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RESEARCH ARTICLE

Propagation dynamics and morphological-biochemical insights of *Lilium* (*Lilium hybrida* L.) scales in soilless media under north-western plains of India

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Abstract

Lilium (*Lilium hybrida* L.) is an important ornamental bulbous crop valued for its beautiful cut flowers. It is propagated by bulbs, bulblets and scales. Scaling is an important technique of propagation as it results in rapid formation of bulblets and subsequently flowering-grade bulbs. This process is greatly influenced by the growing media in which the scales are raised. Hence, the present study was conducted at Punjab Agricultural University, Ludhiana to standardize the best soilless growing media substrate composition for improved bulblet formation and development. The different media compositions included cocopeat, perlite, vermiculite and spent mushroom compost in varying ratios. The results revealed that better bulblet growth in terms of minimum days taken for sprouting (28.27), days taken for visible bulblet production (17.22), maximum number (3.07), weight (1.45 g) and diameter of bulblets formed per scale (1.33 cm) as well as no. of roots/scale (4.90) were observed in media containing perlite + cocopeat (1:1). Additionally, the biochemical parameters analysed for starch content (106.11 mg/g) and total soluble sugars (71.28 mg/g) were found maximum in the bulblets raised in the same media composition. Therefore, the soilless media comprising perlite + cocopeat (1:1) was found the most suitable for the rapid multiplication of Lilies from scaling.

Keywords: bulblets; *Lilium*; perlite + cocopeat (1:1); scaling; soilless growing media

Introduction

Bulbous ornamentals or ornamental geophytes are an important segment of the floriculture industry that comprises of a significantly high amount of trade in terms of turnover as well as quantity. *Lilium* (*Lilium hybrida* L.) belonging to the family Liliaceae and the order Monocotyledonae (1) is one of the most important geophytes that dominate the international market both as a cut flower and a pot plant. The rising demand for this crop calls for new production and marketing strategies, however, the high cost of planting material i.e., bulbs hinder the commercial adoption of the crop by farmers. The sub-tropical conditions of the north-western plains of India, characterized by ample sunshine offer favourable conditions for bulb production during the *Rabi* season, underscoring the need to develop an efficient, economical propagation method for propagation of *Lilium* at the farmer level. Scaling, which involves bulblet formation on detached scales containing a small part of basal plate, presents a valuable technique for rapid propagation of *Lilium*. These bulblets are then encouraged to develop into new bulbs. Since there is development of three to five bulblets from each scale, this method of propagation is particularly beneficial for quickly producing pathogen-free stocks of a new cultivar (2). The bulblet formation from scaling both, qualitatively and quantitatively, is affected by various factors, of which choice of optimum growing media is of utmost importance.

For the commercial cultivation of *Lilium* for cut flower production, a porous, airy and well drained growing medium is required. Due to this reason, the multiplication of Lilium in soilless cultures may be advantageous. Various novel soilless substrates such as cocopeat, perlite and vermiculite (either alone or as components) are commercially being utilized for nursery production of ornamental plants, with a potential to grow and multiply various bulbous ornamentals (3). Cocopeat with its favourable physical and chemical characteristics makes a suitable growing medium, which is offset by high water-holding capacity limiting aeration in the root zone, subsequently impacting optimal growth (4). Therefore, the incorporation of coarser materials like perlite and vermiculite as media additives can help improve its characteristics (5). Perlite, recognized for its large particle size and low water retention, favours formation of air passages and is particularly suitable for mixing with cocopeat for optimizing moisture retention and aeration in the root zone (6) and vermiculite is often utilized as a growth substrate for nursery plants due to its chemical inertness, aeration, lack of microbial growth and effective cation-exchange capacity, all of which support plant growth (7). Additionally, spent mushroom compost is another growing substrate which is in high demand because of its rich nutritional status, high cation exchange capacity and slow mineralization (8). For commercial cultivation, there is requirement of a huge quantity of planting material. Therefore, for production of bulblets, a suitable growing media is required to be standardized, in non-traditional regions, which can be utilized for scaling. These bulblets consequently result in formation of flowering-grade bulbs. However, very few studies have been conducted to optimize soilless media for propagation of Lilium from scales under Punjab conditions. Keeping this in view, the influence of suitable soilless growing media compositions on enhanced bulblet formation from scales in *Lilium hybrida* L. under North-Indian plain conditions was studied.

Materials and Methods

Experimental location

The present investigations were carried out at the Experimental farm of Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana for two consecutive years (2021-22 and 2022-23).

Planting material

The planting material, i.e., mother bulbs of *Lilium hybrida* L. was procured in the month of October.

Treatment details

The different growing media compositions used were:

T_1: Cocopeat (100 %)

T_2: Vermiculite (100 %)

T_3: Perlite (100 %)

T_4: Spent mushroom compost (100 %)

T_5: Perlite + cocopeat (1:1)

T_6: Vermiculite+ cocopeat (1:1)

T_7: Perlite +vermiculite (1:1)

T_8: Perlite + spent mushroom compost (1:1)

T_9: Vermiculite+ spent mushroom compost (1:1)

T_{10}: Cocopeat + spent mushroom compost (1:1)

T_{11}: Cocopeat + spent mushroom compost + vermiculite (1:1:1)

T_{12}: Cocopeat + spent mushroom compost + perlite (1:1:1)

T_{13}: Cocopeat + perlite + vermiculite (1:1:1)

The outer and middle scales of appropriate size were separated from mother bulbs using a sharp blade, treated with the fungicide Bavistin @ 0.2 % for at least fifteen minutes and then planted individually in trays of 45 cm × 30 cm × 8 cm filled with the above-mentioned media compositions. Proper drainage was maintained by making holes at the base of the trays. After planting, the trays were kept at 50 % shade level in a naturally ventilated polyhouse at ambient temperature (Fig. 1) and irrigation was provided in the form of fine misting. The formation and growth of bulblets from scales was checked monthly and the effect of different growing media on bulblet formation from these scales was studied.

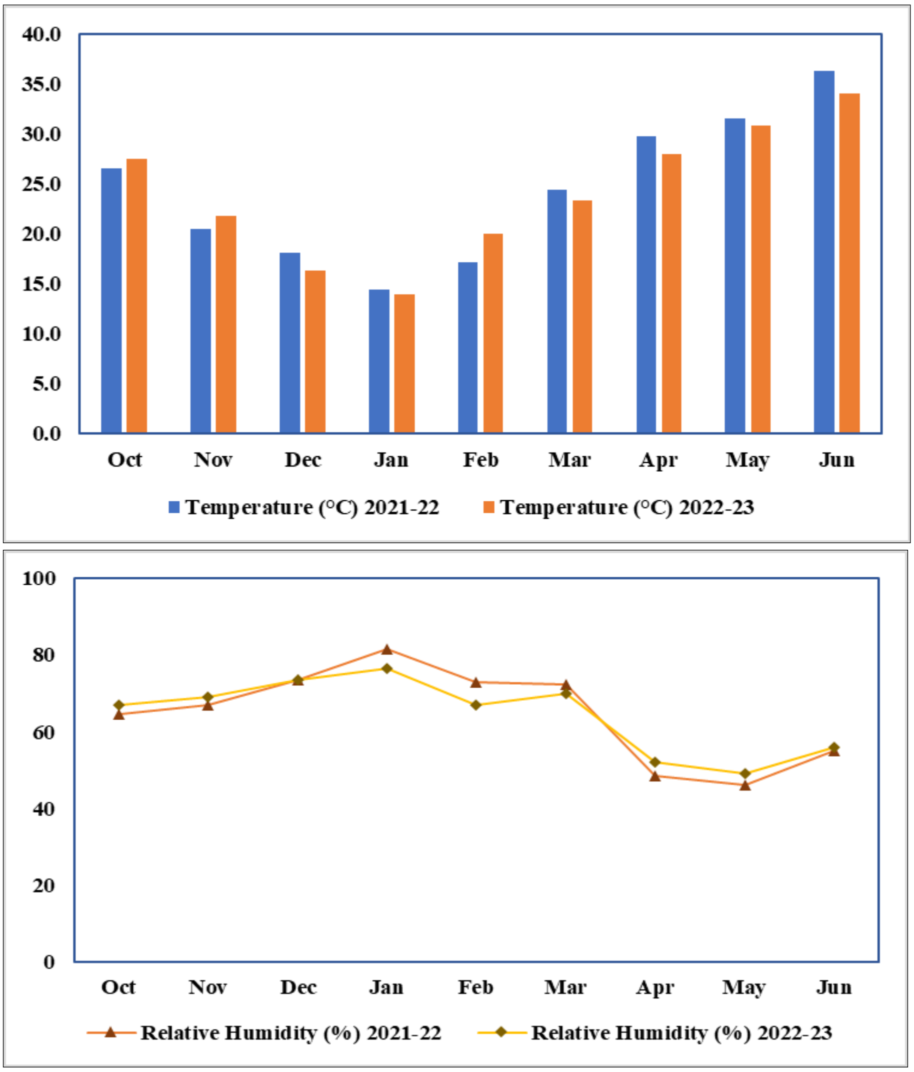

Fig. 1. Average temperature (°C) and relative humidity (%) in the polyhouse during experiment.

The biochemical parameters *viz*., starch content and total soluble sugars were determined by using the methods and formula given in the previous studies (9, 10).

Starch content (mg/g fresh weight) =

$$\frac{\text{Concentration of standard x OD of test sample x Total volume of extract}}{\text{OD of standard x Volume of sample taken from extract x Amount of tissue taken for extraction}} \text{ x1000}$$

Total soluble sugars (mg/g fresh weight) =

$$\frac{\text{Concentration of standard x OD of test sample x Total volume of extract}}{\text{OD of standard x Volume of sample taken from extract x Amount of tissue taken for extraction}} \text{ x1000}$$

Physico-chemical properties of the growing media compositions

The media samples were used for the determination of initial and final pH (potentiometric method), electrical conductivity (EC) (conductivity meter, dS m^{-1}), water holding capacity (%) (Keen's box method) and porosity (Table 1). Further, other physico-chemical properties such as bulk density (g/cm^3) (soil core method), particle density (g/cm^3) (pycnometer method (11)), available N (%) (Kjeldahl method (12)), P (%) (Olsen method (13) and K (%) (Jackson's method (14)) of the media samples were analysed to study their effects on bulblet growth and development (Fig. 2).

Experimental design

The experiment was conducted as per treatments in completely randomized block design (CRBD) replicated thrice, comprising 100 scales per replication and repeated for two consecutive years. The data on vegetative, bulb and biochemical parameters was recorded. The mean data is discussed in the results. The analysis was done using SPSS software version 16 and the treatment means were compared using Duncan's Multiple Range Test (DMRT) at 5 % level of significance (15).

Table 1. Physical properties of growing media compositions evaluated

Treatments	pH		Electrical conductivity (mS cm^{-1})		Water Holding Capacity (%)	Porosity (%)
	Initial	Final	Initial	Final		
T_1: Cocopeat (100 %)	6.4	8.2	0.73	1.65	78.5	60.71
T_2: Vermiculite (100 %)	7.1	8.6	0.16	1.38	70.8	77.38
T_3: Perlite (100 %)	6.7	8.5	0.23	0.73	55.5	79.66
T_4: Spent mushroom compost (100 %)	7.4	8.0	1.87	2.56	85	27.40
T_5: Perlite + cocopeat (1:1)	6.8	7.5	0.45	1.54	73.2	69.23
T_6: Vermiculite + cocopeat (1:1)	6.9	7.9	0.36	1.58	75.4	61.04
T_7: Perlite + vermiculite (1:1)	7.2	8.3	0.30	1.20	55.3	37.21
T_8: Perlite + spent mushroom compost (1:1)	7.3	7.8	2.24	2.95	59.8	58.97
T_9: Vermiculite + spent mushroom compost (1:1)	7.1	8.5	1.36	2.57	52.6	37.78
T_{10}: Cocopeat + spent mushroom compost (1:1)	7.4	7.7	1.93	2.76	89.4	26.32
T_{11}: Cocopeat + spent mushroom compost + vermiculite (1:1:1)	7.8	8.5	0.79	1.42	68.6	73.68
T_{12}: Cocopeat + spent mushroom compost + perlite (1:1:1)	6.5	8.1	1.15	2.08	80	66.13
T_{13}: Cocopeat + perlite + vermiculite (1:1:1)	6.2	7.9	0.18	1.60	67.5	60.26
$C.D._{0.05}$	0.41	0.29	0.05	0.11	3.06	2.68

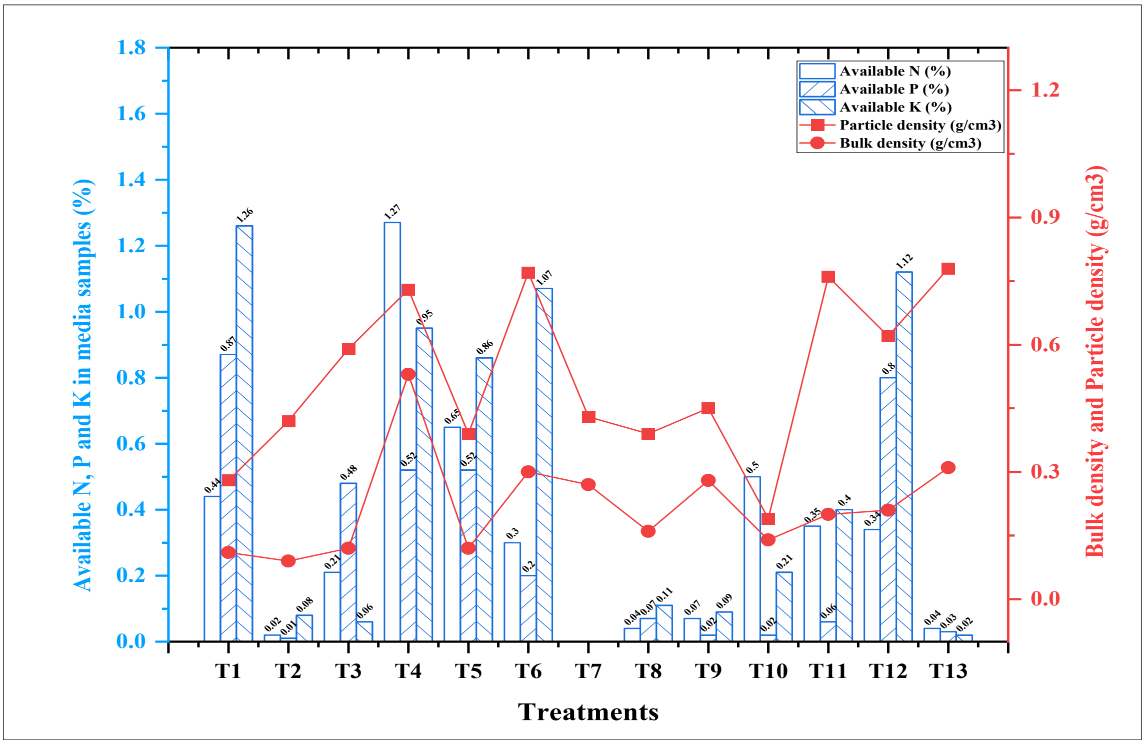

Fig. 2. Physico-chemical properties of different growing media compositions.

Results and Discussion

Vegetative parameters

Days to visible bulblet formation and sprouting

The days to visible bulblet production and days to sprouting were significantly influenced by different growing media compositions (Table 2). The earliest visible bulblet production (28.10) and sprouting (17.22) was observed in the scales planted in T_5 comprising of perlite + cocopeat (1:1) followed by vermiculite + perlite (1:1) [T_6] i.e., 20.28 and 32.30 days, respectively and cocopeat (100 %) [T_1] i.e., 22.5 and 33.28 days, respectively. However, delayed visible bulblet production (33.27) and sprouting (40.77) were observed in T_{10} [cocopeat + spent mushroom compost (1:1)] which was at par with T_8 [perlite + spent mushroom compost (1:1)] (40.52).

Leaf length (cm)

Significant variations were observed for leaf length (cm) as influenced by different growing media compositions (Table 2). After six months of planting, the scales raised in perlite + cocopeat (1:1) [T_5] produced leaves of the longest length (23.14 cm) followed by the leaves produced in the scales raised in vermiculite (100 %) [T_2] (19.24 cm). In contrary, the shortest leaves were produced by the scales raised in cocopeat + spent mushroom compost (1:1) [T_{10}] (13.41 cm) followed by the leaves produced in spent mushroom compost (100 %) [T_4] (15.87 cm), respectively.

Bulblet parameters

Number, weight (g) and diameter (cm) of bulblets formed

A differential pattern of growth was observed in bulblets raised under different growing media compositions (Table 3). The highest number of bulblets (3.07) were recorded in the scales planted in perlite + cocopeat (1:1) [T_5] which was at par with the number of bulblets produced in cocopeat (100 %) [T_1] (2.38). In contrast, the lowest number of bulblets (1.38) were recorded in T_{10} [cocopeat + spent mushroom compost (1:1)] which was found at par with number of bulblets formed (1.47) in T_4 [spent mushroom compost (100 %)] and T8 [perlite + spent mushroom compost (1:1)] followed by the bulblets formed in T_7 [perlite + vermiculite (1:1)] (1.54) and T_6 [vermiculite + cocopeat (1:1)] (1.60), respectively.

Also, bulblets of largest diameter (1.33 cm) were recorded in the media composition of perlite + cocopeat (100 %) [T_5] followed by T_7 [perlite + vermiculite (1:1)] (0.98 cm), T_9 [vermiculite + spent mushroom compost (1:1)] (0.95 cm), T_{13} [cocopeat + perlite + vermiculite (1:1:1)] and T_2 [vermiculite (100 %)] (0.93 cm). The maximum weight of bulblets per scale (1.45 g) was recorded in cocopeat + perlite (1:1) [T_5] followed by the bulblet weight in T_7 [perlite + vermiculite (1:1)] and T_{13} [cocopeat + perlite + vermiculite (1:1:1)] (0.90 g). On the contrary, bulblets of smallest size (0.61 cm) and weight (0.53 g) were recorded in T_{10} [cocopeat + spent

Table 2. Effect of different growing media compositions on days taken for visible bulblet production and days taken for sprouting of *Lilium hybrida* L. bulblets

Treatments	Days taken for visible bulblet production			Days taken for sprouting			Leaf length (cm)		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
T_1: Cocopeat (100 %)	23.37	21.63	22.50^{c}	33.17	33.40	33.28^{b}	16.75	17.34	17.05^{bc}
T_2: Vermiculite (100 %)	26.23	25.67	25.95^{d}	34.60	33.87	34.23^{bc}	19.22	19.26	19.24^{de}
T_3: Perlite (100 %)	26.10	26.40	26.25^{d}	35.60	33.57	34.58^{bcd}	18.96	19.27	19.12^{de}
T_4: Spent mushroom compost (100 %)	30.43	29.80	30.12^{fg}	38.80	39.63	39.22^{ef}	15.71	16.02	15.87^{b}
T_5: Perlite + cocopeat (1:1)	17.30	17.13	17.22^{a}	27.90	28.3	28.10^{a}	23.70	22.58	23.14^{f}
T_6: Vermiculite + cocopeat (1:1)	20.40	20.17	20.28^{b}	31.97	32.63	32.30^{b}	19.61	19.34	19.47^{de}
T_7: Perlite + vermiculite (1:1)	27.10	27.63	27.37^{de}	35.20	34.30	34.75^{bcd}	19.53	20.12	19.83^{de}
T_8: Perlite + spent mushroom compost (1:1)	31.10	31.60	31.35^{g}	40.63	40.40	40.52^{f}	18.22	18.81	18.52^{cd}
T_9: Vermiculite + spent mushroom compost (1:1)	29.70	30.07	29.88^{fg}	37.77	38.03	37.90^{ef}	18.46	18.20	18.33^{cd}
T_{10}: Cocopeat + spent mushroom compost (1:1)	33.23	33.30	33.27^{h}	41.10	40.43	40.77^{f}	12.54	13.49	13.01^{a}
T_{11}: Cocopeat + spent mushroom compost + vermiculite (1:1:1)	28.23	28.20	28.22^{e}	38.27	34.80	36.53^{cde}	20.62	20.03	20.33^{e}
T_{12}: Cocopeat + spent mushroom compost + perlite (1:1:1)	28.77	29.20	28.98^{ef}	34.07	38.70	36.38^{cde}	20.19	19.62	19.91^{de}
T_{13}: Cocopeat + perlite + vermiculite (1:1:1)	29.63	30.17	29.9^{fg}	37.40	37.27	37.33^{de}	18.96	19.63	19.29^{de}

Mean values in each column with the same letters are not significantly different according to Tukey's HSD test at $p < 0.05$.

Superscripted lowercase letters depict the individual treatment effect.

Table 3. Effect of different growing media compositions on different bulblet parameters of *Lilium hybrida* L.

Treatments	Number of bulblets formed per scale			Weight of bulblet per scale (g)			Diameter of bulblets formed (cm)			Number of roots/scale		
	2021	2022	Mean	2021	2022	2021	2022	2021	2022	2021	2022	Mean
T_1	2.17	2.60	2.38^{cd}	0.70	0.69	0.69^{abc}	0.77	0.79	0.78^{abcde}	2.87	3.13	3.00^{def}
T_2	2.00	2.47	2.23^{bc}	0.82	0.85	0.84^{cde}	0.94	0.92	0.93^{def}	3.67	3.90	3.78^{f}
T_3	1.87	2.27	2.07^{abc}	0.64	0.65	0.65^{abc}	0.71	0.74	0.72^{abc}	3.43	3.53	3.48^{ef}
T_4	1.37	1.57	1.47^{ab}	0.63	0.63	0.63^{ab}	0.64	0.73	0.68^{ab}	1.57	1.80	1.68^{ab}
T_5	2.97	3.17	3.07^{d}	1.28	1.61	1.45^{f}	1.32	1.33	1.33^{g}	4.73	5.07	4.90^{g}
T_6	1.40	1.80	1.60^{ab}	0.75	0.63	0.69^{abc}	0.94	0.76	0.85^{bcdef}	3.47	3.10	3.28^{def}
T_7	1.22	1.87	1.54^{ab}	0.894	0.91	0.90^{e}	1.00	0.96	0.98^{f}	3.60	3.53	3.57^{f}
T_8	1.30	1.63	1.47^{ab}	0.69	0.73	0.71^{abcde}	0.78	0.75	0.77^{abcd}	2.27	2.57	2.42^{abcd}
T_9	1.47	1.90	1.68^{abc}	0.73	0.75	0.74^{bcde}	0.97	0.94	0.95^{ef}	2.57	2.70	2.63^{cde}
T_{10}	1.37	1.53	1.45^{a}	0.56	0.50	0.53^{a}	0.67	0.54	0.61^{a}	1.33	1.73	1.53^{a}
T_{11}	1.27	2.07	1.67^{asbc}	0.67	0.75	0.71^{abcd}	0.71	0.95	0.83^{bcdef}	2.53	2.40	2.47^{bcd}
T_{12}	1.87	1.60	1.73^{abc}	0.95	0.60	0.77^{bcde}	0.99	0.76	0.88^{cdef}	3.47	3.53	3.50^{ef}
T_{13}	1.47	1.93	1.70^{abc}	0.87	0.93	0.90^{de}	0.87	1.00	0.93^{def}	2.10	2.07	2.08^{abc}

For treatments, see Table 1.

Mean values in each column with the same letters are not significantly different according to Tukey's HSD test at $p < 0.05$. Superscripted lowercase letters depict the individual treatment effect.

mushroom compost (1:1)] which was at par with T_4 [spent mushroom compost (100 %)] i.e., 0.68 cm and 0.62 g, respectively.

Number of roots per scale

The highest number of roots per scale (4.90) were recorded in bulblets raised in perlite + cocopeat (100 %) [T_5] (Table 3). In contrary, the lowest number of roots per scale (1.53) were recorded in T_{10} [cocopeat + spent mushroom compost (1:1)] which was at par with T_4 [spent mushroom compost (100 %)] (1.68).

Biochemical analysis

Starch content (mg/g fresh weight)

The growing media compositions significantly influenced total starch content and total soluble sugars (mg/g) in the bulblets (Fig. 3). The maximum starch content (59.89 mg/g, 84.72 mg/g and 106.11 mg/g) was recorded in the bulblets raised in T_5 [perlite + cocopeat (1:1)] which was at par with T_{12} [cocopeat + perlite + perlite (1:1:1)] (58.16 mg/g, 83.07 mg/g and 103.39 mg/g) after 2, 4 and 6 months, respectively. In contrast, minimum starch content (43.56 mg/g, 64.93 mg/g and 84.0 mg/g) was recorded in the bulblets raised in cocopeat + spent mushroom compost (1:1) [T_{10}] which was found at par with T_4 [spent mushroom compost (100 %)] (44.58 mg/g, 66.76 mg/g and 85.38 mg/g) at bimonthly intervals, respectively.

Total soluble sugars (mg/g fresh weight)

The total soluble sugars were significantly influenced by different growing media compositions (Fig. 4). Maximum amount of total soluble sugars (34.27 mg/g, 50.02 mg/g and 71.28 mg/g) after 2, 4 and 6 months of planting, respectively, was recorded in the bulblets raised in perlite + cocopeat (1:1) [T_5] which was at par with T_{12} [cocopeat + spent mushroom compost + perlite (1:1:1)] i.e., 32.25 mg/g, 48.85 mg/g and 70.48 mg/g, respectively. However, the minimum amount of total soluble sugars (21.25 mg/g, 31.03 mg/g and 55.88 mg/g) was recorded in the growing media composition T_{10} [cocopeat + spent mushroom compost (1:1)] which was at par with T_4 [spent mushroom compost (100 %)] i.e., 22.34 mg/g, 35.63 mg/g and 56.34 mg/g after the same intervals.

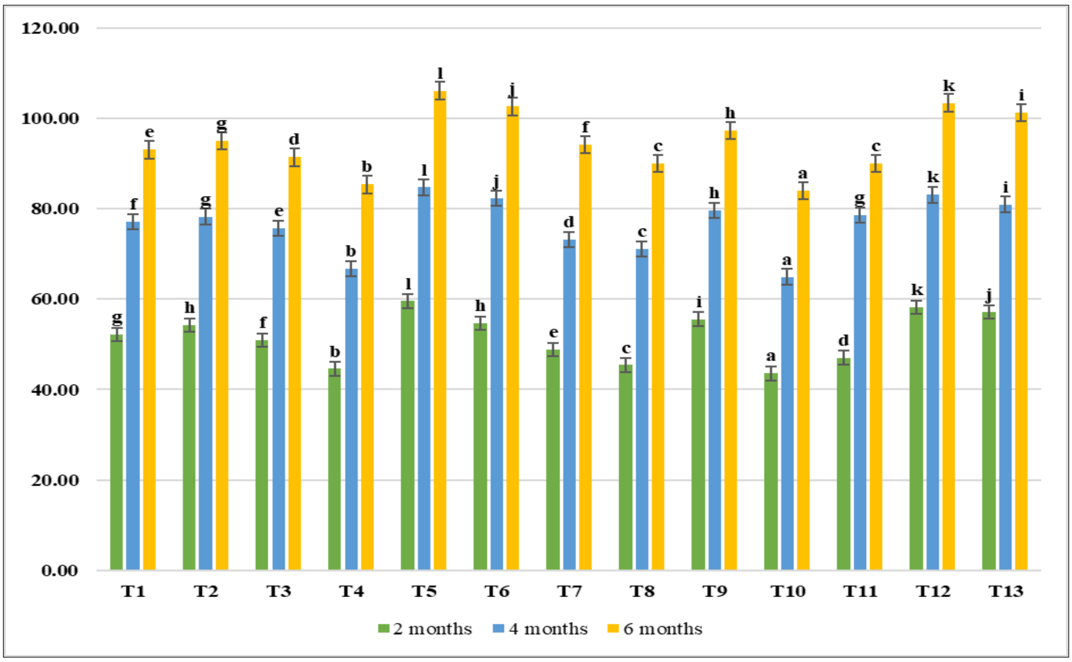

Fig. 3. Effect of different growing media compositions on starch content (mg/g fresh weight) in bulblets at bimonthly intervals.

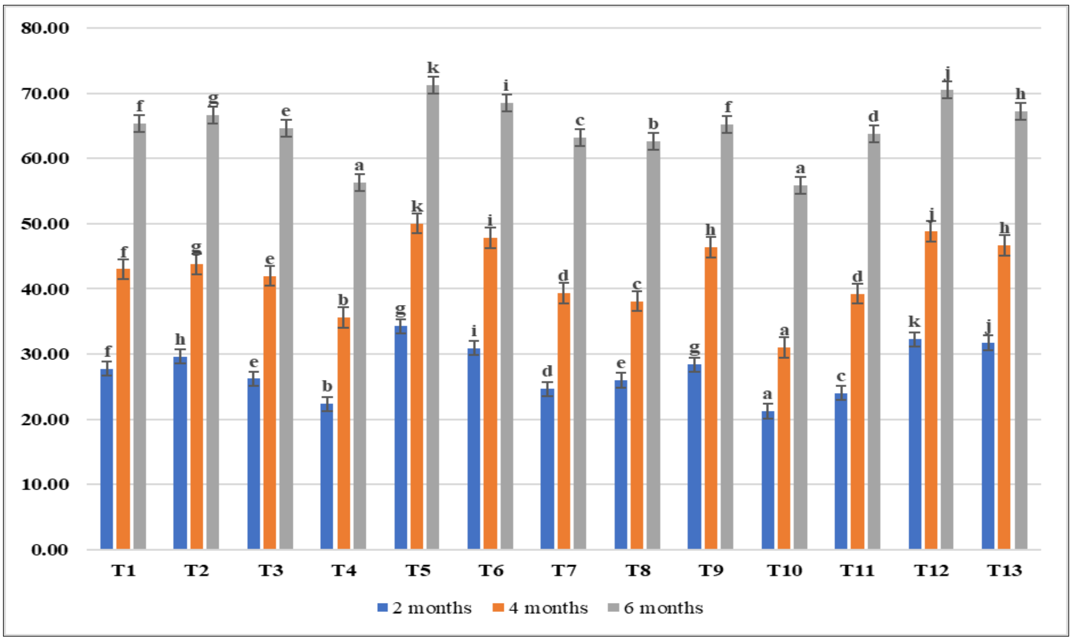

Fig. 4. Effect of different growing media compositions on total soluble sugars (TSS) (mg/g fresh weight) in bulblets at bimonthly intervals.

Comparison of the growing media compositions

All the media compositions showed significant variations with respect to their pH and electrical conductivity (mS cm^{-1}) (Table 1). It has been found that before the experiment was initiated, maximum pH (7.8) was recorded in the media composition T_{10} whereas, T_{13} recorded the lowest value (6.2). However, after the completion of experiment, when the pH was analysed, there was a drastic change which might be due to the external application of irrigation water and nutrients and most of the treatments recorded significantly higher pH values. The growing media composition T_3 recorded the highest pH (8.62), whereas, T_5 recorded the lowest value of pH (7.53) which falls in the suitable range for optimal growth of bulblets.

The highest value of electrical conductivity (mS cm^{-1}) before the start of the experiment was recorded in the growing media composition T_{10} (1.93 mS cm^{-1}) followed by T_4 (1.87 mS cm^{-1}), whereas, T_3 recorded the minimum value of EC (0.16 mS cm^{-1}) followed by T_{13} (0.18 mS cm^{-1}). After the completion of growth period, highest EC was observed in T_{10} (2.76 mS cm^{-1}) followed by T_4 (2.56 mS cm^{-1}) and the minimum values for the same were recorded in T_3 (1.38 mS cm^{-1}) followed by T_{11} (1.42 mS cm^{-1}). The initial pH and electrical conductivity (EC) are crucial properties of the growing medium since they indicate the inherent nutrient status of the medium.

In terms of other physico-chemical properties of the media (Table 1), the highest water holding capacity (89.40 %) was recorded in T_{10} which explains the compaction and hence, lowest porosity (26.32 %) of the same media. However, lowest values for the same i.e., 52.6 % and 37.21 % were recorded in T_9 and T_7, respectively. Additionally, Fig. 2 illustrates the values for other properties of the media. It was observed that maximum values for bulk density (0.53 g/cm^3) and particle density (0.78 g/cm^3) were recorded in T_4 and T_{13}, respectively while the lowest values were recorded in T_2 (0.095 g/cm^3) and T_{10} (0.19 g/cm^3), respectively. Again, highest available nitrogen (1.7 %), was recorded in T_4 and phosphorus (0.87 %) and potassium (1.26 %) were recorded in T_1, respectively while, the lowest values for the same were recorded in T_2 (0.02 % N, 0.01 % P and 0.01 % K).

For enhanced bulblet multiplication from scales in Lilium, the choice of growing medium plays the most important role in providing physical support, aeration, water and nutrient availability and maintaining overall scale health. The soilless growing mediums comprising of cocopeat, perlite, vermiculite and spent mushroom compost in varying ratios have proved their credibility in promoting bulblet growth and differentiation in varying rates. The media comprising cocopeat + perlite (1:1) outperformed all other media combinations and produced bulblets of the highest quality, whereas, the use of spent mushroom compost (100 %) proved least effective yielding inferior quality bulblets. The results of this study render spent mushroom compost unsuitable for scale propagation of Lilium. Earlier studies (16) have also highlighted the limitations of spent mushroom compost as a standalone growing medium in microgreens, due to its poor aeration, high salt content and suboptimal nutrient balance, which adversely affects growth and development of plants.

Further, for rapid multiplication of bulblets from scales, a growing medium with good water-retention and ventilation is desirable (17). Perlite + cocopeat (1:1) makes an excellent medium with optimal properties and aeration for growth of bulblets from scales. Also, the ability of cocopeat being a good insulating agent could have resulted in higher temperature of media mixture than others, resulting in a positive effect on earlier sprouting and bulblet formation of *Lilium* scales; as confirmed in the previous study (18) in *Alstroemeria* spp. cv. 'Serena'. Perlite and vermiculite were also shown as superior substrates for scale propagation of *Hippeastrum vittatum* (19). Additionally, high salt content present in spent mushroom compost hinders water uptake and reduces germination and subsequent sprouting (20).

The leaf length showed a decreasing trend with increased water holding capacity (R = -0.15) of the media. However, an increase in the porosity of the media was directly proportional to the length of leaves (R = 0.47) (Fig. 5). This shows that water holding capacity and porosity of the media are important parameters which affect the bulblet growth and development. Also, increased leaf length in T_5 media composition might be due to the early production of bulblets and subsequent sprouting, leading to accumulation of storage carbohydrates in the bulblets which when transported to the developing meristems might have contributed to the production of longer leaves. Further, the increased availability of nutrients like nitrogen and phosphorus present in cocopeat to the developing bulblets might have resulted in significantly better vegetative growth in terms of increased leaf length. Similar results have also been reported in the previous studies in *Lilium* (21) and in *Alstroemeria hybrida* (22) where the longest leaves were recorded in the bulblets and rhizomes raised in cocopeat-based media. Also, reduced growth due to high salinity and compaction was observed in marigold seedlings raised in fresh spent mushroom compost (23).

The selection of suitable culture medium (in terms of moisture preservation and adequate aeration) is of particular importance in bulblet growth and cell differentiation (24). The increased bulblet formation in T_5 and T_1 could be attributed to higher moisture holding capacity (R = 0.21) and good aeration (R = 0.55) of perlite + cocopeat (1:1) media (Fig. 5). Also, the presence of cocopeat in media mixtures as an organic media amendment having low bulk density keeps the media moist with perlite making it porous, which favours bulblet development. Additionally, the weight and diameter of bulblets were directly correlated to the water holding capacity (R = 0.15, 0.22) and porosity (R = 0.059, 0.18) of media in which they were raised (Fig. 5). These results are in close conformity (25) in *Lilium* where bulbs of larger size and weight were recorded in the media containing cocopeat which might be due to the inherent ability of cocopeat to assimilate more food reserves resulting in an increase in the number, size and ultimately the weight of bulblets. Furthermore, the promising bulb traits in *Lilium* could be attributed to the superior physical, chemical and biological properties of media containing cocopeat combined with perlite and vermiculite, which provide a favourable root environment for the optimal growth of bulbs and bulblets (26, 27). Apart from this, addition of perlite to cocopeat lowers the compaction, further preserving pore space and stabilizing hydraulic conductivity. Also, the inert nature of perlite moderates the nutrient binding ability of cocopeat, leading to enhanced nutrient availability to the developing bulblets (6).

The number of roots were negatively correlated with the water holding capacity (R = -0.01) and positively correlated (R = 0.49) (Fig. 5) with the porosity of the media. This might be due to more compaction of media which hindered root growth. The production of greater number of effective roots per scale in T_5 might be due to favourable physical and chemical characteristics of the growing media which promoted the formation of fleshy storage roots

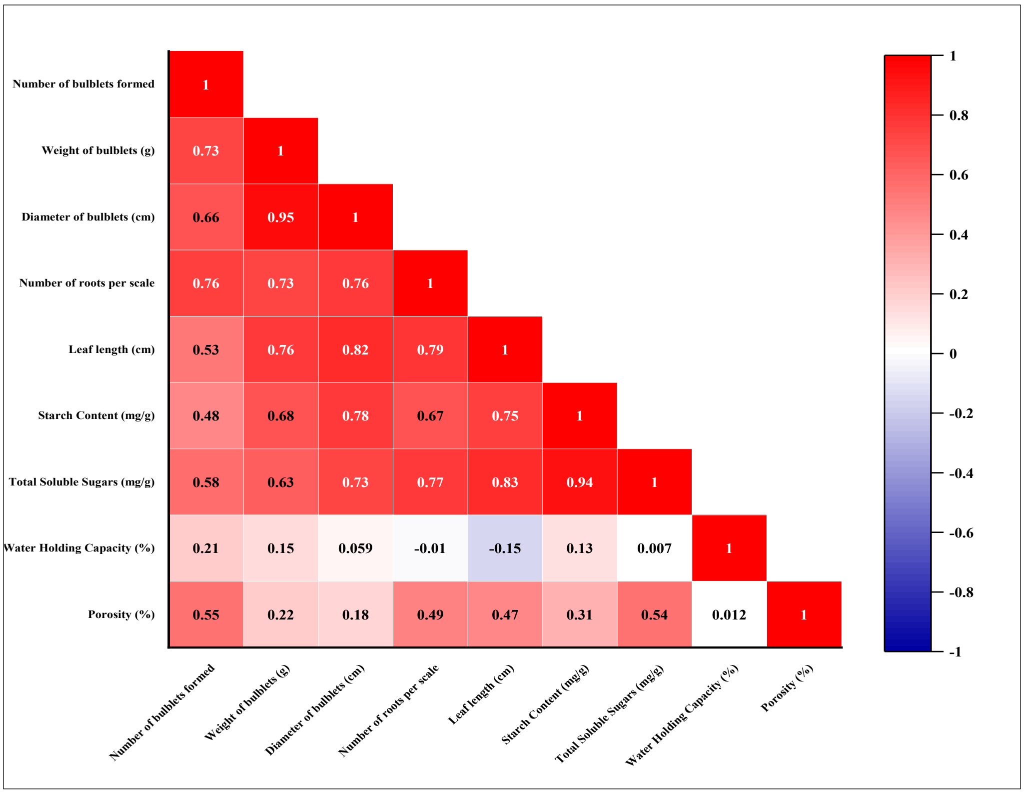

Fig. 5. Correlation between different variables of bulblet growth and properties of growing media.

leading to accumulation more nutrients and water for better bulblet development. Further, addition of perlite to cocopeat media causes a buffering in root zone temperature, offering both organic and inert microhabitats, thereby improving moisture and EC distribution throughout the substrate. Similar results were also obtained in the previous research (28) in *Lilium* where a greater number of roots were recorded when scales were raised in cocopeat-based media.

The bulblet filling process is characterized by the gradual accumulation of starch, which can be used as a nutrient reserve in later growth stages (29). Similar results were also reported in the previous study (30) in *Lilium davidii* var. unicolor where the starch content in the developing bulblets increased circumspectly during the growing period especially at the late developmental stage. The starch content showed a positive correlation with the water holding capacity (R = 0.13) and porosity (R = 0.31) (Fig. 5) of the media. Better nutrient and water availability in some growing media compositions resulted in earlier bulblet formation which might have resulted in early and increased accumulation of starch in the bulblets as compared to other media composition treatments.

Carbohydrates (sugars) are essential for the morphogenesis and growth of bulblets in lily scale cutting. A steady increasing trend was observed for total sugars as the growth of bulblets superseded. Similar findings have also been reported in the previous study (31) in *Lycoris radiata* where it was proposed that the total soluble sugars increased as the newly formed bulblets gradually developed. The soluble sugars derived from the mother scales were transported to the zones where bulblet was initiated, supporting the subsequent development of bulblets. Early bulblet formation accompanied by sprouting might have led to conversion of starch into soluble sugars for growth. The scales raised in media having good physical properties showed early bulblet formation which is a sign of promoted starch accumulation and its subsequent conversion to soluble sugars. The sugars were directly correlated with water holding capacity (R = 0.007) and porosity (R = 0.54) of the media (Fig. 5). Also, the developing leaves undergoing photosynthesis might have produced carbohydrates which then transported to the developing bulblet to be utilised as starch which would then breakdown to sugars for subsequent growth of bulblets. Further, the delayed bulblet formation in spent mushroom compost might have led to slower starch accumulation which might have imposed an additional constrained bulblet growth.

Consequently, it was determined that the bulblet is an energy sink tissue for reproduction through scales in which starch and sucrose are mobilized for photosynthetic organs and are broken down to sugars, which function as a precursor to essential metabolites. These results are in accordance with the findings with earlier studies (30) in *Lilium davidii* var. unicolor. It was established that starch is crucial for bulblet emergence and development while sugars are essential for bulblet morphogenesis (32).

Further, the high difference in pH within the treatments before and after the growth of bulblets was complete might be due to the higher accumulation of salts. In contrast, reduced accumulation of salts during the growth period of bulblets due to the larger particle size, porosity and drainage of the media explains the low difference within the same treatment for pH. The acceptable range of initial pH should be 5.8-6.5 and that of EC of a good soilless media should be between 0.4 and 1.5 mS cm^{-1} (4). These results are in accordance with the results recorded in this experiment which explain the desirable results with respect to vegetative and bulb parameters in T_5 [perlite + cocopeat (1:1)] in the media composition having good drainage and less compaction as compared to all other growing media treatments. Also, the diversified compositions of growing media have had a profound effect on physical, chemical and biological properties of the substrate and these parameters influence plant growth and development by affecting nutrient availability, water availability and aeration of substrate (18).

Conclusion

Therefore, the present findings suggest that for quality bulblet formation from scales in *Lilium* (*Lilium hybrida* L.), a porous and well-drained growing media composition consisting of perlite + cocopeat (1:1) was found the most effective for promoting better bulblet growth under north-western plains of India. However, there is still a scope of optimizing suitable growing media compositions tailored to the specific morphological and physiological requirements of different groups of Lilium (Asiatic, Oriental, etc), validating performance across agro-climatic zones and elucidating rhizosphere-microbial interactions to further enhance bulblet yield and quality.

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Authors' contributions

RS, PS and DC conceived of the study and participated in its design and coordination. DC carried out the execution of lab/field experiment and data collection. DC and RS caried out the analysis of data and interpretation. DC, RS and PS did the preparation of manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

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

Ethical issues: None

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