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Bulb and bulblet production of *lilium* influenced by planting materials and shade conditions

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ABSTRACT

An experiment was conducted at Floriculture Research Field, Horticulture Research Centre, Bangladesh Agricultural Research Institute during August 2020 to June 2021 to evaluate bulb and bulblet production of Lilium with two propagating materials under three shade conditions. A Completely Randomized Design (CRD) was used with two factors: planting materials (bulblets and scales) and three shade conditions: greenhouse (55% sunlight reduction), UV polyhouse (50% sunlight reduction), and polycarbonate sheet house (70% sunlight reduction). Bulblet-derived plants produced significantly longer roots (13.65 cm), more bulbs per hill (0.85), and the heaviest (5.42 g) and largest (2.0 cm) bulbs. The UV polyhouse yielded the highest root count per plant (8.07), maximum leaves at 90 and 120 days after transplanting (12.25 and 17.64), maximum number of bulbs/hill (1.13), the heaviest and largest bulb (8.34 g & 2.82 cm). The polycarbonate sheet house promoted the longest roots (14.18 cm) and tallest plants (13.50-16.98 cm) started from transplanting to 150 days after transplanting. Greenhouse conditions favored bulblet formation, with the highest number (3.43) and weight (3.05g) per hill. Overall, using bulblets in a UV polyhouse gave the best performance across key growth and yield traits.

Key words: Bulb, bulblet, *lilium*, scale, shade conditions.

INTRODUCTION

Lilium, belongs to the family *Liliaceae* is a high demanded cut flower in international flower trade due to its wide diversity of color, attractive shape, multi-flowering stalk, and having long post-harvest vase life (Lucidos *et al.*, 2013). The importance of this flower in the world flower market is due to diversity and availability of large number of commercial hybrids and other cultivars. This lucrative flower is recently being imported in Bangladesh from other countries especially from China to meet up the demand of the local users and is selling in the market with high price (150-200 BDT/stick) (Khan and Ambia, 2018). Research on *lilium* flowers showed that this flower is possible to cultivate in Bangladesh successfully. Farmers are also interested to cultivate this flower but due to unavailability and high cost of *Lilium* bulbs (60-80 BDT/bulb), commercial cultivation has not been popularized yet.

Availability of a large quantity of bulbs is one of the prerequisites for commercial cultivation of *lilium* flower. Normally this flower propagated asexually by natural formation of daughter bulbs, by axillary bulblets developed in the axils of leaves, stem bulblets and through scales. A single bulb normally produces one or two daughter bulb and with average of five to eight bulblets in each season. Due to a very low rate of natural multiplication of its bulb and bulblet, the result is non-availability of enough planting materials. To mitigate this problem, multiplication of bulbs through improved techniques may play an important role. Various planting materials like bulblet, scales, etc. are very important for producing initial stock of *lilium* bulbs. Van Aartrijk *et al.* (1990) reported that the main constraints in conventional propagation of *lilium* include the inadequate availability of healthy, disease-free planting material, and slow multiplication rates.

The conventional method of propagating *Lilium* involves scaling yields at most three to five bulbs from each scale, depending on the bulb scale size and species or variety. Thus scaling a bulb yields somewhere between 50 and 100 bulblets, to meet the present demand for planting material (Varshney *et al.*, 2000). Moreover, the growth of plant, bulb and bulblets are influenced by various growing conditions like shade, temperature, humidity etc. *Lilium* grow best under moderate temperatures (20-25°C day, 10-15°C night), while heat stress negatively affects development and flower quality. The higher temperature produced a dwarf crop with a smaller number of flower buds per stem. The plants should not be grown under direct sunlight. Filtered light is crucial; shade netting that reduces sunlight by 50-75% enhances vegetative growth, plant health, and bulb development (Thangam *et al.*, 2016). Carbohydrate availability and temperature also influence bulblet initiation, with optimal sucrose levels and controlled conditions being key factors (Kumar and Kanwar, 2006). So, suitable propagating material with appropriate growing condition is much important to produce quality bulbs of *lilium*.

Out of many factors affecting the growth and development of *lilium* flower from bulbs and bulblets, planting materials and growing conditions are equally important. By adopting efficient propagation methods and managing environmental conditions, *lilium* could emerge as a high-value crop, supporting farmer's income and rural livelihoods as well. There is little evidence on literature about propagating materials grown under appropriate growing condition on quality bulb production of *lilium* in Bangladesh. Considering the aforementioned situation, the present investigation was carried out with following objective

i. To standardize the suitable planting materials under optimum shade condition for quality bulb production in *Lilium spp.*
ii. To enhance the availability of quality propagating materials for commercial cultivation of *lilium* in Bangladesh.

MATERIALS AND METHODS

The experiment was conducted at Floriculture research field, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701 during August 2020 to June 2021. A two-factor pot experiment was arranged in a Completely Randomized Design (CRD) with three replications. The two factors were:

- Factor A - Planting materials
  A_1-: Bulblets
  A_2-: Scales
- Factor B - Growing conditions
  B_1-: Greenhouse

B_2-: UV polyhouse

B_3-: Polycarbonate sheet house

The *Lilium* bulblets (0.5-2.5 cm diameter) derived naturally at the base of mother bulb in the leaf axils and two layer outer scales of bulb were taken as planting materials. Besides, various shade house like greenhouse (containing 20-22°C day and 14-18°C night temperature, 70% relative humidity) which reduces 55% sunlight, UV poly-house covered with UV-stabilized polyethylene film which reduces 50% sunlight and polycarbonate sheet house which reduces 70% sunlight due to prolong aging and lack of cleanliness.

Planting materials were initially sown in cork sheet boxes [45 cm (length) × 25 cm (width) × 24 cm (depth)] filled with a growing medium of 75% coco dust, 25% soil and compost. Bulblets and scales were placed near the surface and lightly covered, then set under their respective growing conditions. After one month, the plantlets were transplanted into 36-hole plastic trays (one plant per hole) and later moved to 10-inch pots (three plants per pot) for further development. Flower buds were removed throughout the growing period to promote vegetative growth and bulb formation. Standard intercultural operations, including regular watering, weeding, and straw mulching during high temperatures, were maintained. Protective measures were taken to prevent animal damage. Though *Botrytis* blight is common in *Lilium*, no significant incidence occurred. Preventative spraying with Autostin (1 g/L water) was done, along with periodic applications of neem oil and Biomax (1 mL/L water) to manage insect pests.

Data were collected from five randomly selected plants at each stage from cork sheet boxes, trays, and pots. Bulbs and bulblets were harvested only after full leaf senescence indicated physiological maturity. After harvesting, planting materials were stored in cold conditions at 2.1-2.4°C and 85-91% relative humidity. All quantitative data were statistically analyzed using R software. Treatment means were compared using Tukey's Honest Significant Difference (HSD) test, following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Establishment and Root Growth Characteristics of Lilium

The establishment and root growth of *Lilium* were significantly influenced by planting materials and various shade conditions (Table 1). Among planting materials, only root length at the transplanting stage (from cork sheet boxes to trays) showed a significant differences. Plants from bulblets had the longest roots (13.65 cm), significantly longer than those from scales (11.38 cm). While other parameters were not statistically different, bulblet-derived plants showed better trends in germination (92.59%), survival (98.99%), and root number per plant (7.52), indicating greater physiological maturity and root initiation potential, consistent with Lazare and Zaccai (2016), who observed effective vegetative propagation in *Lilium longiflorum* via underground bulbs. Various shade conditions significantly influenced all parameters except germination percentage. The highest survival rate (100%) was recorded in greenhouse and UV polyhouse environments; significantly the lowest (95.46%) was in the poly carbonate sheet house. The UV polyhouse produced the maximum root number per plant (8.07), followed by the poly carbonate sheet house (7.63), and the green house produced the minimum (6.43). Conversely, the longest roots (14.18 cm) developed in the poly carbonate sheet house followed by root development in the green house (12.75 cm) whereas the plants grown in the UV poly house produced the shortest root (10.63cm). This may

Table 1: Establishment and root growth characteristics of *Lilium* as influenced by planting materials and shade conditions.

Treatments	Germination (%)	Survival (%)	Root number/ Plant	Length of longest root (cm)
Planting materials				
Bulblet (A_1)	92.59 (9.61)	98.99 (9.94)	7.52	13.65a
Scale (A_2)	89.82 (9.47)	97.98 (9.89)	7.23	11.38b
Level of significance	NS	NS	NS	**
Shade conditions				
Greenhouse (B_1)	93.06 (9.64)	100a (9.99)	6.43b	12.75a
UV poly house (B_2)	93.06 (9.64)	100a (9.99)	8.07a	10.63b
Polycarbonate sheet house (B_3)	87.50 (9.35)	95.46b (9.76)	7.63ab	14.18a
Level of significance	NS	*	*	**
CV (%)	3.04	1.47	10.48	8.26

Means with the same letter (s) are not significantly different at 1% by LSD; Figures in parentheses are transformed values; ** and * are significant at 1% and 5% level respectively, NS = Not Significant

Table 2: Establishment and root growth characteristics of *Lilium* as influenced by the combined effect of planting materials and shade conditions.

Treatments	Germination (%)	Survival (%)	Root number	Length of longest root (cm)
A_1B_1	94.45 (9.71)	100 (9.99)	6.47	13.97
A_1B_2	94.45 (9.71)	100 (9.99)	8.33	11.25
A_1B_3	88.89 (9.42)	96.97 (9.84)	7.75	15.73
A_2B_1	91.67 (9.57)	100 (9.99)	6.4	11.53
A_2B_2	91.67 (9.56)	100 (9.99)	7.8	10.0
A_2B_3	86.11 (9.28)	93.94 (9.68)	7.5	12.62
Level of significance	NS	NS	NS	NS
CV (%)	3.04	1.47	10.48	8.26

Figures in the parentheses are transformed values; NS = Not Significant
A_1=Bulblet, A_2=Scale, B_1=Greenhouse, B_2=UV poly house, B_3=Poly carbonate sheet house

be due to that the higher shade levels may stimulate root elongation indicating poly carbonate sheet house reduces the highest (70%) sun light and UV poly house reduces the lowest sun light (50%). Moreover, the maximum number of roots/plants found in the UV poly house may regulate the shortest root. These findings may indicate that while planting materials had limited influence on early vegetative growth, shade conditions, particularly light intensity and microclimate, strongly affected root development and plant survival. Optimizing both factors is essential in improving propagation efficiency and bulb development in *Lilium*.

All the parameters didn't show statistically significant variation among the treatment combinations (Table 2). However, the bulblet + UV polyhouse combination consistently outperformed others. This may be due to the bulblets' greater initial size and vigor compared to scales, coupled with the UV polyhouse's favorable microclimate, which offers sufficient light while shielding plants from harmful radiation.

Vegetative performance of Lilium as influenced by planting materials and shade conditions

Plant height : Plant height showed no significant differences until 120 and 150 days after transplanting (DAT) by the planting materials (Figure 1), when plants from bulblets were significantly taller (15.83 cm at 120 DAT and 15.96 cm at 150 DAT) than those from scales (13.94 cm and 14.04 cm, respectively). Although earlier differences were not statistically significant, bulblet-derived plants consistently outperformed those from scales. Shade conditions significantly affected plant height at all intervals (Figure 2). The tallest plants (16.98 cm) at 150 DAT were observed under the poly carbonate sheet house, followed by the greenhouse (15.43 cm), suggesting that reduced

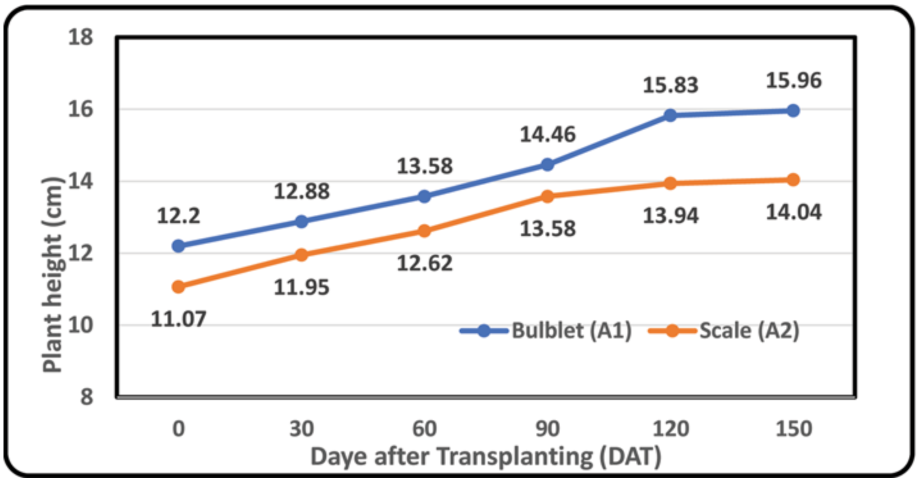


Fig. 1: Height of *Lilium* plant at different days after transplanting influenced by planting materials.

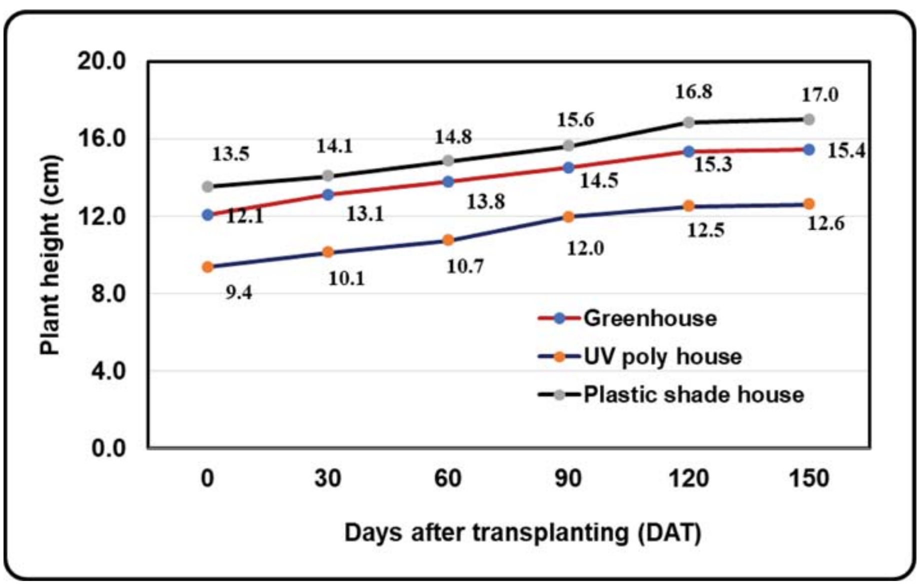
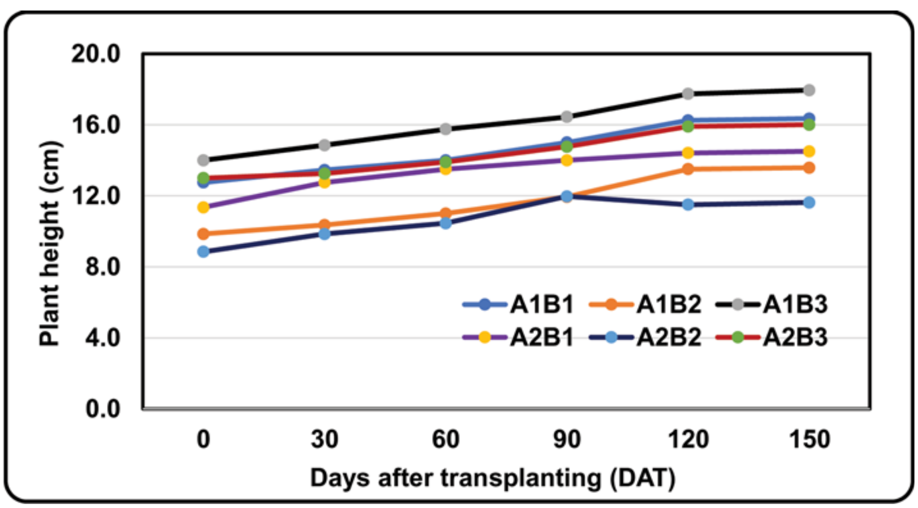


Fig. 2: Height of *Lilium* plant at different days after transplanting influenced by shade conditions.

light may have induced elongation as plants stretched toward available light. In contrast, plants in the UV polyhouse were shorter but performed better overall in other growth and yield traits, indicating a more favorable balance of light and environmental conditions. Similar findings were recorded by Khan *et al.* (2023) where they reported Black net shade which reduced more sun light, produced the longest plant. This may be due to the competition occurred within plants for sun light resulting longer plants.

Plant height at various intervals was not significantly affected by the interaction between planting materials and shade conditions (Figure 3). However, the combination of bulblets and a Polycarbonate sheet house consistently produced the tallest plants started during transplanting to 150 DAT (14.0 cm to 17.95 cm). This may be result from the reduced light intensity promoting stem elongation under shade. As noted by Kittas *et al.* (2009), shade houses enhance light diffusion and ventilation while minimizing heat stress, thereby supporting favorable conditions for vegetative growth in many species. Miao and Michael (2014) reported that shade cloth significantly affected plant growth and development when a field study was designed to evaluate the growth and development of *Lilium* hybrids treated with natural full sun, 50% black shade cloth and 50% aluminet shade cloth. The stem length was significantly greater for *lilium* grown under 50% aluminate shade cloth (47.3 cm) followed by 50% black shade cloth (45.3 cm) compare to natural full sun (34.7 cm) which supported the present findings.

Leaf number : Leaf number measured at different intervals after transplanting did not differ significantly between the two planting materials (Table 3). However, bulblet-propagated plants consistently showed higher leaf numbers across all stages. This may be due to the bulblets' larger size and nutrient reserves, which enhance early vegetative vigor and support maximum leaf number. As preformed organs, bulblets are physiologically more advanced than scales, giving them a growth advantage. Lazare and



A_1=Bulblet, A_2=Scale

B_1=Greenhouse, B_2=UV Poly house, B_3=Polycarbonate sheet house

Fig. 3: Height of *Lilium* plant at different days after transplanting influenced by the combined effect of planting material and growing conditions.

Table 3: Leaf number of *Lilium* plants on different days after transplanting as influenced by planting materials and growing conditions.

Treatments	Leaf number					
	During transplanting	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
Planting materials						
Bulblet (A_1)	2.75	4.78	7.80	11.48	17.07	17.25
Scale (A_2)	2.72	4.53	7.42	11.03	16.63	16.70
Level of significance	NS	NS	NS	NS	NS	NS
Growing conditions						
Greenhouse (B_1)	2.49	4.05	6.93	10.27b	16.05ab	16.13
UV poly house (B_2)	2.98	5.13	8.38	12.25a	17.64a	17.75
Polycarbonate sheet house (B_3)	2.75	4.80	7.53	11.23ab	16.88ab	17.05
Level of significance	NS	NS	NS	**	*	NS
CV (%)	34.25	17.03	12.53	6.17	5.47	6.27

** and * are significant at 1% and 5% level of significance, respectively, NS = Not Significant.

Zaccai (2016) similarly noted that *Lilium longiflorum* propagates efficiently through bulblets, a strategy that promotes plant establishment and enhances vegetative traits like leaf number and overall vigor.

Leaf number at different intervals after transplanting did not vary significantly among growing conditions, except at 90 and 120 DAT (Table 3). At 90 DAT, the plants under the UV polyhouse had the maximum leaf number (12.25), followed by the Polycarbonate sheet house (11.23). Almost similar pattern was seen at 120 DAT, with the UV polyhouse producing 17.64 leaves per plant followed by the plants under Polycarbonate sheet house (16.88) and greenhouse (16.05). These results indicated that the UV polyhouse provided a more favorable environment for vegetative growth compared to other conditions. This aligns with Thangam *et al*. (2016), who found that 50-75% shade enhanced leaf development in ornamentals like lilies. The UV polyhouse likely achieved an optimal balance of light transmission and protection from solar radiation, reducing heat stress and improving photosynthesis. In contrast, more shading in the polycarbonate sheet house may have slightly limited light availability, though it still outperformed the greenhouse in supporting foliage growth. Kittas *et al.* (2009) also noted that excessive shading can suppress leaf production and lead to elongation. However, in this study, moderate shading under UV polyhouse conditions proved most beneficial. Although Lazare and Zaccai (2016) did not specifically assess leaf number, they emphasized the importance of controlled environments for maximizing vegetative propagation in *Lilium*, supporting the current findings.

While no significant interaction effects between planting materials and growing conditions were observed for leaf number at different interval of DAT (Table 4), the bulblet + UV polyhouse combination consistently showed superior leaf development across all stages. This performance likely results from the combined advantages of bulblet vigor and the microclimatic benefits of the UV polyhouse. UV-stabilized shade structures help buffer against abiotic stresses such as intense sunlight, while improving temperature regulation (Teitel *et al.,* 2008). These factors collectively

Table 4: Number of Lilium leaves at different days after transplanting as influenced by the combined effect of planting materials and growing conditions.

Treatments	Leaf number					
	During transplanting	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
A_1B_1	2.50	4.25	7.00	10.45	16.45	16.50
A_1B_2	3.00	5.25	8.75	12.50	17.78	18.00
A_1B_3	2.75	4.85	7.65	11.45	17.00	17.25
A_2B_1	2.47	3.85	6.85	10.10	15.65	15.75
A_2B_2	2.95	5.00	8.00	12.00	17.50	17.50
A_2B_3	2.75	4.75	7.40	11.00	16.75	16.85
Level of significance	NS	NS	NS	NS	NS	NS
CV (%)	34.25	17.03	12.53	6.17	5.47	6.27

NS=Not Significant; A_1=Bulblet, A_2=Scale; B_1=Greenhouse, B_2=UV poly house, B_3=Polycarbonate sheet house

create optimal conditions for robust vegetative growth in *Lilium*.

Bulb and bulblet production of Lilium : Planting materials showed no significant differences in most bulb and bulblet traits, except for bulb number per hill and bulb weight (Table 5). Bulblets produced significantly more bulbs per hill (0.85) than scales (0.73), aligning with Van Aartrijk *et al.* (1990), who reported better bulb formation from bulblets in *Lilium*. Bulblets also yielded the heaviest bulbs (5.42 g), compared to 4.49 g from scales, indicating their superior performance as propagation material. Though other parameters didn't show significant variations, but bulblets showed better performances. Shade conditions significantly influenced all measured parameters (Table 5). The UV polyhouse yielded the highest number of bulbs per hill (1.13), the heaviest and largest bulbs (8.34 g and 2.82 cm). In contrast, greenhouse-grown plants produced the fewest, lightest and smallest bulbs (0.50 bulbs/hill, 0.50g weight, and 0.50g diameter) but the maximum number and weight of bulblets per hill (3.43 and

Table 5: Bulb and bulblet production of *Lilium* as influenced by the main effects of planting materials and growing conditions.

Treatments	Bulb number/hill	Bulb weight (g)	Bulb diameter (cm)	Bulblet number/hill	Bulblet weight (gm)
Planting materials					
Bulblet (A_1)	0.85a	5.42a	2.0	2.98	2.85
Scale (A_2)	0.73b	4.49b	1.91	2.87	2.69
Level of significance	*	*	NS	NS	NS
Growing conditions					
Green House (B_1)	0.50c	0.50c	0.50c	3.43a	3.05a
UV poly house (B_2)	1.13a	8.34a	2.82a	2.73b	2.73b
Polycarbonate sheet house (B_3)	0.75b	6.03b	2.55b	2.61b	2.53b
Level of significance	**	**	**	**	**
CV (%)	12.23	15.47	7.09	8.91	6.46

** and * are significant at 1% and 5% level of significance, respectively, NS = Not Significant.

Table 6: Bulb and bulblet production of *Lilium* as influenced by the main effects of planting materials and growing conditions.

Treatments	Bulb number/hill	Bulb weight (g)	Bulb diameter (cm)	Bulblet number/hill	Bulblet weight (gm)
A_1B_1	0.50c	0.50	0.50	3.50	3.17
A_1B_2	1.29a	9.13	2.89	2.75	2.80
A_1B_3	0.77bc	6.64	2.61	2.68	2.58
A_2B_1	0.50c	0.50	0.50	3.37	2.93
A_2B_2	0.96b	7.55	2.73	2.71	2.67
A_2B_3	0.74bc	5.24	2.49	2.53	2.48
Level of significance	*	NS	NS	NS	NS
CV (%)	12.23	15.47	7.09	8.91	6.46

** and * are significant at 1 and 5% level of significance respectively, NS = Not Significant

A_1=Bulblet, A_2=Scale, B_1=Greenhouse, B_2=UV Poly house, B_3=Polycarbonate sheet house

3.05g, respectively). This suggests that the greenhouse environment favored bulblet formation over bulb development. These findings are consistent with Sharma *et al.* (2018), who highlighted the potential of protected cultivation for enhancing *Lilium* bulb production.

Interaction effects on bulb and bulblet production : No significant differences in bulb and bulblet production were observed due to the interaction between planting materials and growing conditions, except for the number of bulbs per hill (Table 6). The combination of bulblets grown under the UV polyhouse produced the maximum number of bulbs (1.29 per hill), while both planting materials under greenhouse conditions recorded the minimum (0.50 per hill). These findings align with Ranpise *et al.* (2007), who noted that shade nets not only reduce light intensity but also enhance vegetative growth, improve quality, and extend vase life in Spathiphyllum (Peace lily). Although other parameters were not statistically significant across treatment combinations, bulblets under UV polyhouse conditions consistently performed best, producing the heaviest (9.13 g) and largest bulbs (2.89 cm), highlighting the combined advantage of robust planting material and a favorable shade conditions.

CONCLUSION

This study highlights the significant influence of planting materials and shade conditions on the vegetative growth and propagation efficiency of *Lilium*. Bulblets consistently outperformed scales, demonstrating superior plant height, leaf number, root development, and notably, bulb yield and quality. Among the various shades tested, the UV polyhouse provided the most favorable microclimate, enhancing both vegetative vigor and bulb development. The combination of bulblets with UV polyhouse conditions yielded the highest number, weight, and size of bulbs, indicating a strong synergistic effect. Given the slow natural multiplication rate of *liliums*, this strategy presents a viable solution for improving commercial propagation in Bangladesh.

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