth some leaf nutrient diagnostic values suiting to Gerbera (Keditsu, 2012a). The growth and development of gerbera depend on a number of factors, out of which planting time and the use of nutrients. Although, gerbera cultivation has bound to be a profitable enterprise, experimental data in their planting time and the effect of organic fertilizer along with inorganic fertilizers on the flower crops under Nagaland conditions are extremely lacking. Though some work has been done on these aspects, but results are highly location specific. In light of these breakthroughs, the diagnosis of nutrient constraints and their remediation with reference to Gerbera has been thoroughly reviewed.

2. Soil fertility and plant nutrition

Demographic pressure of a burgeoning population has kept researchers on their toes to find out possible alternatives of raising productivity of horticultural crops including flower crop like Gerbera on per unit land area and time basis. Nutrient management, especially on INM basis is an approach that seeks to both increase quality of production and protect the environment for posterity. It relies on nutrient application and conservation, new technologies to increase nutrient availability to plants, and the dissemination of knowledge between farmers and researchers (Palm *et al.,* 2001). In the past, nutrient management has been driven by the need for maximizing production. But now, nutrient management that is sustainable involves maximizing production, preventing on-site soil degradation, and minimizing off-site involvement of applied nutrients (Tagaliavini and Marangoni, 2002).

Organic amendments such as manure, compost biosolids, and humic substances provide a direct source of C for soil organisms as well as an indirect source via increased plant growth and plant residue return (Bunemann *et al*., 2006). Organic and integrated production systems offer alternatives to conventional production systems (Curl *et al*., 2002; Peck *et al*., 2005) irrespective of soil and crop type. However, integrated production methods have yet to attain the same widespread farmers' acceptance as organic production methods. On the other hand, when the factors relating agro-pedological conditions, indirectly taken as planting time (which exploits all the growing conditions) is standardized, both INM and planting time could well translate into an improved flower yield coupled with ray floret and disc floret quality. In this review, efforts have been made to highlight the results accrued chronologically on the above two important issues relating to Gerbera quality production.

Variation in soil fertility and plant nutrition is the single most important factor that dictates both flower yield and quality in addition to influencing soil health. Baser and Soyergin(1998) studied the fertility of greenhouse soils growing cut flowers was studied using 36 soil samples were taken from rose, carnation, freesia and gerbera greenhouses. The soils were loam-textured, non-saline, slightly and strongly alkaline, of low to medium lime content, and with medium and high levels of organic matter. Phosphorus and K contents were adequate. Bacteria present in the rhizosphere of *Gerbera jamesonii*, *Dianthus caryophyllus* and *D. barbatus* were characterized in a compacted red ferralitic soil at San Jose de las Lajas, Cuba. The rhizobacteria studied (*Pseudomonas [Burkholderia] cepacia, P. fluorescens* and *Azospirillum brasilense*) exhibited chemoattraction to root exudates. Pseudomonas was dominant over *Azospirillum*, *Bacillus* and *Streptomyces*. *P. cepacia* exhibited the maximum chemotactic responses to root exudates of both genera after 14 days and 40 minutes of exposure (Hernandez *et al*., 2000).

Study to estimate the population of *Azotobacter* in the rhizospheres of flower crops (Gladiolus, Chrysanthemum, Aster, tuberose, rose and Gerbera) showed sufficient population of *Azotobacter* was present in the rhizospheres of all the flower crops grown in medium black soil (pH 7.6) of Western Maharashtra Plain Zone, India. However, the highest population (18,589) of *Azotobacter* per gram of soil was observed in the rhizosphere of Gladiolus, whereas, the least (12 820) number was seen in the rhizosphere of rose. It is suggested that *Azotobacter* prefer slightly alkaline soil for their multiplication and growth (Debnath and Wange, 2003). Studies by Soroa *et al.* (2003) showed that treatment with *G. fasciculatum* (arbuscular mycorrhizal fungi were applied at 35 spores/g of soil and the rhizobacteria at 108 cfu/g of soil.) was the most effective, with significant increases in flower diameter (27.9%), yield and flower initiation (50 days earlier) compared with the untreated control. The greatest number of flowers was produced by the untreated control, but this was not significantly different from the numbers produced with *G. fasciculatum* plus *A. brasilense* and *B. cepacia* alone.

To improve the nutrient acquisition property, efforts were made to develop an efficient growing medium specifically adapted for the mineral content of the species. The adaptation was based on the elemental analysis of the adult plant. The growth of Gerbera in adapted media was compared with the growth on Murashige and Skoog's (normally used) and Driver and Kuniyuki Walnut media. The propagation of Gerbera was best in the adapted medium; plantlets were larger and easier to separate, resulting in a higher multiplication rate. The comparison of the mineral content of plants showed that the higher uptake of Ca, P and Fe could be responsible for the improved growth. There was no exhaustion of any mineral in the media used, so differences in relative concentrations should be responsible for better growth in adapted media (Bouman and Tiekstra, 2001). The effect of various nutrients (including N, P, K, Ca, Mg, Mo and biofertilizers) on the performance of Gerbera jamesonii was found conspicuously different (Soroa, 2005).

A study was conducted to investigate if Gerbera plants show significant differences in growth and flower production when grown in two different soilless growing systems, with (closed system) and without nutrient solution recycling (open system). Growth indices showed no significant differences between the two systems. Nutrient concentration inside the substrate was lower in the closed system, possibly due to recycling of nutrient solution. Analysing mineral contents in dry matter, luxury consumption of nitrogen, phosphorus and potassium was found in the open growing system, but it did not have an effect on production and quality of flowers. Total flower production was 12.5 per plant, while diameter and stem length were 10-12 and 40 cm, respectively, in both systems. Moreover, the amount of nutrient lost per year was calculated measuring the nutrient concentrations in the drainage solution. Results showed that about 93, 6.8, 165, and 107 kg/ha/year of N, P, K, and Ca, respectively, were released into the environment (Ferrante *et al.,* 2000). The other results indicated that the K/Ca, Mg/Ca and $P/(SO_4^{2-} + NO_3^{-})$ ratios in the reference nutrient solution should be higher than the values suggested for the supply solution (Savvas,2001).

3. Leaf nutrient norms

Precision based fertilization is the call of the day for any nutrient management programme irrespective of the crop. A leaf nutrient norm facilitates a plant diagnostician to identify precisely the hidden nutrient hunger in the plant at different growth stages, without expressing the nutrient deficiency symptoms. In Gerbera Tjia and Joiner (1989) first described deficiency symptoms along with leaf nutrient concentration. Kacperska (1985) suggested optimum leaf nutrient concentration as: 2.38-2.80% N, 0.37-0.425 P and 3.43-4.63% K using Peter variety of Gerbera grown on acid soils of Poland.

The leaf samples collected from the youngest fully open leaf (first leaf) to the oldest healthy leaf (10th leaf) before the start of flowering of carnation were analysed for different nutrient concentration Nitrogen concentration in leaves varied from 3.11 (10th leaf) to 4.47% (1st leaf) and was 3.92% in the 3rd and the 4th leaves. Phosphorus concentration ranged from 0.13(10th leaf) to 0.24% (1st leaf) with a concentration of 0.19% in the 3rd and the 4th leaves. Potassium concentration varied from 2.92 (10th leaf) to 4.72% (1st leaf) with a concentration of 3.89% in the 4th leaf. Calcium ranged from 0.93 (1st leaf) to 2.43% (10th leaf). Magnesium ranged from 0.39(1st leaf) to 0.82 (9th leaf), while Sulphur varied from 0.26(10th leaf) to 0.34% (4th leaf). Iron ranged from 89 (1st leaf) to 199 ppm (10th leaf), Manganese from 230 (1st leaf) to 399 ppm (7th leaf), Zinc from 36 (2nd – 4th leaf) to 54 ppm (10th leaf) and Copper from 10(10th leaf) to 26 ppm (1st leaf) (Bhargava and Singh, 2002).

Anjaneyulu (2008) applied DRIS on Gerbera, and suggested. The optimum leaf N ranges from 2.54 to .287%, P from 0.13 to 0.16%, K from 3.37 to 4.37%, Ca from .145 to 1.99% Mg from 0.56 to 0.74% and S from 0.17 to 0.22%.

Jeong *et al.,* (2009) suggested deficient level of N as 1.60%, P as 0.07% and K as 0.40% while optimum concentration was advocated as : 5.7% N, 0.55% P and 4.0% K in Gerbera. Recent studies by Keditsu (2012b) suggested leaf nutrients norms as: 2.22 % to 2.56% N, 0.18% to 0.25% P and 1.80% to 2.20% K in relation to fruit yield of 2.50 to 3.75 flowers/m^2 using DRIS (Diagnosis and Recommendation Integrated System)-based analysis for open field Gerbera on Alfisol. These leaf nutrient standards can be used for efficient fertilizer programming and to correct the nutrients in question for obtaining good flower yield and quality of flowers under protected conditions

4. Organic manures as growing medium

Flower crop like Gerbera, being basically a cut flower crop recognizes very responsively under both soilless and open field growing conditions. Gerbera cv Dutch Lion grown on rockwool slabs, peat in plastic bags or peat, a 5:7:8 compost:rice husk:peat mixture or a 1:1 compost:peat mixture in jute sacks was highest on the 1:1 compost:peat mixture in jute sacks from August to October (6-8 months) (Pinamonti *et al*., 1996). Pinamonti *et al.* (1997) compared the rockwool, white peat, and 8:7:5 mix of white peat, rice chaff and compost (v/v) and a 1:1 mix of white peat and compost in soilless cultivation of Gerbera daisy (*Gerbera jamesonii*). Compost amended growing media offered a clear advantage in terms of improved plant nutrition, better vegetative growth and increased in both quantitative and qualitative characteristics of production. The physical and physico-chemical properties of compost combined with white peat offered higher production potential than with pure rockwool or peat. Furthermore, the use of compost did not lead to dangerous increases in the content of heavy metals (Zn, Cu, Ni, Pb, Ca and Cr).

Marfa *et al.* (1998) used linear parametric programming (LPP) was used to establish the most suitable substrates mixtures as growing media for cut Gerberas and carnations, according to crop requirements (aeration, available water and salinity). Experimental values of easily available water and bulk density were quite closed to predicted values of the mixtures. The results showed that LPP can be used as an efficient tool to formulate mixtures in which cattle manure compost takes part. Researches by Anuje *et al*. (2004) evaluating different media for Gerbera cultivation under polyhouse conditions demonstrated that the medium consisting of red soil + farmyard manure in a 1:1 ratio recorded the maximum values for plant height and flower stalk length. In their research, the medium consisting of cocopeat and farmyard manure in a 1:1 ratio observed the maximum values for leaf number, flowers/plant, flower diameter and vase life as well as the time to earliest flowering. The thickest flower stalk was observed in the medium containing cocopeat + garden soil + farmyard manure in 1:1:1 ratio. Similar work in a glasshouse showed that the best media was a mix of saw dust: ash bran: organic manure (v/v) in 7:7:6 ratios (Wang *et al*., 2005).

Certain microorganisms present in compost and compost extracts such as *Trichoderma*, *Rhizobacteria*, and fluorescent *Pseudomonas* are known to stimulate plant growth (Sylvia, 2005). These microbes benefit plants through different mechanisms of action including the production of secondary metabolites such as antibiotics and hormone-like substances, the production of siderophores, antagonistic to soil-borne root pathogens, phosphate solubilization, and nitrogen fixation (Dubeikovsky *et al.,*1993). Manures applied to soil improve its quality by altering the chemical and physical properties, increase organic manure content, water holding capacity, overall diversity of microbes, provide macro- and micronutrients essential for plant growth and suppress diseases with indirectly contribute to plant growth enhancement (Scheurell and Mahaffe, 2004; Heather *et al.,* 2006). Such composts having microbes of twin utility hold more promise in INM package for cut flower like Gerberas.

The trials in Argentina, micropropagated gerbera plantlets (cultivars Pacific and Donga) were grown hydroponically in the greenhouse in an organic substrate (a mixture of manures, pine needles and soil) in black plastic pots in an inert substrate (perlite) in black plastic bags. The number of flowers produced per plant and per m^2 was higher in perlite than in the organic substrates and was higher in Pacific than in Donga. Plants of cv Pacific growing in perlite produced 140 flowers/m^2 between November and February. While plants grown in perlite had longer stems and larger and more uniform flowers than plants grown in organic substrates (Mascarini, 1998). Boztok (1995) observed that stem length and number of stems/m^2 were greater for Jaguar than Barones in 1:1 mixture of peat and sand. In both cultivars, these two parameters were greatest in the pumice stone medium and least in the peat/sand mixture. Capitulum diameter of the cut flowers was greater in Barones than in Jaguar. Overall quality was best on the pumice stone medium. The yield and quality of the gerbera cultivars viz., Fame, Party, Regina and Ximena were evaluated in a heated plastic greenhouse using perlite, zeolite, sand or rockwool as substrates. Plants grown on the perlite medium had the highest total yield for all varieties, with a peak of 75-80 flowers. The lowest yield performance was found in zeolite, while rockwool and sand were intermediate. In all cases, the cultivar Party showed the highest yield, with small differences compared to the other varieties. Quality was a function of substrate, variety and production year. For most cultivars, perlite produced better quality flowers during the first period (7-8 months) of production, but no quality differences were observed among the all substrates during the second period of production (Maloupa and Gerasopoulas, 1999).

Singh and Singh (2003) carried out an experiment to partially substitute the chemical fertilizers by organic manures and bio – fertilizers in Rose cv. Gruss – an – Teplitz, and recorded maximum plant height in plants treated with FYM + dose of NPK by chemical fertilizers + *Azotobacter*. In a study on the cut flower yield and quality of *G. jamesonii* by Thane *et al*. (2007) under greenhouse conditions, 100% of the recommended fertilizer rates (RFR; 150:50:150 kg NPK/m^2), 40 or 70% RFR + 0.5 g *Azotobacter*/m^2, 40 or 70% RFR + 0.5 g PSB [phosphate solubilizing bacteria]/m^2, 40 or 70% RFR + *Azotobacter* + 0.5 g PSB/m^2, and *Azotobacter* + PSB. The application of 70% RFR + *Azotobacter* + PSB resulted in the greatest flower stalk length (52.96 cm), flower stalk diameter (0.70 cm), flower diameter (9.20 cm), number of flowers/plant (7.22) and /m^2 (70.03), and vase life (8.95 days). Of late, due to environmental concerns and diminishing supplies of peat soils for horticultural substrates, cocopeat is being considered as a renewable substitute for use as a promising substitute in growing medium in horticulture (Aswath and Padmanabha, 2004).

The results of an experiment on the effect of crop establishment and substrates on the performance of *Gerbera jamesonii* showed that high-ridge culture enhanced survival, number of tillers, leaf growth increment and cut flower quality compared with seedbed culture. The evaluated substrates also improved leaf vigour and cut flower quality, with the combination slag + dregs of mushroom + organic fertilizer at 3:1:1 ratio, being the most effective. The air permeability of the substrate was one of the major factors that affected plant growth (Song *et al*., 2004). The results by Sindhu *et al.* (2010) revealed that the medium amended with soil + FYM + vermicompost + samridhi + sawdust took maximum number of days (9.81days) for the appearance of first new leaf. Leaf length (35.45 cm) and leaf width (17.24 cm) were found to be significantly higher in medium amended with samridhi. Maximum plant height (29.89 cm), number of leaves/plant (31.10 leaves), number of flowers/plant (10.03 flowers), flower head diameter (10.82 cm), flower stalk length (59.20 cm), and vase life (13.17 days) were found highest in medium amended with samridhi. Response of different INM modules using organic manures and inorganic fertilizers has produced significant increase in the performance of open field Gerbera (Table 1).

Table 1
Response of different INM-module of substrate on performance of open field Gerbera (Pooled data).

Treatments	**Vegetative growth**			**Floral characteristics**			**Flower yield**	
	Number of leaves/plant	**Leaf area (cm^2)**	**Plant height (cm)**	**Full bloom from planting time (No. of days)**	**Flower size (cm)**	**Stalk length (cm)**	**Fresh weight of flower (g)**	**Flower yield (kg/m^2)**
T_0	10.85	44.74	21.88	135.16	7.51	25.59	9.07	1.95
T_1	12.61	60.66	26.07	133.89	7.95	29.80	10.77	2.16
T_2	17.07	80.46	29.07	136.60	8.07	26.79	11.02	2.63
T_3	12.54	85.03	26.59	133.70	8.10	26.99	11.05	2.49
T_4	13.21	99.73	29.13	129.38	9.06	26.29	12.95	3.19
T_5	15.79	86.28	29.55	130.51	7.85	26.27	9.20	1.84
T_6	11.78	97.48	25.12	131.30	7.72	25.67	9.03	1.76
T_7	16.61	90.34	26.30	131.92	7.85	25.56	9.55	2.08
CD (p=0.05)	4.63	6.12	3.12	1.98	0.62	NS	0.98	0.13

T_0 – 100% RDF (60 kg N : 40 kg P_2O_5 : 60 kg K_2O/ha), T_1 – 50% RDF + 50% Coco pith (N-equivalent basis), T_2 – 50% RDF + 50% Pig manure (N-equivalent basis), T_3 – 50% RDF + 50% FYM (N-equivalent basis), T_4 – 50% RDF + 25% Pig manure + 25% FYM, T_5 – 50% RDF + 25% Cocopith + 25% Pig manure, T_6 – 50% RDF + 25% FYM + 25% Cocopith, T_7 – 50% cocopith + 25% Pig manure + 25% FYM.
Source: Keditsu (2012b).

Different treatments produced significant response on leaf nutrient composition. Interestingly, 100% RDF as T_0 on N-equivalent basis has not been so effective with regard to maintaining higher concentration of nutrients in index leaves (2.0% N, 0.16% P and 1.7% K). Incidently, when 50% cocopith is incorporated into 50% RDF as treatment T_2(1.5% N, 0.13% P and 1.3% K), showing no superiority over T_1. But when T_1, T_2 and T_3 are compared, carrying cocopith, Pig manure and FYM as 50% RDF replacement to T_0, T_2 turned out to be the most effective treatment (2.2% N, 0.19% P and 1.9% K) over T_3 (2.0% N, 0.17% and 1.8% K). In subsequent treatments carrying both combination two organic manures, Pig manure + FYM, along with 50% RDF, e.g. T_4 registered all the three nutrients in highest concentration (2.6% N, 0.26% P and 2.5% K), significantly superior to rest of the treatments (Table 2). Execution of different treatment induced favourable changes in available pool of nutrients like $KMNO_4$-N, Bray-P and NH_4OAc-K (Table 2). Out of different treatments, T_4 induced maximum favourable changes on available supply of nutrients in soil (158.3 mg/kg $KMnO_4$-N, 6.6 mg/kg Bray-P and 115.1 mg/kg NH_4OAc-K) indicating that these organic manures when linked with inorganic fertilizers turned out to be more effective than either of the two when applied alone. Even exclusive use of inorganic fertilizers (147.2 mg/kg $KMnO_4$-N, 5.7 mg/kg Bray-P and 105.5 mg/kg NH_4OAc-K) have not proved superior over organic manures T7 (147.9 mg/kg $KMnO_4$-N, 5.2 mg/kg Bray-P and with 104.3 mg/kg NH_4OAc-K).

Table 2

Response of INM treatments on leaf nutrient composition (fully expanded leaves) and available soil macronutrients of Gerbera.

Treatments	Leaf nutrient composition (%)			Available nutrients (mg/kg)		
	N	P	K	N	P	K
T_0	2.0	0.16	1.7	147.2	5.7	105.5
T_1	1.5	0.13	1.3	150.1	4.7	104.3
T_2	2.2	0.19	1.9	156.6	6.3	111.5
T_3	2.0	0.17	1.8	149.8	5.5	107.3
T_4	2.6	0.26	2.5	158.3	6.6	115.1
T_5	2.3	0.19	2.1	150.1	5.4	105.9
T_6	2.3	0.19	2.1	145.7	4.9	116.8
T_7	2.1	0.18	1.9	147.9	5.2	104.3
CD (p = 0.05)	0.17	0.014	0.24	2.0	0.21	1.1

T_0 – 100% RDF (60 kg N : 40 kg P_2O_5 : 60 kg K_2O/ha), T_1 – 50% RDF + 50% Coco pith (N-equivalent basis), T_2 – 50% RDF + 50% Pig manure (N-equivalent basis), T_3 – 50% RDF + 50% FYM (N-equivalent basis), T_4 – 50% RDF + 25% Pig manure + 25% FYM, T_5 – 50% RDF + 25% Cocopith + 25% Pig manure, T_6 – 50% RDF + 25% FYM + 25% Cocopith, T_7 – 50% cocopith + 25% Pig manure + 25% FYM.
Source: Keditsu (2012b).

5. Response of vermicompost

Vermicomposting is the bio-oxidation and stabilization of organic matter involving the joint action of earthworms (Oligochaete annelids) and microorganisms (Aira *et al*., 2007), thereby, turning wastes into a valuable soil amendment called vermicompost. The compost is rich in macro- and micronutrients, N fixers, and humus-forming microorganisms (Bano *et al*., 1987), besides acting as a bioconcentrator of heavy metals and toxic substances (Edwards and Thompson, 1973). Vermicomposting could be developed and applied as a useful tool for profitable utilization of organic wastes for: i. organic pollution retardant by rapid reduction of bulk and elimination of offensive odor, ii. production of vermi-fertilizer for application in both annual as well as perennial crops for providing efficient nutrition, and iii. production of earthworm tissue systems for large-scale proliferation. Native earthworm species which are surface feeders, easy to breed, and responsive to improved cultural techniques, are ideal for vermicomposting (Bugg, 1994; Wang *et al*., 2007).

Chemical, microbial, and growth regulator analysis of earthworm casts by Grappelli *et al*. (1985) showed that these casts have nearly neutral soil pH (6.5) with 51.60% water content, 16.78% total C,1.37% inorganic C, 1.63%

total N, 0.40% NO_3-N , 0.92% total PO_4-P, 0.14% available PO_4-P, 1.61% K_2O, 8.60% total Ca, 0.14% available Ca, 2.51% total Mg, 0.45% available Mg, 910.10 mg/kg Fe, 218.40 mg/kg Mn, 7.20 mg/kg Cu, 0.35 mg/kg B, 68.30 mg/kg Zn, 1.8×10^8 cells/g bacteria, 2.8×10^6 cells/g actinomycetes, 2.0×10^5 cells/g fungi, 2.75 µ m/g GA_3, 1.50 mm/g cytokininns (Indole pyruvic acid), and 3.80 µ m/g IAA on a dry weight basis. Studies later suggested an enrichment technique of vermicompost with *Azotobacter chroococcum*, *Azospirillum lipoferum*, and *Pseudomonas striata* for improved solutilization of rock phosphate (Kumar and Singh, 2001; Sailaja Kumari and Usha Kumari, 2002). Biochemical properties of vermicompost showed that activity of cellulolytic enzymes was higher in casts than in soil, while activities of urease, protease, and phosphatase were lower in worm casts than undigested soil (Zhang *et al*., 2000). These observations suggested that earthworms use microorganisms as a secondary food resource (Zachariah and Chhonkar, 2004; Zhang *et al*., 2004).

Bugg (1994) reported about the involvement of earthworms in the process of nitrification. Influence of two species of earthworm viz., EF and EE was studied by Talashilkar *et al*. (1999) on the changes in chemical parameters governing the compost maturity of local grass, mango leaves, and farm wastes. A decrease in the C: N ratio and an increase in humic acid, cation exchange capacity, and water soluble carbohydrate were observed up to 150 days of composting. In another study, Rao *et al*. (1997) observed considerable increase in available K extracted from the wormcasts over non-ingested soil, due to partial conversion of non-exchangeable K with exchangeable form, as a result of shift in soil K equilibrium.

The benefits of earthworms on soil physical conditions are well documented (Atiyeh *et al*., 2001; Mota *et al.,* 2007; Munnoli and Bhosle, 2008). These benefits include: mixing of organic manure from the surface into lower soil horizons, improvement of aggregate stability through castings, and hydraulic properties of the soil through the creation of permanent burrows (Lee and Pankhurst, 1992; Chan and Heenan, 1992; Friend and Chan, 1995; Trojan and Linden, 1998). Munnoli and Bhosle (2008) observed that microbes in 1 g of pressmud derived vermicompost with 100 x 10^9 cfu/g held 200 g of soil in position. The actual beneficial effect varies with different species of earthworms (Lee, 1985). The exact reason is not clear, but this could be due to the higher organic carbon levels and better drainage found in the burrowed clays (Chan *et al*., 1988). The higher organic C levels provide a larger food reserve, making it possible to support a larger number of earthworms and better drainage of water within the soil profile. Cast production can be as high as 50 Mg/ha/year (Lal and De Vleeschauwer, 1982). In both temperate and tropical regions, the wormcasts have more favourable soil conditions for plant growth (Lal and Akinremli, 1983) while, there have been evidences of favourable effect of earthworm activity on the availability of N and P in the soil, relatively less is known about its effect on the behaviour of K. Zaller (2006) suggested vermicompost extract very effective as foliar spray in field grown tomato.

6. Response of pig manure

Vermicompost-based pig manure has been promoted as a viable alternative container media component for the horticulture industry. The incorporation of vermicompost of pig manure origin into germination media upto 20% v/v enhanced root and shoot weight, leaf area, and root:shoot ratios of both, tomato and French marigold seedlings; however, amendment with vermicompost had little influence on pepper and cornflower seedlings growth. Moreover, there was no affect on the germination of seeds of any species. When the seedlings of tomato, French marigold and cornflower were transplanted into 6 cell packs there was greater plant growth in the media amended with vermicompost compared to the controlled media, and the greatest growth when vermicompost was amended into both the germination and transplant media. This effect was increased when seedlings in the transplant media were irrigated with water containing fertilizer (Bachman and Metzger, 2008). Among the five growing media evaluated, growth and flower quality of Gerbera were better in soil with vermicompost followed by soil with FYM. Dalma was the prolific bearer with 70.24 flowers/plant/year followed by Savannah and Rosalin. Growing media had no significant effect on yield of flowers per plant probably due to uniform fertigation given to all media (Thangal *et al.*, 2009).

Giardini *et al*. (1992) reported that Poultry manure treatment significantly decreased bulk density and increased total microporosity, infiltration capacity, and available water capacity. Overall efficiency of organic manures with respect to native plant nutrient availability in an acid Alfisol showed the following trend: Poultry manure > Pig manure > Farmyard manure. Other soil properties such as pH, humic, and fulvic carbon contents showed differential patterns with nutrient availability at different intervals. Suwaree *et al.* (2009) observed that the treatments of Pig manure or cow manure with chemical fertilizer showed the best performance with maximum values in leaf and flower number. The medium treated with pig manure extract also performed well. These results revealed a potential for growing pot gerbera using organic fertilizers alone like Pig manure.

7. Response of Cocopeat

Cocopeat is an organic amendment, and a multi-purpose growing medium, that provides new opportunities for potting mixture suppliers, seedling, nurseries, hydroponic growers and a dynamic source for substrate development for a variety of horticultural crops. Gerbera grower's worldover have been using coco peat very successfully as growing medium, especially in form of cocopeat disks. Cocopeat has the same role to play with respect to changes in physical and chemical properties of rowing medium as it does with any other organic manure. The pH of cocopeat is 5.8-6.4 an ideal pH for any crop to grow including Gerbera. According to Pivot (1988), physical properties were improved with different rates of peat or absorbent rockwool mixed with the 2 raw materials. All mixtures were fertilized before cultivation of Gerbera, following usual recommendations. Cultivation in the 2 raw materials gave poor results compared with mixtures of those containing 40% (by volume) peat or 20% rockwool, or with the control (80% peat + 20% perlite).

Gerbera growers prefer cocopeat as growing medium on account of i. amendment behaviour, ii. high level of water absorbing capacity, iii. material free of weeds and pathogens, iv. acts as soil conditioner, v. seasonal product but available round the year, and iv. Slow decomposing with good stability (Abad *et al.*, 2002). Paradiso and Pascale (2008) observed that addition of coco fibre to the perlite raised the rate of net assimilation (13.7 versus 12.1 m^2/s) of Gerbera plants compared to perlite alone, and higher differences were observed during the warmer months. This was accompanied by higher leaf area coupled with number of stems (54 versus 49 stems/plant) and higher concentration of leaf nutrients. Aswath and Padmanabha (2004) reported that a medium containing 100% cocopeat supplied with nutrient solution having EC of 1.8 dS/m produced good quality Gerbera flowers in addition to higher concentration of N, P, K and Cu in index leaves analysed after 9 months of transplantation. Gupta *et al.,* (2004) in another study found the best response of cocopeat + saw dust + sand (1:1:1 v/v) with respect to number of days required for bud initiation (75.0), flowers diameter (9.75 cm), flowers stalk length (35.31 cm), number of flowers/plant (29.55), number of flowers/m^2 (210.0) and vase life (13.35 days) with a net profit of Rs. 18,794/100 m^2.

Khalaj and Amiri (2012) observed that the medium containing perlite + peat + expanded clay (25% + 70% + 5%) had significant difference with other media in number of flowers, flower disk diameter, shoot diameter, shoot neck diameter, flower height and vase life. In this media, number of flowers, flower disk diameter, shoot diameter, shoot neck diameter, flower height and vase life were 207 per m^2/year, 12.4 cm, 0.8 cm, 0.58 cm, 54.5 cm, and 11.6 days, respectively. With respect to the quantitative and qualitative traits of gerbera flower, among the studied substrates in this experiment, mixture of perlite + peat + expanded clay (25% + 70% + 5%) was the best medium suitable for Gerbera.

Gerbera could be forced in various kinds of soils, however growing medium should be well aerated, with good water holding capacity, good drainage and good physical structure. In heavy soils without enough drainage, the development of root system is suppressed and plants are more susceptible to soil borne diseases (Beattie and White, 1992). Due to high lily requirements for growing medium, growers very often use boxes instead of planting bulbs directly into the soil on greenhouse beds. Sphagnum peat with different additives, such as soil, sand or bark is usually used in different proportions. Since the last few years cocopeat, also known as coir dust or coconut mesocarp, has been considered as a renewable sphagnum peat substitute for the use in horticulture (Pickering, 1997; Yau and Murphy, 2000). Cocopeat has good physical properties, high total pore space, high water content, low shrinkage, low bulk density and slow biodegradation (Evans *et al*., 1996; Prasad, 1997). The results of many experiments revealed that cocopeat used alone, or as a component of soil medium, is suitable for roses (Blom, 1999), gerbera (Labeke and Dambre, 1998), many potted plants (Kreij and Leeuven, 2001; Meerow, 1995; Noguera *et al*., 1997; Pickering, 1997; Treder and Nowak, 2002) and also for Gerberas. Due to usually high initial level of potassium and sodium in cocopeat, the fertilization program should be adjusted carefully to plant requirements.

The number of flowers produced per month was highest in the peat + perlite medium and lowest on pumice. Irrigation frequency had little effect on any of the parameters measured. Photosynthetic rate was higher in plants grown on soil than in those grown on the other media. Evapotranspiration was highest in plants grown on peat + perlite (Maloupa *et al*., 1996).Studies with 3 Gerbera cultivars showed that cut flower yields and quality are higher on mineral wool than on peat (Chmeil and Wrega, 1996). In another study, Lenzi *et al*. (1998) assessed the effects of substrate (large 3-5 mm perlite particles, fine 0.5-2 mm perlite particles, or 2:1 ratios of large:fine perlite or large perlite:peat) and drainage (25% and 40% of total water added) on growth and performance of *Gerbera jamesonii*. Different drainage levels were achieved by varying the frequency of fertigation. Total flower production was similar in all substrates (averaging 435 flowers/m^2 over 2 years) and there was no significant difference between drainage treatments. Gerbera cv. Bora Bora was grown in pots of perlite or a 3:1 mixture of peat:perlite (v/v). Plants grown in the mixture had a 20% greater leaf mineral content and 80% higher cut flower yield than those grown in perlite alone (Rea *et al*., 1999). Studies (Georget, 2000) were later carried out to compare the growth of *Hydrangea macrophylla*, *Ceanothus repens* and *Cupressocyparis leylandii* in pots filled with 3 substrates. Substrate 1 was composed of 40% peat + 60% pine bark, substrate 2 of 40% peat + 50% bark + 10% coir, and substrate 3 of 40% peat + 40% bark + 20% coir. Gerbera growth was best in substrate 1 (*C. repens*), substrate 2 (*C. leylandii*), and substrate 3 (*H. macrophylla*).

The effects of CO_2 concentration (350 and 1200 micro mol/mol), growing media (peat+perlite, 3:1; peat+coco dust, 1:1; and coco dust alone) and concentration of nutrient solution (EC 2.1 and 2.8 mS/cm) on the growth of gerbera (*Gerbera jamesonii*) cv. Queen Rebecca microcuttings, leaf nutrient content and the chemical properties of the growing media were investigated. Plants grown in peat + coco dust had the highest dry weights of leaves and roots. CO_2 enrichment increased all growth variables, except leaf number. Leaf nutrient content of gerbera cuttings and chemical properties of growing media after eight weeks of growth, with reference to all treatments, are discussed and presented as tables (Nowak and Gabryszewska, 2001).

Gerbera cv. Mammut was grown on coir pith media (coir pith + garden soil + farmyard manure (FYM), sawdust media (sawdust + garden soil + FYM), commercial mixture (sand + red soil + FYM), sand media (sand + FYM) and red soil media (red soil + FYM), and sprayed with gibberellic acid (GA) at 100, 150 and 200 ppm, and water (control). GA at 200 ppm produced the highest number of flowers per plant (7 flowers/plant). The treatment combination consisting of GA at 200 ppm and coir pith media resulted in high yield and good quality flowers. Flowers produced from plants in the coir pith treatment had the longest vase life (Sekar and Sujata, 2001). Barreto and Jagtap (2002) assessed the substrate media namely; coco-peat, peat, soilrite, perlite, vermicompost, compost and garden soil in various proportions were assessed under pot culture of gerbera cv. Sangria under naturally ventilated polyhouse. Vegetative growth was best in coco-peat alone. The flower quality with respect to head and disc diameter, number of ray florets and stalk length was superior in the pots having the combination of peat and vermicompost (1:1, v/v). The highest flower yield with remarkable vase life was produced by coco-peat combined with either compost or vermicompost (1:1, v/v).

The effects of growing media (sphagnum peat, 90% white peat + 10% perlite, brown peat, 60% brown peat + 40% calcined clay, and coir dust) on the yield and quality of gerbera (*Gerbera jamesonii*) showed intensive growth in white peat + perlite and coconut peat during the first three months of cultivation. The flowering date was not significantly affected by the growing media. The highest flower yields (per plant) were obtained with coconut peat (41.9), brown peat + calcined clay (36.1) and white peat + perlite (34.9). The lowest flower yield was obtained with sphagnum peat, on which flowering was pronounced during the early period of cultivation but declined substantially after 6 months (Abou and Strojny, 2003).

Gerbera was grown through 24 months in five growing media: sphagnum peat; white peat 90% + perlite 10% (v.v.); brown peat; brown peat 60% + calcined clay 40% (v.v.), and coir dust. Cut flower production of gerbera was the highest in media: white peat 90% + perlite 10% (v.v.), brown peat 60% + calcined clay 40% (v.v.), and coir dust. These media were also favourable for flower quality. The lowest cut flower production was observed in white peat alone. However, flowering intensity was good at the beginning but in this medium decreased markedly after 6 months of cultivation, compared to the other media, when its physical properties changed significantly due to fast decomposition (Nowak and Strojny, 2003). The effects of growing media (sphagnum peat + perlite, brown peat and coco fibre) on the flower yield, stem length, inflorescence diameter and fresh weight of cut flowers of gerbera were determined. The total porosity, bulk density, shrinkage water capacity and air capacity of the growing substrates had significant effects on the number and weight of fresh flowers, with total porosity and bulk density having the most significant effects. A high correlation among the physical properties of the growing media was recorded (Nowak and Strojny, 2004).

Two organic culture media, i.e. perlite:peat:organic manure (v/v) at 9:7:4 and sawdust:ash bran:organic manure (v/v) at 7:7:6, was compared with a conventional soil culture method of cut flower of *Gerbera. jamesonii* in a greenhouse. The biomass, flower number and quality, and the concentrations of N, P, and K in leaves grown in various culture media were significantly different. The best result obtained from the recycling medium mixed with sawdust, ash bran and organic manure, and the second favourite medium was the new mixture of perlite, peat and organic manure. The resistance to cold of the plants was closely related to the concentrations of N and P in the leaves. The concentrations of N and P in the leaves were negatively related to the ratios of the plants injured by the coldness. The effect of P in improving resistance to cold was greater than that of N (Wang *et al.,* 2005). A study was conducted on *Gerbera jamesonii* grown on mixtures of cinder, mushroom residue, peat and saw dust with organic fertilizer to determine which among these mixtures of culture media is best suited for organic ecotype soilless culture of the species. Results showed that the growth of *Gerbera. jamesonii* was most significant on the mixture of 3 parts cinder, one part mushroom residue, and 5 (kg) muck and a kg of compound fertilizer per m^3 medium, followed by mixture of 2 parts peat, 4 parts saw dust, 2 parts cinder, 5 parts mushroom residue and 5 parts muck and 1 part compound fertilizer per m^3 medium (Fu *et al.,* 2001).

Caballero *et al.* (2007) suggested that some peat-substitute substrates can provide Fe-chlorosis in sensitive plants, which has traditionally been ascribed to the elevated pH of the growing media. Sarkka *et al*. (2008) observed that the total yield of Gerbera under greenhouse conditions was highest (approx. 430 flowers/m^2/year) in DPG30 (dark peat granules 30% + coarse sphagnum peat 70%), perlite and PG40 (Peat granules 40% coarse sphagnum peat 60%) and lowest in AApeat (extra coarse sphagnum peat) and PG10+E (peat granules 10% + Eriophorum peat 90%). The yield in AApeat decreased after the first year of cultivation and remained at that low level until the end of the experiment. In contrast, the yield in PG40 started to increase after one year. The prolonged cultivation time reduced the yield quality in all growing media. Physical parameters changed only little during the experiment. Irrigation, soil moisture, pH, EC and $NO_{3-}N$ were recorded regularly. Peat based substrate stabilizers held their structure throughout the 2.5 years of cultivation (Särkkä, *et al.*, 2008). In another study, two horticultural by-products viz., coconut coir and spent mushroom compost were tested by Ahmad *et al*. (2012) for their suitability as growing media for cut flower production. No major difference in flower yield was observed between conventional media and both the horticultural by-products. However, the flower quality was improved when both of the substrate was used in combination with conventional media. Moreover incorporation of coconut coir and mushroom compost lowered pH and increased available organic matter in addition to improved plant nutrition.

8. Inorganic fertilizer requirement

Soil fertility problems associated with human-induced nutrient depletion are widespread worldwide (Tan *et al*. 2005). The use of man-made inorganic fertilizers is a fundamental component of INM, yet it is often either under-used or over-used in the absence of information on soil test-based fertilization assessment. There is a multiplicity of methods and techniques currently available for determining nutrient requirement, emphasizing the importance attributed to an awareness of fertilizer requirements. The fertilizer requirement of annual or perennial crops depends upon the objectives of fertilization, whether the purpose is to grow the crop or feed the crop. Fertilizer experiments have not generally provided calibrated soil or leaf test data because of their short-term nature, the biennial or variable production of many tree crops, their narrow focus and the difficulty in demonstrating yield responses because tree crops have relatively low rates of nutrient removal over long periods of time. Nutrient balance is basically a sound approach in the development of fertilizer recommendation, and can be easily estimated from crop nutrient removal data.

Gerbera plants (cv. Joyce) supplied with a nutrient solution with a low K:Ca ratio (0.8-0.9:3.0-4.0 mmol/litre) showed symptoms of K deficiency (shortened stems and leaf damage), whereas plants supplied with a high ratio solution (7.0:0.8 mmol/litre) showed no symptoms of K deficiency. At both ratios, plants supplied with 0.6 mmol Mg/litre were of better quality than those supplied with 1.7 mmol Mg/litre (Kreij, 1989). Volpi and Farina (1987) recommended optimum fertilizer requirement as : 60 kg N, 48 kg P_2O_5 and 96 kg K_2O/1000 m^2 annually. Dufault *et al*. (1990) observed that the number of marketable flowers of Gerbera seedlings (cv Florist Strain Yellow) increased as both N and K rates increased up to 110 kg/ha, but as the N rate was increased to 220 kg/ha cull flower production increased. In the 2nd year, marketable and cull yields increased as N rate increased but increasing K rate had no effect on yields. Marketable and cull yields also increased as plant density increased from 24 000 to 72 000 plants/ha in both years. Flower size and quality were unaffected by planting density. N and K rates had no effect on flower size, quality or vase life in either year.

Aswath *et al.* (1997) found that very few characters were significantly influenced by different N application rates. Varieties x N interactions were noticed for two characters. Split application of 100 kg N/ha in the first year was found to be the best for over all performance. Experiments on Gerbera cv. Maria cut flowers showed both vase life and flower diameter were influenced by the soil N and K content. Cut flowers lasted longest from a crop grown on soil containing 33 mg N and 40 mg K/100 g soil (Alexe and Amariutei, 1998). In another study Hunmili and Paswan (2003) observed that NPK at 30:10:20 g/m^2 had the highest plant height (45.69 cm), leaf area per plant (3435.67 cm), days to first flower bud (84.60), number of flowers per plant (67.01), flower size (12.15 cm), stalk length (42.79 cm), vase life (26.35), and suckers per plant (30.40). The number of days to full bloom was highest (7.80) with no NPK fertilizers. Gurav *et al.* (2002) observed that treatment with the highest level of N (20 g/m^2) resulted in maximum plant height (41.52 cm), stem length (50.35 cm), flower stem diameter (0.67 cm) and flower diameter (8.85 cm). Likewise, the highest levels of P (20 g/m^2) and K (20 g/m^2) also resulted in maximum plant height (40.93 and 40.02 cm), flowers per plant (30.62 and 29.00), stem length (48.63 and 45.53 cm), flower stem diameter (0.69 and 0.67 cm) and flower diameter (8.97 and 8.70 cm, respectively). Another studies by Sujatha *et al.* (2002) observed that fertigation with 80% straight fertilizers (urea, super phosphate and muriat of potash) or 80% water soluble fertilizers (with an NPK grade of 16:8:24) was the most suitable for growth. Flower stalk length was highest with 80% water soluble fertilizers (51.74 cm). Fertigation with 80% water soluble fertilizers recorded the highest flower diameter (10.20 cm). Ibiza recorded maximum flower diameter (10.29 cm). Fertigation with 80% straight fertilizers recorded the maximum length of ray florets (4.30 cm). Maximum length of ray floret was recorded in Ibiza (4.49 cm). The cumulative flower yield was highest with 80% water soluble fertilizers (89.4). The highest yields were obtained with 80% water soluble fertilizers in Ibiza (116.00) and minimum with 60% water soluble fertilizers in Rendezvous (44.00). Interaction effects due to fertigation and cultivars had a significant effect on cumulative yield.

A study was conducted by Mohariya *et al.* (2004) to investigate the effects of phosphorus (0, 7.5, 10 and 12.5 q/m^2) and potash (0, 10, 12.5 and 15 g/m^2) on the qualitative parameters and vase life of gerbera (*Gerbera jamesonii*) grown under polyhouse conditions. The highest values for flower stalk length, flower diameter, number of grade I flowers per plant and vase life were obtained with 12.5 g P_2O_5/m^2 and 15 g K_2O/m^2. Nayak *et al.* (2005) observed that a mixture of NPK at 4, 2 and 2 g/pot, respectively, was the best in respect of number of plantlets per pot (3.70), days to flower bud formation (137.20 days), number of flowers per plant (15.60) and diameter of flower (8.92 cm). With the increase of the amount of K, the number of flowers per plant and diameter of flower decreased. The diameter of the flower stem was maximum (0.55 cm) under 2:2:2 g NPK/pot. The flower stem length was the highest (36.60 cm) with NPK at 6, 1 and 2 g/pot, respectively. The parameter such as plant height, number of leaves per plant, flower yield, flower stalk length, flower diameter, flower stalk thickness and vase life of Gerbera increased, whereas the number of days before bud appearance and flowering decreased with increasing rates of phosphorus (Dalal *et al*., 2005). The results of other studies by Deshpande *et al.* (2005) indicated that plant height, number of leaves per plant and number of flowers per plant were increased with increasing P and potash rates. The days required for flower bud appearance and flowering were minimum in higher P and potash rates. All the observations were found to be superior in the plants treated with 12.5 g P_2O_5/m^2 and 15 g K_2O/m^2.

Higher concentrations of nitrogen increased the production of Gerbera flowers but the mean quality index and vase life did not show significant differences. The uniformness of the production was improved by a higher availability of nitrogen. Lower level of nitrogen tended to reduce the vase life (Mascarini *et al*., 2005). In another study, flower yield, flower stalk, thickness and number of grade I and II flowers were highest with the application of 10 g N and 15 p/m^2. The number of grade III flowers was highest (1.91) with the application of 5 g N/m^2. Application of 5 g N and 15 g P/m^2 resulted in the longest vase life of flowers (11.83 days) (Pimple *et al*., 2006). A higher number of marketable flowers were harvested following 6 or 12 irrigations with 0.5 or 1-strength nutrient solutions compared with 2-strength solutions. More flowers were harvested in May than in March and April (Hwang *et al.,* 1997).

9. Perspectives

Gerbera cultivation gradually is experiencing paradigm changes, especially with respect to greater intervention of production driven technologies. This has induced a distinct change in per capita consumption of flowers. Thumping success of Gerbera under protected conditions has extensively discouraged growers to raise this crop under open field conditions, with the result, most of the studies have accrued out under protected conditions. The cut flowers like Gerbera is intensively cultivated and substantial amounts of nutrients are anticipated to be removed with every harvest. The definitive role of soil-climate specific agro-techniques is being increasingly explored to sustain the flower production coupled with quality as an important flower trade attribute. Improvisation in of flower yield alongwith quality makes this maiden but important task, all the more challenging, especially in the context of vagaries associated with open field conditions. Exploiting the prevailing growing conditions (e.g. planting time) and maintaining water-nutrient synergy through an integrated nutrient supply system across crop phenophases are considered as the two most important aspects of Gerbera cultivation, and if addressed to their potential, are supposed to bring some discernible changes in the overall scenario of Gerbera cultivation in northeast India, especially in Nagaland. Unfortunately, soil as a finite source of nutrients has seldom been attempted to engineer through exogenous application of both organic manures (also carries beneficial microbes, and can function as effective bioinoculants) and inorganic fertilizers in such a way that it sustains the crop nutrient demand so effectively, keeping any potential possibility of nutrient mining at no risk. This is where, the concept like integrated nutrient management finds its utmost intervention. The benefits of such technique can only harvest when all other growing conditions are maintained within optimum requirements.

The role of plant nutrition in improved crop performance is well established. But, its impact is to be carried forward to evaluate the possibility of extending the vase life further through elevated activity of antioxidant profile of crop. In this context, expanding the use efficiency of applied nutrients could play a vital role. Application of automated fertigation including the bubbler/pulse fertigation could find greater perspective in years to come both under greenhouse as well as open field conditions. Nutrient diagnostics, preferably cultivar-based will further pave the way towards precision oriented fertilization programme so that sustained improvement in productivity of Gerbera alongwith both flower quality and vase life turn more of a reality. Such collective efforts will surely lead towards developing export oriented production technology of Gerbera as a major cut flower domestically as well as globally.

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