

## MACRO AND MICRONUTRIENTS REGIMES IMPACT GROWTH DYNAMICS OF *Lilium L. LA HYBRID BULBLETS*

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### ABSTRACT

*Lilium*, a member of family Liliaceae, is among top ten highly demanded geophytic cut flowers in global markets; and during recent years, its demand has increased several folds in local markets as well. However, quality bulb production of *Lilium* in different regions of the world is a major limiting factor and nutrients for best quality bulb production needs to be optimized. Therefore, a study was conducted to evaluate the efficacy of various macro and micronutrients on bulblet growth and bulb development of *Lilium L. LA* hybrid cv. 'Indian Summerset'. Treatments included no additional nutrient application (control), nitrogen (N) (123.5 kg ha<sup>-1</sup>), phosphorous (P) (148.2 kg ha<sup>-1</sup>), potassium (K) (148.2 kg ha<sup>-1</sup>), nitrogen + phosphorous (NP) (123.5:148.2 kg ha<sup>-1</sup>), nitrogen + potassium (NK) (123.5:148.2 kg ha<sup>-1</sup>), phosphorous + potassium (PK) (148.2:148.2 kg ha<sup>-1</sup>), nitrogen + phosphorous + potassium (NPK) (123.5:148.2:148.2 kg ha<sup>-1</sup>), nitrogen + phosphorous + potassium + secondary elements (NPK + SE) (CaSO<sub>4</sub> (Ca) @ 61.75 kg ha<sup>-1</sup>, MgSO<sub>4</sub> (Mg) @ 1.23 kg ha<sup>-1</sup>, and Sulphur (S) @ 2.5 kg ha<sup>-1</sup>), nitrogen + phosphorous + potassium + micronutrients (NPK+ Micro) (ZnSO<sub>4</sub> (Zn) @ 12.35 kg ha<sup>-1</sup>, FeSO<sub>4</sub> (Fe) @ 2% solution and boric acid (B) @ 2% solution) and nitrogen + phosphorous + potassium + secondary nutrients + micronutrients (NPK + SE + Micro). All treatments were replicated three times with 20 bulblets in each replicate, which were laid out in a randomized complete block design. Application of various nutrients exhibited statistically significant differences regarding various growth and development attributes. Plants supplemented with NPK + SE + Micro produced statistically improved weight (34.4 g) and diameter (36.4 mm) of bulblets. Plants supplemented with NPK + SE + Micro exhibited significantly higher photosynthetic rate, transpiration rate, stomatal conductance and sub stomatal CO<sub>2</sub>. Highest leaf SPAD values, greatest leaf N, Mg and S contents were recorded in plants treated with NPK + S.E. Highest leaf P, K, Ca and Zn contents were recorded in plants supplemented with NPK + SE + Micro. Plants fertilized with NPK + Micro produced greatest leaf area and Fe contents. Plants deficit in nutrients exhibited poor growth and bulb development. It is concluded that exogenous application of NPK+ SE + Micro produced superior quality *Lilium LA* hybrid 'Indian Summerset' bulbs compared to other nutrient regimes. Growers and bulb producers may use NPK + SE + Micro in combined form for commercial cultivation and bulb production of *Lilium LA* hybrid.

**Keywords:** Bulb production, cut flowers, geophytes, primary nutrients, secondary elements, micronutrients.

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### INTRODUCTION

*Lilium*, a member of family Liliaceae, holds a special significance in cut flower market because of its large trumpet shaped, fragrant flowers available in a wide range of colours that make them versatile for floral arrangements (Pahare and Mishra, 2020). Plant nutrition is one of the most critical factors for bulb and bulblets production in *Lilium* (Singh *et al.*, 2024). Uniform size bulb production in *Lilium* demands optimal nutrients application to avoid nutrient deficient disorders such as blind shoots, bud abortion, leaf discoloration and necrosis (Barnes *et al.*, 2011). Macro and micronutrients applications have a vital impact on bulblet growth and development. Initiation of meristematic activity is one of the primary roles of N. Appropriate supply of N encourages cell division, cell enlargement, trigger chlorophyll, protein and amino acid formation (Pahare *et al.*, 2019). Inadequate P levels may result in shorter flowering stems. K promotes the movement of sugars and starches, which regulates stomatal movement and osmotic pressure, reduces wilting and respiration, and increases the protein content of plants (Jin *et al.*, 2023).

NPK application on *Lilium* cv. 'Nashville' improved its floral attributes viz., bud diameter, flower diameter and number of buds (Pahare *et al.*, 2019). Secondary element, Ca, improved flower longevity and chlorophyll contents of oriental hybrid cv. Sorbonne. (Chang *et al.*, 2012). *Lilium* cv. 'Blackout' exhibited significant variations regarding weight and diameter of bulb and bulblets when NPK (300:50:300 kg ha<sup>-1</sup>) nutrients were applied (Walling *et al.*, 2020). Exogenous

application of NPK (160:120:100 kg ha<sup>-1</sup>) produced superior quality bulbs of *Lilium* LA hybrid 'Masai' by improving bulb circumference, fresh and dry weight of bulbs (Saraswati *et al.*, 2024).

There is limited literature available about the optimal fertilizer application for high quality bulb production of *Lilium* LA hybrid in agro-climatic conditions of Pakistan. Establishment of effective and sustainable local bulb production system is required due to the rising commercial demand for *Lilium*, higher import costs and laborious import procedures and quarantine regulations. Therefore, a study was designed to evaluate the efficacy of various primary and secondary elements along with micronutrients in various combinations on morpho-physiological and quality attributes of *Lilium* bulblets produced by scale propagation. It was hypothesized that application of appropriate combination of macro and micronutrients to field grown bulblets will produce uniform and high-quality *Lilium* bulbs. The specific objective of this study was to optimize macro and micronutrients for uniform and high-quality *Lilium* bulb production in local agro-climatic conditions of Punjab, Pakistan.

## MATERIALS AND METHODS

**Plant material and experimental conditions:** A field experiment was conducted on *Lilium* L. LA hybrid 'Indian Summerset' to optimize macro and micronutrients for high quality *Lilium* bulb production at Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, located at of 31°-26' N latitude, 73°-06' E longitude, and 184.4 m altitude above sea level, during 2023-24. Treatments included no additional nutrient application (control), nitrogen (N) (123.5 kg ha<sup>-1</sup>), phosphorous (P) (148.2 kg ha<sup>-1</sup>), potassium (K) (148.2 kg ha<sup>-1</sup>), nitrogen + phosphorous (NP) (123.5:148.2 kg ha<sup>-1</sup>), nitrogen + potassium (NK) (123.5:148.2 kg ha<sup>-1</sup>), phosphorous + potassium (PK) (148.2:148.2 kg ha<sup>-1</sup>), nitrogen + phosphorous + potassium (NPK) (123.5:148.2:148.2 kg ha<sup>-1</sup>), nitrogen + phosphorous + potassium + secondary elements (NPK + SE) (CaSO<sub>4</sub> (Ca) @ 61.75 kg ha<sup>-1</sup>, MgSO<sub>4</sub> (Mg) @ 1.23 kg ha<sup>-1</sup>, and Sulphur (S) @ 2.5 kg ha<sup>-1</sup>), nitrogen + phosphorous + potassium + micronutrients (NPK+ Micro) (ZnSO<sub>4</sub> (Zn) @ 12.35 kg ha<sup>-1</sup>, FeSO<sub>4</sub> (Fe) @ 2% solution and boric acid (B) @ 2% solution) and nitrogen + phosphorous + potassium + secondary nutrients + micronutrients (NPK + SE + Micro). Urea, single super phosphate (SSP) and sulphate of potash (SOP) served as source material for N, P and K. N was supplemented in two splits, 1<sup>st</sup> at bulblet planting time and second split at 30 days after 1<sup>st</sup> application. P, K, Ca, Mg, S and Zn were applied at bulblet planting time, while Fe and B were applied as foliar sprays until runoff at 30 days after planting. Experiment was set up in a randomized complete block design (RCBD) with 11 nutrient combinations randomized in each block, and each treatment was replicated three times. Each replication consisted of 20 bulblets planted in each experimental unit with net plot size of 1.2 m × 1.8 m.

**Crop Husbandry:** One-year old scale bulblets of *Lilium* L. LA hybrid cv. 'Indian Summerset' was planted 8-10 cm deep in thoroughly tilled and laid out field on 60 cm spaced ridges with 15 cm spacing between bulblets. Standard cultural practices, viz. irrigation, weeding and IPM were same across treatments during study period. Plants were irrigated as needed keeping in view the weather conditions, while weeds were eradicated manually. Soil samples from different blocks (two samples were randomly collected from each block to a depth of 0-30 cm, evaluated individually and averaged) of experimental field were collected randomly before the start of experiment to evaluate physico-chemical properties of the soil and results are presented below:

**Table: 1. Pre-sowing physico-chemical characteristics of soil in experimental field**

Soil Properties	Soil depth (0-30 cm)
Organic matter (% age)	1.5
pH	8.2
EC (dS m <sup>-1</sup> )	1.73
N (%)	0.075
Available P (mg kg <sup>-1</sup> )	10.62
Exchangeable K (mg kg <sup>-1</sup> )	200
Available Zn (mg kg <sup>-1</sup> )	0.55
Available Fe (mg kg <sup>-1</sup> )	2.87
Available B (mg kg <sup>-1</sup> )	0.75

**Measurements:** Five random bulbs were selected from each replication. At the end of growing season, when above ground leaves turned yellow, bulb were dug out and fresh weight of each bulb was calculated using electric weighing balance (DM-305F). Bulb diameter was recorded using digital vernier caliper (0-150 mm, model 500-196-30 Mitutoyo, Japan). Five random bulbs were selected from each replication and average was computed. Five healthy plants were randomly

selected from each replication and leaf area of three recently matured leaves was measured. Length and width from centre of each leaf were recorded with measuring scale. Leaf area was computed by multiplying leaf length and maximum width of leaf with a constant factor according to Carleton and Foote (1965). Leaf area = Length  $\times$  Max. Breadth  $\times$  0.68 (constant factor).

Healthy, disease-free leaves from middle of mature plants were selected for evaluating the physiological parameters viz, photosynthetic rate, leaf chlorophyll contents, leaf transpiration rate, stomatal conductance and sub-stomatal CO<sub>2</sub>, which were measured using Infra-Red Gas Analyzer (IRGA) (Licor-6400) according to the method described by Corelli-Grappadelli and Magnanini (1997). Five random plants from each replication were selected and average was computed.

Healthy, disease-free leaves were selected for evaluating the leaf nutrient status in *Lilium* plants and kept in brown perforated paper bags. Leaves were washed and air dried for 48 h under shade and were packed in perforated paper bags and placed in oven for drying at 70°C for over 72 hrs. The leaf samples were ground to powder and kept in properly labelled sealed bottles at room temperature for further process. N was estimated by the method of Chapman and Parker (1961). Leaf sample (1 g) was transferred to Kjeldhal's digestion flask along with concentrated sulfuric acid (30 mL) and digestion mixture (5 g). The mixture was boiled until a transparent green liquid material was obtained. 10 mL aliquot was distilled in micro Kjeldhal's apparatus, and the distillate was titrated against sulfuric acid. The N percentage was calculated by using the following formula:

$$N (\%) = A - B \times C \times 0.0014 \times 100D$$

Where; A = Quantity of N/10 sulfuric acid used

B = Blank reading (N/10 sulfuric acid used in blank reading)

C = Volume made after digestion (250 mL)

D = Volume of digested sample used

0.0014 = Factor.

Leaf samples (0.5 g) were digested with HNO<sub>3</sub> and HClO<sub>4</sub>, left overnight and heated gradually until a transparent colorless solution was obtained. The digested solution was diluted to 100 mL with distilled water and samples were kept in plastic containers for subsequent analysis. P and K were estimated by the method of Chapman and Parker (1961). For phosphorous estimation, colour of the sample was developed with dilute H<sub>2</sub>SO<sub>4</sub>, 5% ammonium molybdate and 0.25% ammonium vanadate (5 mL each). A standard curve was prepared by using KH<sub>2</sub>PO<sub>4</sub> and sample transmittance was measured at 420 nm with a spectrophotometer. The P contents were measured by using the following equation:

$$P (\%) = \frac{\text{ppm on graph} \times \text{dilution}}{10^6} \times 100$$

Flame photometer was used to measure K. K contents were calculated in parts per million by comparing the flame photometer's emission to the standard curve and converted to %age by using the following formula:

$$K (\%) = \frac{\text{ppm on graph} \times \text{dilution}}{10^6} \times 100$$

Ca, Mg, Fe, and Zn contents in leaves of *Lilium* L. LA hybrid cv. 'Indian Summerset' was estimated using Atomic Absorption Spectrophotometer (Hitachi Polarized Zeeman AAS, Z-8200, Japan). Standard solutions were prepared for calibration of instruments, and a calibration curve was established. Nutrient concentrations were recorded based on the sample reading.

**Statistical analysis:** The experiment was conducted under field conditions using a Randomized Complete Block Design (RCBD), and the experimental data of all studied parameters were statistically analyzed using Statistix 8.1 software. In this design, replications were treated as blocks to control field heterogeneity. The analysis was performed using a two-way ANOVA appropriate for RCBD (without interaction), where treatments and blocks were considered as two separate sources of variation. The block (replication) effect was found to be significant in most cases, indicating the presence of field variability; however, in some instances, it was non-significant.

The statistical model used for the RCBD was:

$$Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij}$$

where

$Y_{ij}$  = observed response,

$\mu$  = overall mean,

$\tau_i$  = effect of the  $i^{th}$  treatment,

$\beta_j$  = effect of the  $j^{th}$  block (replication),

$\varepsilon_{ij}$  = random error term.

This model appropriately accounts for both treatment effects and block-to-block variation. Moreover, Tukey's Honest Significant Difference (HSD) test was used to compare treatment means at 5% level of significance (Steel *et al.*, 1997). Correlations were also developed among weight of bulblets, diameter of bulblets, leaf area, leaf SPAD values, photosynthetic rate, transpiration rate, and leaf N, P and K contents using Pearson's correlation.

## RESULTS

Application of macro and micronutrients significantly improved physical characteristics of bulblets of *Lilium* LA hybrid 'Indian summerset'. Application of NPK + SE + Micro produced greatest bulblets weight followed by application of NPK + Micro, which were statistically at par with NPK + SE (Table 2). Plants grown without any additional nutrients (control) had least bulblets weight. Largest bulb diameter was produced with NPK + SE + Micro application followed by plants supplemented with NPK + SE and NPK + Micro (Table 2). For bulblet diameter, application of NPK alone exhibited greatest bulblet diameter, while least diameter of bulblets was recorded in plants grown without any additional nutrients (control). Greatest leaf area was recorded in plants supplemented with NPK + Micro, which was statistically similar to plants supplemented with NPK + SE + Micro followed by NPK + SE (Table 2). Plants without additional nutrients application (control) exhibited smallest leaf area. For leaf SPAD values, photosynthetic and transpiration rate, results demonstrated highly significant differences among various nutrient regimes. Highest leaf SPAD values were recorded in plants supplemented with NPK + SE and NPK + SE + Micro followed by NPK alone and NPK + Micro (Table 2). Least leaf SPAD values were recorded in nutrient deficient plants (control). Plants supplemented with NPK + SE + Micro exhibited higher photosynthetic rate and transpiration rate, which were statistically similar to NPK + SE and NPK + Micro supplied plants (Table 3). Least photosynthetic rate was recorded in plants supplemented with P alone, while lowest transpiration rate was recorded in plants fertilized with PK. Highest stomatal conductance and sub stomatal CO<sub>2</sub> conductance were exhibited by plants supplied with NPK + SE + Micro. Plants without additional nutrients (control) exhibited lowest stomatal and sub stomatal CO<sub>2</sub> conductance (Table 3).

**Table 2. Effect of various nutritional regimes on weight of bulblets, diameter of bulblets, leaf area and leaf SPAD values of *Lilium* cv. 'Indian Summerset'. (n = 15±S.E.)**

Nutrient regimes	Weight of bulblets (g)	Diameter of bulblets (mm)	Leaf area (cm <sup>2</sup> )	Leaf SPAD values
Control (no additional fertilizer)	20.34±0.59 e	25.57±0.58 d	4.07±0.033 d	40.30±0.62 g
N	24.00±0.58 cd	29.37±0.60 c	4.80±0.520 bcd	43.42±0.55 fg
P	22.33±0.55 de	27.58±0.58 cd	4.40±0.115 cd	42.52±0.59 g
K	22.40±1.10 de	28.42±0.46 cd	4.33±0.088 cd	42.50±1.09 g
NP	26.33±0.60 c	29.58±0.58 c	5.00±0.144 bcd	48.33±0.55 e
NK	25.50±0.66 c	30.25±0.66 c	5.20±0.115 abc	54.33±0.60 d
PK	25.33±0.73 c	29.34±0.58 c	4.57±0.237 cd	46.25±0.38 ef
NPK	30.32±0.61 b	33.32±0.58 b	5.60±0.115 ab	60.21±0.58 bc
NPK + SE	32.39±0.55 ab	35.51±0.62 ab	6.10±0.058 a	63.50±0.66 a
NPK + Micro	32.42±0.55 ab	34.57±0.62 ab	6.20±0.058 a	59.42±0.65 c
NPK + SE +Micro	34.42±0.65 a	36.43±0.57 a	6.18±0.012 a	63.37±1.50 ab

Means sharing similar letters in a column are different non-significantly ( $P>0.05$ ).

N = Nitrogen, P = Phosphorus, K = Potassium, SE = Secondary elements, Micro = Micronutrients

Highest leaf N contents were recorded in plants supplemented with NPK + SE followed by NPK + SE + Micro (Table 4). Plants without additional nutrients (control) had lowest leaf N contents. Highest leaf P contents were recorded in plants supplemented with NPK + SE + Micro, while plants without additional nutrients (control) had lowest leaf P contents (Table 4). Plants fertilized with NPK + SE + Micro and NPK + Micro exhibited greatest leaf K contents and were statistically similar, while those without additional nutrients (control) exhibited least leaf K contents (Table 4). Highest leaf Ca contents were recorded in plants supplemented with NPK + SE + Micro, while plants without additional nutrients (control) had lowest leaf Ca contents (Table 4). Plants supplemented with NPK + SE demonstrated highest leaf Mg contents (Table 4). Plants without additional nutrients (control) revealed lowest leaf Mg contents. Highest leaf S contents were recorded in plants nourished with NPK + SE followed by NK, while plants supplied with PK had lowest leaf S contents (Table 4).

**Table 3. Effect of various nutritional regimes on photosynthetic rate, transpiration rate, stomatal conductance and sub stomatal CO<sub>2</sub> of *Lilium* cv. 'Indian Summerset'. (n = 15±S.E.)**

Nutrient regimes	Photosynthetic rate (mmol m <sup>-2</sup> s <sup>-1</sup> )	Transpiration rate (mmol m <sup>-2</sup> s <sup>-1</sup> )	Stomatal conductance (mmol m <sup>-2</sup> s <sup>-1</sup> )	Sub stomatal CO <sub>2</sub> (mmol m <sup>-2</sup> s <sup>-1</sup> )
Control (no additional fertilizer)	4.38±0.144 ef	1.61±0.012 ef	0.26±0.012 h	244.17±1.02 h
N	4.93±0.025 de	1.89±0.023 cd	0.51±0.006 f	284.51±1.17 f
P	4.13±0.012 f	1.64±0.023 ef	0.34±0.012 g	280.03±1.76 f
K	4.25±0.050 f	1.54±0.012 f	0.31±0.006 gh	256.45±2.89 g
NP	5.47±0.200 cd	1.82±0.012 de	0.78±0.023 e	327.28±2.04 d
NK	5.64±0.023 c	1.50±0.115 fg	0.85±0.012 e	325.22±1.74 d
PK	5.62±0.012 c	1.31±0.006 g	1.15±0.020 d	315.08±2.53 e
NPK	7.20±0.115 b	2.10±0.058 bc	1.29±0.050 c	363.19±5.09 c
NPK + SE	7.68±0.050 ab	2.28±0.023 b	1.67±0.023 b	380.43±1.22 b
NPK + Micro	7.61±0.053 ab	2.54±0.023 a	1.63±0.017 b	378.43±1.16 b
NPK + SE +Micro	7.78±0.051 a	2.64±0.023 a	1.83±0.025 a	389.57±5.47 a

Means sharing similar letters in a column are different non-significantly ( $P>0.05$ ).

N = Nitrogen, P = Phosphorus, K = Potassium, SE = Secondary elements, Micro = Micronutrients

Highest leaf Zn contents were recorded in plants treated with NPK + SE + Micro, NPK + Micro and NPK + SE, which were statistically similar (Fig. 1A). Plants without any additional nutrients (control) had least leaf Zn contents. Highest leaf Fe contents were recorded in plants fortified with NPK + Micro, while those without any additional nutrient application depicted lowest leaf Fe contents (Fig. 1(B)).

**Table 4. Effect of various nutritional regimes on leaf N, P, K, Ca, Mg and S contents of *Lilium* cv. 'Indian Summerset'. (n = 3±S.E.)**

Nutrient regimes	Leaf N contents (%)	Leaf P contents (%)	Leaf K contents (%)	Leaf Ca contents (mg kg <sup>-1</sup> )	Leaf Mg contents (mg kg <sup>-1</sup> )	Leaf S contents (mg kg <sup>-1</sup> )
Control (no additional fertilizer)	0.35±0.012 f	0.36±0.012 f	0.71±0.035 e	1790± 0.82 j	1193±0.63 g	1580±1.26 f
N	0.52±0.006 ef	0.46±0.012 cde	1.53±0.017 cd	2455± 0.91 g	1393±0.97 e	1900±1.58 e
P	1.03±0.009 d	0.38±0.012 ef	1.39±0.012 d	2671± 0.68 f	1271±0.71 f	2353±2.37 bc
K	0.70±0.087 e	0.41±0.006 def	1.65±0.012 cd	2852± 0.71 e	1365±0.67 e	2313±2.05 bc
NP	1.16±0.029 d	0.49±0.010 cd	1.54±0.023 cd	2349± 0.76 h	1683±0.60 d	2166±0.96 cd
NK	1.14±0.020 d	0.45±0.010 cde	1.57±0.237 cd	3244± 0.77 c	1731±0.63 cd	2700±1.58 a
PK	1.20±0.058 d	0.52±0.012 ce	2.15±0.012 cc	3106± 0.87 d	1752±0.55 c	1500±3.16 f
NPK	1.64±0.026 c	0.63±0.017 b	2.58±0.359 b	2133± 0.61 i	1943±1.3 b	2436±1.93 b
NPK + SE	2.80±0.058 a	0.75±0.015 a	3.49±0.023 a	3372± 0.61 b	2040.8±0.67 a	2820±2.58 a
NPK + Micro	1.75±0.045 c	0.73±0.010 a	3.51±0.006 a	3173±0.64 d	1945±0.80 b	2116±2.41 d



<b>DBL</b>	0.988**	1.000							
<b>LA</b>	0.977**	0.976**	1.000						
<b>SPAD</b>	0.959**	0.960**	0.964**	1.000					
<b>PhR</b>	0.980**	0.962**	0.963**	0.967**	1.000				
<b>TrR</b>	0.866**	0.858**	0.876**	0.784**	0.825**	1.000			
<b>N</b>	0.897**	0.902**	0.873**	0.907**	0.883**	0.699*	1.000		
<b>P</b>	0.985**	0.977**	0.949**	0.924**	0.972**	0.873**	0.894**	1.000	
<b>K</b>	0.956**	0.963**	0.922**	0.892**	0.932**	0.822**	0.900**	0.976**	1.000

Upper values indicated Pearson's correlation coefficient. \* = Significant (P<0.05); \*\* = Highly significant (P<0.01)

WBL = Weight of bulblets, DBL = Diameter of bulblets, LA = Leaf area, SPAD = Leaf SPAD values, PhR = Photosynthetic rate, TrR = Transpiration rate, N = Leaf N contents, P = Leaf P contents, and K = Leaf K contents.

## DISCUSSION

Bulb weight and diameter are two important indices to access the bulb quality in liliium. In the present study, improvement in weight and diameter of bulblets have been observed with application of NPK + SE + Micro, which demonstrated the availability of all essential nutrients that work synergistically with each other in many physiological and biochemical processes and ensure higher nutrient uptake by the plants for better growth and best quality production. Sufficient supply of NPK accelerated photosynthetic activity, protein synthesis and increased carbohydrate contents of bulblets resulting in improved bulblet weight and size (Rajiv and Misra, 2000). These findings correlated with the outcomes of Prakash *et al.* (2010), who attributed that greatest weight of *Lilium* cv. 'Chianti' bulbs was recorded with application of N and P. Moreover, NPK application increased bulblet weight and size of *Lilium pumilum* (Yi-peng and Fang, 2021), while *Lilium longiflorum* cv. 'Nellie White' exhibited least fresh weight when grown without NPK (Niedziela *et al.*, 2008).

A significant difference in physiological activities was observed in plants fertilized with macro and micronutrients. Greatest leaf area was recorded in plants supplemented with NPK + Micro. Whereas highest leaf SPAD values were recorded in plants supplemented with NPK + SE and NPK + SE + Micro. The positive effect of application of nutrients might be due to the presence of N and Mg that are structural components of chlorophyll molecules. Mg atom resides in the centre of the chlorophyll molecule, within the four N atoms of the porphyrin ring, enabling chlorophyll molecule efficiently to capture light energy during photosynthesis. Highest photosynthetic rate, transpiration rate, greatest stomatal conductance and sub stomatal CO<sub>2</sub> conductance was recorded in plants supplied with NPK + SE + Micro. This might be due to the presence of P being an essential component of ATP, which is utilized in photosynthesis. Application of Zn and Mg are involved in chlorophyll synthesis which enhanced plant growth and development in gladiolus (Kumar and Arora, 2000). Zn activates enzymes, i.e., RuBisCO essential for photosynthesis. Chlorophyll contents in *Lilium lancifolium* increased with the application of N and K (Wang *et al.*, 2023). Insufficient amount of these elements results in lack of photosynthetic carbon assimilation, which leads to extreme production of reactive oxygen species. P deficiency limits plant productivity by disrupting the photosynthetic machinery and electron transport to photosystem I (Carstensen *et al.*, 2018). Therefore, plants without additional nutrients application produced smallest leaves and least leaf SPAD values as compared to fertilized plants. Plants supplemented with primary and secondary nutrients exhibited greatest stomatal and sub stomatal conductance as compared to unfertilized plants. This might be due to availability of K<sup>+</sup> and Ca<sup>+</sup> ions, which regulate opening and closing of stomata. In present study, nutrient absorption by plants was significantly higher by nutrient applications. Highest nutrients accumulation was recorded in plant leaves provided with NPK + SE + Micro. Greater leaf nutrient contents may likely be due to passive transport associated with a higher nutrient availability in the external medium.

**Conclusion:** Macronutrients in combination with micronutrients significantly enhanced bulb production and improved the quality characteristics of *Lilium* LA hybrid 'Indian Summerset' bulbs. Exogenous application of NPK + SE + Micro produced heaviest and largest bulbs exhibiting greatest photosynthetic and transpiration rate and sub stomatal CO<sub>2</sub> and leaf P, K, Ca and Zn contents. Plants deficit in nutrients exhibited poor growth and bulb development.

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**Author contributions:** I. Summan executed the experiment, collected data and wrote 1<sup>st</sup> draft of manuscript. I. Ahmad planned the experiment along with provision of resources, monitored data collection and analysis and review of the manuscript draft. M. Usman guided in data analysis and reviewed the draft. I. Afzal helped with physiological analyses, language improvement and review.

**Declaration of Competing Interest:** The authors declare no conflict of interest.

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