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REVIEW ARTICLE

Foliar fertilization: A key strategy for enhancing growth and bio productivity in flower crops

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Abstract

The foliar application of nutrients in flower crops is gaining popularity as an efficient agronomic practice that involves spraying nutrient solutions directly onto plant leaves for quick absorption of nutrients. This technique is especially for flower crops, where the quality and aesthetics of blooms are critical. This review explores the role of foliar fertilization in plant growth and nutrition, highlighting its advantages over soil-based fertilization methods. This paper also examines the mechanism of nutrient uptake through leaf parts. Various macro and micronutrient applications in flower crops exhibiting positive results on growth parameters, yield parameters and essential oil production are also discussed in detailed manner. Research indicates that floral excellence, colour intensity and shelf life are improved through foliar application. Moreover, this foliar fertilization can be used to deliver growth regulators and plant protectants, enhancing crop performance and resilience against pest and diseases. Despite its benefits, the successful adoption of foliar fertilization requires attention to technical aspects such as nutrient formulation, concentration, timing and environmental conditions to optimize nutrient uptake and improve physiological responses. Emerging trends such as use of nanofertilizer, offer promising results in enhancing nutrient delivery, improving flower quality and yield. This review synthesizes recent research findings to provide a comprehensive guide on effective foliar practices that can boost flower production, productivity and sustainability.

Keywords

efficient; flower yield; macronutrient; micronutrients; nanofertilizer; nutrient uptake

Introduction

Plants require totally 17 essential elements for their normal functioning and growth. Under normal circumstances, plants acquire three primary nutrients such as carbon, hydrogen and oxygen from air. When soil conditions are optimal in terms of air and water content, these three nutrients pose no issues in function. The remaining thirteen elements includes nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, copper, boron, manganese, zinc, iron, molybdenum and chlorine can also be absorbed through leaves when

applied as a foliar spray on the foliage of plant at the right concentration (1). Foliar fertilization has become a common method for addressing nutrient deficiencies in plants. This technique offers potential benefits when compared to traditional soil-based fertilizer application. One key advantage is that it may enhance the overall efficiency of fertilizer usage (2). Application of nutrients through leaves passes the cuticle and stomatal pores of leaves and hence this process enables for efficient and quick uptake of nutrients (3). Foliar nutrient can also be absorbed in three ways such as through the waxy outer layer and cuticle of the leaf, by passing through the cell wall and via penetration of plasma membrane (3). Environmental conditions such as light intensity, temperature, air, moisture levels, spray solution characteristics like nutrient concentration, finally plant species and variety, leaf surface properties, age and current nutritional status of the plant are some of the plant related factors that affect how well the mineral nutrients are absorbed (4).

Foliar sprays are mainly meant for three main purposes such as sustaining optimal levels of specific nutrients in plants, providing a nutrient boost to crops at crucial stages of their growth cycle, addressing and correcting nutrient deficiencies (5). It has also been found that providing supplementary fertilizers through foliar means during crop growth enhances the nutrient status and increase the yield of crop (6). The practice of foliar is a relatively recent and debated approach in plant nutrition. Foliar nutrient spray can be considered as environmentally friendly approach to fertilization, because it involves directly delivering the limited amount of nutrients to the plants that helps to minimize the environmental impact typically associated with soil fertilization. Because of various advantages such as rapid and effective response to plant needs, reduced product requirements and independent of soil conditions, the focus on foliar fertilizers increasing steadily (3). A detailed review on foliar fertilization in flower crops with their effect on the growth, yield and quality of commercial cut, loose flowers and ornamental flower crops are discussed in this review.

Mechanism of foliar nutrient uptake

Cuticular membrane on the surface of the leaves allow both organic and inorganic ions to pass through as undissociated molecules (7). After passing through the cuticle, the nutrients are taken up by the cells inside the leaf which happens via the cell membranes. Some nutrients may enter through active transport (requiring energy) or passive transport (without energy), depending on the type of nutrient. The type of charge, absorbability and ionic radius are the factors that are responsible for the permeability of ions. As in roots, under normal circumstances ion uptake results in build-up against a concentration gradient. The energy needed for active absorption is obtained from respiratory metabolism or as in case of green leaves from photosynthesis which demonstrates that quality and intensity of light enhances the pace at which ions are absorbed by leaves (7). The three steps in which the leaves absorb ions are as follows.

- Substances applied to the leaf surface enter through cuticle and cellulose wall via limited or free diffusion.
- Subsequently, these substances move into the free space and adhere to the surface of plasma membrane through some binding.
- Finally, the absorbed substances are transported into the cytoplasm, a process that depends on metabolic derived energy.

Once absorbed, the nutrients are transported within the leaf cells and tissues via the phloem and xylem systems. After being transported, the nutrients are utilized in various metabolic processes like photosynthesis, enzyme activation and cell growth, contributing to overall plant health and growth. Sometimes, inorganic ions may pass through the layers between cuticular wax, cuticle, cell wall and plasma membrane (8). Uptake of nutrients through foliar means will be very much easier during the opening of stomata (9). Each of the stomatal pore is surrounded by two guard cells that control its opening and closing of stomata. It serve as the primary routes for the loss of water through evaporation, the exchange of gases during photosynthesis and the regulation of water transport across the epidermis (10). Treating broad bean leaves with abscisic acid to induce stomatal closure reduced the absorption of foliar applied solutions. This experiment confirmed that stomatal penetration is involved in the uptake of solutes from the surface of leaves (11). However certain researchers argue that compared to cuticle penetration, stomatal uptake of foliar applied nutrients is of minor or negligible significance (12, 13). The Cuticle serves as the primary pathway for solute penetration into leaves upon contact, extending partially across the stomatal cavity to form ledges. These cuticle ledges also hinder the capacity of stomata to absorb solutes (14). The electrochemical and concentration gradient from outside the cell along with coefficient of permeability of the molecule across the plasma membrane, are the main factors that influence the uptake of solutes into the cell core after they have penetrated the cuticle. Active uptake by the cell also plays a crucial role. Both apoplastic and symplastic pathways can be used by solutes taken by leaf cells to reach vascular tissues for subsequent transport. From palisade and mesophyll cells, these nutrients are passively transported to vascular tissues. Foliar applied nutrients follow the pathway of photosynthetic assimilates through the phloem for translocation (12) as depicted in Fig.1 not only do various plant species differ in how quickly their aerial portions absorbed the nutrients that are provided by minerals but many varieties within a single species also differ in this regard (15).

Specific characteristics of nutrients used for foliar feeding (16).

1. Solubility - the foliar fertilizers should be freely soluble in water without forming any suspensions and contain the active ingredients in the form of soluble salts, chelates or complexes of mineral nutrition.
2. Molecular weight - the fertilizers that applied through

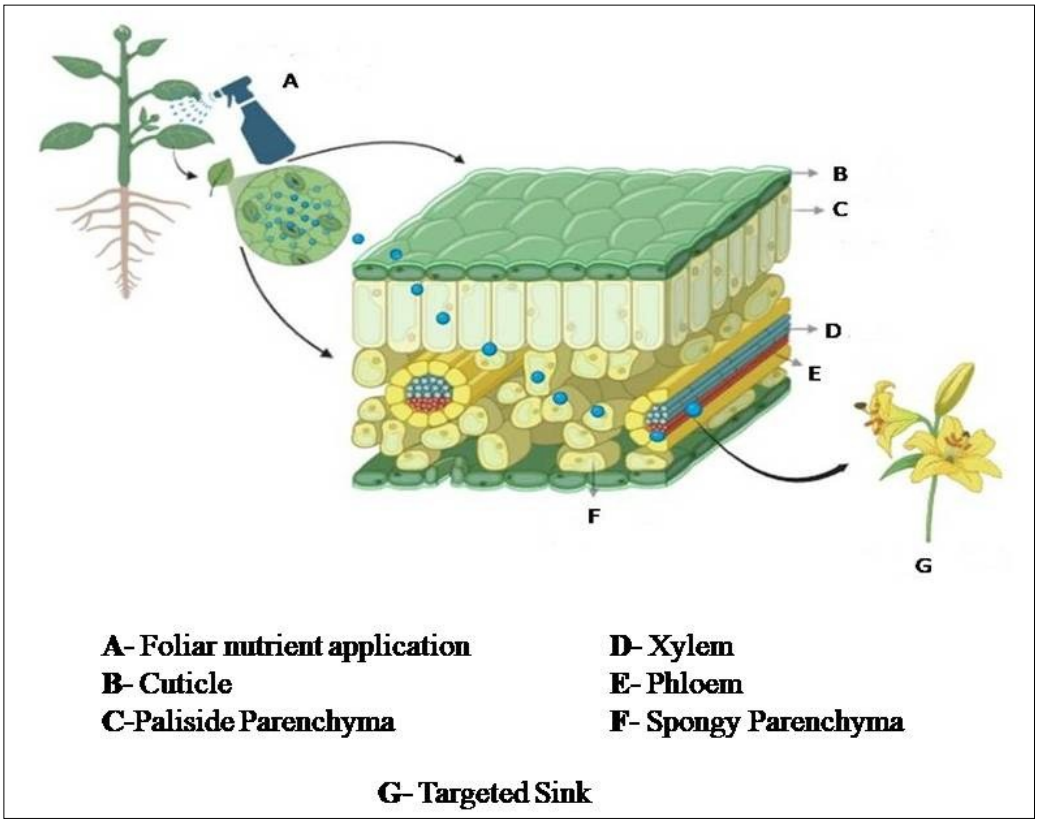

Fig. 1. Diagrammatic representation of nutrients uptake by leaves.

foliar means should possess low molecular weight. Since lower the molecular weight, higher the penetration of the mineral molecules into leaf cuticle.

3. Solution pH- the pH of the solution should be adjusted for active mineral transportation and to prevent scorching of plants.
4. Forms - the ammonium ions are highly absorbable than nitrate ions. Urea has high penetration capacity in leaf cuticle than other inorganic nitrogen fertilizers. KCl is unfit for foliar feeding because of its rapid crystallization on leaf surface.
5. Salt index- inorganic foliar fertilizers should possess low salt index. High salt index causes damage to plant tissues especially in nitrate and chloride forms.
6. Purity - the substance that used for foliar feeding should be in pure form in order to eliminate interference while spraying, solution compatibility and to avoid foliar damage.

Effect of foliar macronutrients application on growth, quality and yield parameter of traditional flowers

In Rose, Potassium (K) and Zinc (Zn) were applied either alone or in combination as K_2SO_4 and $ZnSO_4$ at concentration of 0.5 % or 1 %. The application was done manually four times per growing season initially at the start of stem elongation and leaf formation in damask rose, followed by application every two weeks thereafter. The findings indicated significant enhancements in growth parameters, yield of flowers, relative content of water (RWC) and conductance of stomata due to K and Zn treatments. Contents and composition of essential oils including compounds like nonadecane, citronellol, geraniol, nerol and linalool were also positively influenced. Moreover, protein content, chlorophyll content, total soluble sugars (TSS) rose,

Table 1. Time taken for 50 % absorption of applied nutrients into plant tissues (16)

Nutrient	Time taken for 50% of absorption
Nitrogen (in urea)	0.5-2 hours
Phosphorous	5-10 days
Potassium	10-24 hours
Calcium	1-2 days
Magnesium	2-5 days
Sulphur	8 days
Zinc	1-2 days
Manganese	1-2 days
Iron	10-20 days
Molybdenum	10-20 days

but the content of amino acids that are free fell, suggesting that K and Zn applications altered the distribution and metabolism of nitrogenous compounds within the plants. The findings indicate that incorporating foliar applications of K and Zn into fertilization regimen for damask rose could enhance both flower quantity and quality as well as improve essential oil yields (17). Foliar treatment with Calcium nitrate at 10 g/L markedly increases blossoms production to 993.56/ bush. Increasing the concentration of Calcium nitrate ($Ca(NO_3)_2$)systematically to 7.5, 10, 12.5 g/L resulted in increase in oil content up to 0.44 % in first season and 0.041 % in the second season (18). Applying micronutrients in *Rosa hybrid* cv. Cardinal and Whisky Macvia as foliar spray along side NPK led to notable improvements in various growth characteristics such as height of the plants, more flowers per plant, buds and diameter of blooms, together with both the fresh and dry weight of flowers, improved the flower quality compared to plants treated solely with NPK and control (19).

Application of 100 % recommended dose of fertilizer of nitrogen 100 kg, phosphorous 75 kg and potassium 75 kg + 25 % recommended dose of farm yard manure (50 quintals /ha) through foliar application leads to improved population of bacteria, fungi, actinomycetes and organic carbon in marigold cv. Pusa Narangi Gainda (20).

Effect of foliar micronutrients application in growth and yield parameters in traditional flowers

In Rosa hybrid, foliar application with zinc accounts maximum height of plant, more leaves/branch, largest leaf area, more flowers/plant, lengthiest flower stalk and highest foliage. However, combined foliar spray of zinc along with boron showed maximum bud diameter, flower diameter, fresh weight and dry weight of flowers (21).The combined application of different levels of $ZnSO_4$ 0.5 % and $CuSO_4$ 0.25 % showed significantly superior results for growth, flowering and yield parameters in tuberose (22). Foliar spray of micronutrients (Fe, Zn, B) either alone or in combinations, at different growth stages (60, 90, 120 days after planting) resulted in significant improvement in various growth parameters of tuberose plants under calcareous soil (23). Foliar application of 3 % fish amino acid along with 0.6 % $ZnSO_4$ showed highest flower yield per plant in African Marigold (24). Foliar application of Marigold with Zn_4SA_3 (Zinc 1 %+Salicylic acid 1 mM/L Salicylic acid) (25) and 0.5 % $ZnSO_4$+0.5 % $FeSO_4$+0.5 % $MgSO_4$ and 1 % Potassium humate) on 25 days and 50 days after transplanting shows maximized bio productivity in African marigold (26). The combined foliar spray of $FeSO_4$ and $ZnSO_4$ at 0.5 % enhances in Chrysanthemum cv. Mayur 5 resulted in enhanced yield and productivity (27). Table.2 explains the effect of combined foliar application of nutrients in traditional flower crops.

Foliar nanofertilizer application in traditional flowers

Marigold: Marigold plants that received combined application of Silicon nanoparticles (SiNP) 200 mg/L through foliar spray and 600 mg/L of SiNP through soil application showed higher quantity of flowers, larger floral diameter, increased fresh and dry masses of flowers, extended flowering periods and shorter duration to first bud initiation (33). Additionally, combining mineral NPK at 100 mg/L and nano NPK at 50 mg/L showed significant interactions during both growing seasons, further enhancing growth quality (34). The mechanism lies behind is the ability of nano fertilisers or nano-encapsulated nutrients to release chemical fertilisers and nutrients as needed to control plant development and improve targeted output (35).

Tuberose: Application of silicon nanoparticles in Tuberose (SiNPs) either through root or foliar application under greenhouse condition significant improvements in morphological parameters such as leaf fresh weight, flowering stem length, flowering stem dry weight and number of florets along with soluble carbohydrates and proteins. Moreover, the vase life of flowers in treated plants was prolonged upto 32 % when SiNPs applied at the rate of 200 mg/L via roots and SiNPs applied at the rate of 400 mg/L via application to directly on to the leaves (36).

Jasmine: Application of potassium sulphate per pot and foliar spray with 1.5 g/L of lithovit resulted in superior growth parameters like maximum plant height, no. of. branches and leaves/plant as well as fresh and dry weights and superior in flowering parameters such as flower diameter and more numbers of petals, more quantity of flowers per plant in Arabian jasmine var. double petals (37).

Effect of foliar macronutrients application in growth and yield parameters of cut flowers

The foliar spray treatment with 4 g/L Potassium oxide (K_2O) significantly improved various parameters compared to control in Gladiolus cv. American Beauty (38). Application of nutrients and Gibberillic acid 20 mg/L through foliar means exhibited more number of nodes per plant and greater number of buds in Lilium hybrids (39).

Don Pedro Rapido variety in carnation exhibited superior performance in harvesting span of flowers, increased fresh and dry weight of single cut flowers, high number of petals per flower, shortened days for initiation of flower bud and first flower opening when grown with a nutrient level of 6000 ppm N, 4000 ppm P_2O_5 and 2000 ppm K_2O (40). Utilization of major elements and minor elements of 0.6 % in combination leads to exhibit improving the criteria of blooming in Carnation cv. Red Sim (41). Foliar spray of 1.5 % NPK +1 % Zn resulted in maximum height of plant (91.66 cm), leaf chlorophyll contents (85.53 spade), leaves number per plant (65.33 leaves/plant) and increased length of stalk (87.63 cm), diameter of the florets (4.93 mm) and minimum days to flowering in Stock (42).

Effect of foliar micronutrients application in growth and yield parameters of cut flowers

Application of $FeSO_4$ by foliar means at the concentration 0.4 %, 0.5 %, 0.6 % showed maximum plant height at first, second and third year respectively in gladiolus (43). Foliar application of 0.6 % $ZnSO_4$ in Gladiolus in naturally ventilated polyhouse conditions under Prayagraj agro climatic conditions demonstrated superior performance including vase life (9.66 days) among all treatments (44). Foliar application of micronutrients including B, Zn and Fe all at 2 % level in Gladiolus in calcareous soil exhibited increase in height of the plant, amount of chlorophyll in leaf, length of the flower stalk, initial weight of flower, length of spike, quantity of florets per spike, vase life of flower, flower diameter and fresh weight of corms (45). Foliar application

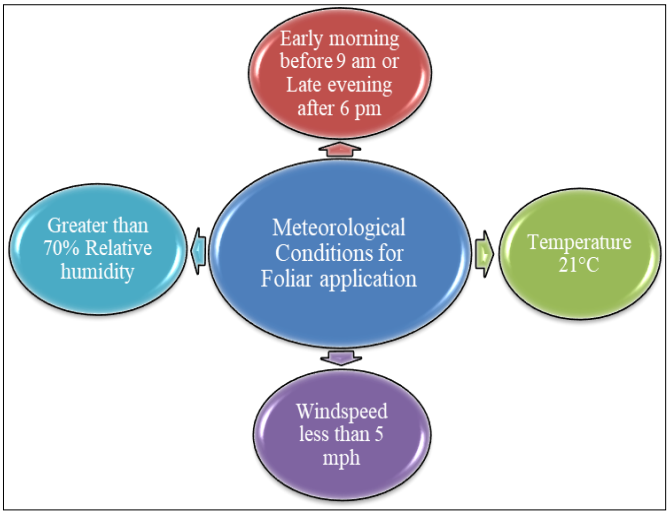

Fig. 2. Environmental conditions for foliar application of nutrients (16).

Table 2. Effect of combined foliar application of nutrients in traditional flower crops

Crop	Species /culitvar	Foliar formulation	Result	Reference
Marigold	Pusa Narangi Gainda	0.5 % Zinc sulphate combined with NPK	increase in height of plant more flowers per plant maximum weight of fresh flowers	(20)
		Zn_4SA_3 (Zinc 1 %+Salicylic acid 1 ppm)	highest content of chlorophyll and carotene more number of flowers/plant (62.33).	(25)
		$ZnSO_4$+0.5 % $FeSO_4$+0.5 %$MgSO_4$ and 1 % Potassium humate	maximized spread of plant Increased weight of single flower and dry matter production Increased floral yield per plant high xanthophyll concentration per flower	(26)
Rose	*Rosa hybrida*	Zinc sulphate and Magnesium sulphate at 1 % was combined with NPK	increase in the content of citronellol+ nerol Increase in Z-rose oxide and E-geraniol	(21)
	cv. Top Secret	0.4 % $ZnSO_4$ and 0.4 % $FeSO_4$	improvement in various flower quality parameters and Flower production metrices	(28)
Chrysanthemum	*Chrysanthemum morifolium*	0.8 % $FeSO_4$ combined with NPK	Increase in height of plant More sucker production Increased production of flowers with enhanced fresh weight	(29)
	cv. Mayur 5	combined foliar spray of $FeSO_4$ and $ZnSO_4$ at 0.5 %	Increase floral yield per sq.m Enhanced vase life of flowers	(27)
Jasminum sambac	cv. Mysuru Mallige	Humic acid at 0.5 %, Chelated Zinc and Borax at 0.75 g each per plant + 100 % RDF of NPK	Increased flower yield per hectare Enhanced shelf life	(30)
Tuberose	Arka Prajwal	0.4 % $ZnSO_4$ + 0.4 % $FeSO_4$	Induce earliness for floral maturity up to 50 % Improved quality standards such as diameter of the spike length of the spike vase life also extended.	(31)
		0.5 % $ZnSO_4$ +0.4 % $FeSO_4$ + Boron	Increase plant height its longevity in vase	(32)

of $FeSO_4$ 0.5 %+$ZnSO_4$ 0.25 % in Gladiolus cv. Novalux leads to increase in height of the plant (64.80 cm), count of branches/plant (9.26), flowering duration (15.10 days), number of days taken for commencement of spike (98.53), number of spike/ha (1.35 lakhs), length of spike (103.40 cm) number of days taken for opening of first floret (111.60) (46).

Integrating and applying MS macro + MS micro and MS vitamins resulted in improved floral bud parameters in Lilium hybrids cv. Tresor (47).Foliar spray of $FeSO_4$ in China Aster cv. Princess expressed maximum plant height, spread of plants across and along the row, fresh weight of floral head, green weight and dry weight of vegetation cover (48). Table 3 explains the effect of micronutrients as foliar application that improves the bio-productivity in cut flowers.

Foliar nanofertilizer application in cut flowers

Lisianthus: The foliar application of a copper based zinc Nano fertilizer at a concentration of 2 ml/L significantly enhanced various growth parameters of Lisianthus variety purple picotee such as tall as plant height (78.8 cm), maximum number of leaves (104.3), stem diameter (5.4 mm), stem length (56.8 cm) and higher flower yield was obtained from this treatment (52).

Gladiolus: Application of Lithovit nitrogen at the rate of 900g/fed and humic acid at 2.5 kg/fed in Gladiolus cv. white prosperity exhibited maximum leaf number, plant height and leaf length (53). Foliar application of Moringa leaf extract (MLE) 10 % resulted in the highest floret count per spike and length of spike (cm). Further, combination of Moringa leaf extract (MLE) at 10 % with Nano-NPK at 1 g/L showed increased stem and flower diameter (cm), as well as moist and dehydrated weights of cut spikes (g), further the bio molecular components like chlorophyll a and b, carotenoids in fresh leaves (mg/g) and levels of primary plant nutrients and total amount of carbohydrates were also significantly improved by this treatment in Gladiolus cv. Rose supreme (54). This conjugating performance is due the presence of major and minor nutrients (K, Ca, Fe),Vitamins A, B and C, plant growth promoting hormones like auxin and cytokinin, antioxidants (ascorbates and phenolics) in moringa leaf extract contributes for pest and disease resistance mechanism (55) along with high specific surface area and density of reactive areas of nanofertilizers (56) leads yield improvement upto 20-35 %. Foliar application of nano-iron at 0.25 g/L in Gladiolus cv. American beauty improved the height of plant, quantity of the leaves, count

Table 3. Effect of foliar application of nutrients in cut flowers

Crop	Species / culitvar	Foliar formulation	Result	Reference
Gladiolus	cv. American Beauty	4g/L Potassium oxide (K_2O)	Increase height of plant length of spike and rachis were also increased	(38)
	cv. pink friendship	0.4 % $ZnSO_4$+0.2 % $CuSO_4$	produce highest quantity of leaves moist weight and dehydrated weight maximum durability of florets	(49)
Carnation	cv. Red Sim	Major elements (20 % of N, P and K each, 0.12 % of Mg) and minor elements (14 ppm Zn, 70 ppm Fe, 42 ppm Mn, 16 ppm Cu, 24 ppm Mo and 72 ppm B)	Increase in both quantity and size of moist and dehydrated weight of flowers/plant	(41)
Gerbera (under protected conditions)	*Gerbera jamesonii*	$ZnSO_4$ (0.2 %) + $MnSO_4$ (0.2 %) + $FeSO_4$ (0.1 %)	Improved growth parameters along with quantity of cut flowers/plant longer vase life	(50)
Lilium hybrid	cv. Tresor	Potassium nitrate 19 ppm, ammonium nitrate 16.5 ppm, potassium dihydrogen phosphate 1.7 ppm, calcium chloride 4.4 ppm and magnesium sulphate 3.7 ppm	92 % greater number of buds in lily flowers	(47)
	cv. Navona	0.4 % $ZnSO_4$+0.4 % $FeSO_4$	Produce more quantity of flowers increase longevity	(51)
China Aster	cv. Princess	0.2 % $FeSO_4$	Maximum plant height fresh weight of floral head is also increased	(48)

of shoots, half of its sprouting, length of the spike, initiation of first spike, weight of the corm in each plant, corms per plot and longevity in vase (57).

Lilium: When 0.5 mM Nano K was applied as a foliar spray, the results showed that the highest stem fresh weight in Asiatic Lilium hybrid cultivar Tresor (58).

Foliar application of nutrients in minor flower crops

Applying mineral NPK at the rate of 6.0 or 12.0 g/plant along with foliar applications of ascorbic acid at either 200 or 400 mg/L led to improvement in height of plant, plant branches, area of leaf, number of leaves, dry weight of plant ,more inflorescences, more florets per inflorescences, duration of inflorescence development as well as enhancements in leaf chemical compositions parameters such as total chlorophyll content, N,P and K content in Geranium (59). Combined foliar application of 1.8 mg/L iron chelated Nano fertilizers and cycocel 1000 mg/L or iron Nano fertilizer alone, were applied to *Euphorbia pulcherima* plants resulted in shorter plant height more leaves, more shoots, longer roots, increased overall volume and bracts with more vibrant coloration. The leaf surface area was greater in plants treated solely with 1.8 g/L iron nanofertilizer without cycocel, while reduced root volume and maximum chlorophyll content were observed when iron Nano fertilizer were combined with cycocel (60).Foliar application of Iron and Zinc in Chamomile showed superior performance in flower number, flower yield and essential oil content (58).Foliar application sulphate of zinc (1.5 g/L, 3 g/L and 4.5 g/L) and boric acid (5 ppm,10 ppm and 20 ppm) at all these above mentioned concentrations resulted in improved growth, flowering characteristics, bulblets number and yield/plant in Iris plant (61). Foliar application of nano NPK in *Kalanchoe blossfeldiana* exhibited positive results by increasing the number of leaves, plant diameter and number of flowers per plant (62).

Benefits of foliar nutrient application

- Foliar application requires only small quantities of nutrients as compared to nutrients required for soil application and the ultimate advantage is enabled the plant to respond according to the its conditions (12).
- Applying nutrients to leaves can enhance uptake efficiency and lower the production expenses, while also reducing the discharge of phosphorous applied through soil which causes lakes and streams to become eutrophic (63).
- Foliar application of nutrients resulted in easy absorption of mineral elements, bypassing potential soil interactions that could hinder root uptake, such as nutrient immobilization in soil (64). For certain nutrients iron, which are fixed in the soil, applying them to foliage is more efficient and cost-effective than applying them to soil.
- During the early stages of growth, when plant roots are not fully developed, foliar fertilization offers greater absorption advantages compared to soil application (65).
- When adequate moisture is not available in top soil to absorbs the applied nutrients by plant roots, foliar spray will be effective (16).
- Physiological disorders caused by any nutritional deficiency and stress conditions can be easily overcame by application of nutrient through leaves (66).
- Combining fertilizers with, many commercial pesticides can often enhance the effectiveness of foliar fertilizers and pesticides together, thereby reducing plant protection costs (67).
- Unnecessary wastage of fertilizers and targeted delivery of nutrients may be possible through foliar nutrient application.

Limitations in foliar nutrient application

- Fertilizer materials intended for foliar application need to dissolve in water to be effective. Many of the substances are salts and if applied too concentrated will causing burning of leaves. Often, the safe concentration of these fertilizers in the solution is quite low, necessitating repeated applications to adequately meet the need of plants (1).
- Leaf area should be large enough in foliar application of nutrients to obtain good efficiency (16). Sticking agent is also required to get more efficiency of nutrient uptake (16).
- The quick evaporation of spray solutions hinders the penetration of solutes and application during rainy days will also result in run off nutrients (68).
- On windy days during foliar fertilization, it is crucial to be cautious to prevent uneven distribution of nutrient solution, as wind significantly contributes to variability in spray deposition.

Future perspectives

- Efforts should be made to integrate foliar fertilization with precision agriculture by real time crop health monitoring through sensors, drones and satellite imagery.
- Research deliverables on Variable Rate Technology (VRT) will allow for the precise adjustment of fertilizer applications according to the nutrient needs of different parts of a field, reducing waste and ensuring more efficient use of fertilizers.
- Foliar fertilization holds immense potential, meanwhile further research and careful management are required to overcome its limitations, such as risk of leaf burn and evaporation issues.
- Studies will emerge with bio-based foliar fertilizers by incorporating beneficial microorganisms such as bacteria and fungi improving nutrient absorption could become a major thrust.

Conclusion

Foliar fertilization has emerged as a highly efficient method for supplementing plant nutrition, particularly when addressing nutrient deficiencies and optimizing growth parameters in various flower crops. It can be able to deliver nutrients through the leaves ensures quicker and more efficient uptake, making an ideal alternative to traditional soil fertilization methods. However, its success is dependent on various factors like nutrient concentration, growth stage of plant, environmental conditions and nutrient concentrations. Overall, as agricultural practices evolve, foliar fertilization is set to play a significant role in enhancing crop yield and quality

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Authors' contributions

Writing of original draft and conceptualization were done by JG. RKR, SKM, BA, VK, UB done the revision of draft, proof reading, formatting and supervision.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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