Vegetative propagation of Kusum (*Schleicheraoleosa*(Lour.) Oken) through air layering for the mass multiplication of quality planting stock

Abstract

Schleicheraoleosa(Lour.)Oken, locally known as kusumbelongs to the family Sapindaceae, is an important lac host tree, on which the lac insect (*Kerrialacca*), produces better quality lac, the kusmi lacStudy on vegetative Propagation of *kusum*was undertaken during 2014-17to generate quality planting stock through air layering in the Research Farm of the ICAR-Indian Institute of Natural Resins and Gums, Ranchi, Jharkhand. Sixteen phytohormone-medium combinations were taken for air layering, plus one already standardized for *litchi* as control, on *kusum* with 20 air layerings under each combination; 10 each with black polythene and 10 with transparent each year. The overall results revealed better rooting percentage during the pre-monsoon season (66 %) as compared to just 38 per cent during the monsoons, with black polythene in both seasons. During the pre-monsoon season, treatment combination with phyto-hormones in higher concentration (IBA: NAA: Kinetin as 3000:1500:150) with media (sand: silt: clay: vermi compost: Sphagnum moss = 2:1:1:1:1) resulted in cent per centrooting. This was followed by combination with IBA: NAA: Kinetin as 2000:1000:100 and Sphagnum moss (90 %), which also resulted in highest rooting percentage (90 %) during the monsoon season. The detached air-layeringwere hardened in the tree shade. Overall survival percentage of air-layerings was 32.76 per cent. The technique can be helpful in mass propagation of true to type planting stock from plus trees or elite trees identified for lac production, germplasm conservation and management.

Keywords: Air layering, clonal multiplication, *kusum*, lac productivity, tribal upliftment

Introduction

Schleicheraoleosa(Lour.)Oken, locally known as *kusum*belongs to the family Sapindaceae, is widely distributed across the globe, locally known as *pongro* in Combodia and France, gum lac tree in Filipino, *kasambi* in Indonesia and Sudan, *Kusambi* in Malaysia, *takhro* in Thailand and cy-van-rao in Vietnam. It is a multipurpose species, chiefly used for lac cultivation, besides providing timber, small durable wood for minor implements, fuelwood, tannins and dyes from bark, fodder from leaves (with crude protein 10.5%, nitrogen free extract 49% and crude fibre 32.5%), medicines from seeds (anti-ulcer) and bark (astringent) and oil from seed called*kusum* oil, constituting 59-72 % of the seed kernel, which is having multiple uses (Bhattacharya and Anees, 2013).

Comment [KP1]: The abstract provides an overview of the study, including the objectives, methodology, and key findings. However, it could be improved by explicitly mentioning the implications of the findings for lac cultivation and tribal upliftment. Additionally, the survival rate of 32.76% could be contextualized further to highlight areas for future improvement.

Comment [KP2]: Check the capitalizations

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Comment [KP8]: Standardized the word in the whole text: air-layering or air layering

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There are more than 113 species of lac insect host plants but *Kusum*is an important major lac host tree grown in India (Kumar and Kumar, 2013). The other major lac hosts include palas (*Buteamonosperma*) and ber (*Zizyphusmauritiana*)among trees, *Flemingiasemialata*, *F.macrophylla* and *Cajanuscajan* (pigeon pea) among shrubs. The kusmi strain of the lac insect, *Kerrialacca*, which produces the best quality lac in the world, thrives on the fresh twigs of the branches, settles there and secretes a covering of lac resin over itself, with two crops in a year, each of 6 months.

Genetic Improvement and mass multiplication of the improved planting stock (true to type) of lac hosts can prove a vital enhancing role for increased lac productivity, which in turn can have significant effect on the lac production and socioeconomic conditions of the lac cultivators. In kusum, there are two types of trees, *kariya* and *charka*, of which *kariya* is better suitable for lac production (Kumar and Kumar, 2013)and at early stages, the two are not easy to differentiate. The tree being slow growing in nature becomes suitable for lac cultivation after 15-20 years of plantation.The tree is propagated by seed and vegetative propagation. The seedlings propagated through seed are not true to type, thus vegetative propagation is the most important approach for production of true-to-type and better quality *kariya*seedlings for lac cultivation. The institute has selected plus trees across the state and neighboring states especially Odisha, West Bengal Madhya Pradesh and Chattisgarh, with higher lac insect survival and lac productivity.

But vegetative propagation of kusumhas not yet been successfully done with satisfactory results.Air layering is an important vegetation propagation technique, which can be helpful in elite host multiplication. In this technique, adventitious roots are inducted from the aerial portions of the stem while it is still attached to the mother plant.Besides generation of true-to-type quality planting material, it shall lead us a step ahead in germplasm conservation and establishment of clonal banks, vegetative multiplication garden and clonal seed orchard for the species in the long run.Keeping in view the need of the hour, the study was conducted at ICAR-Indian Institute of Natural Resins and Gums, Ranchi, Jharkhandfor three years with the objective of 'standardization of air layering technique for mass multiplication of quality planting stock in kusum (*Schleicheraoleosa*)'.

Comment [KP14]: check spelling

Comment [KP15]: check spelling

Comment [KP16]: standardized the word in the whole text: kusum or *kusum*

Comment [KP17]: spacing

Comment [KP18]: suggestion word: However

Comment [KP19]: The phrase "has not yet been successfully done with satisfactory results" is redundant. Instead, "has not yet yielded satisfactory results" is more concise.

Comment [KP20]: The use of "inducted" in "adventitious roots are inducted" is uncommon in this context. "Induced" is more appropriate.

Comment [KP21]: the generation

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Comment [KP24]: The transition between the problem and the study's objectives could be smoother. The phrase "Keeping in view the need of the hour" could be replaced with a more formal alternative.

Materials and Methods

For the standardization of the protocol, four different factors were considered, which included phytohormone to be applied, growing media to be used for wrapping over the exposed cambium layer, colour of polythene to be wrapped over the growing media and season of doing

the air layering procedure.Four phytohormone combinations comprising of Indole Butyric Acid (IBA), Naphthalene Acetic Acid (NAA) and Kinetin, four types of growing media (constituting sand, silt, clay,vermi-compost, sphagnum moss, decomposed farm yard manure), two colors of polythene: Black (B) and Transparent (T) and two seasons: Pre-monsoon and during Monsoon season were used. The details are given in the Table 1. So, in total 16 phytohormone-growingmediacombinations(T1M1, T1M2, T1M3, T1M4,T2M1, T2M2, T2M3, T2M4,T3M1, T3M2, T3M3, T3M4, T4M1, T4M2, T4M3, T4M4 besides control (already standardized for litchi) were used and under each treatment ten air layerings were done for both the seasons over the period. The air layerings were cut after 60 days and hardening of planting stock was done in the nursery before establishment in the field.

Table 1. Details of different phyto-hormone treatments and media used for air layering

Labels	:	Treatment component
T1	:	IBA: NAA: Kinetin @ 500:250:25
T2	:	IBA: NAA: Kinetin @ 1000: 500:50
T3	:	IBA: NAA: Kinetin @ 2000:1000:100
T4	:	IBA: NAA: Kinetin @ 3000: 1500: 150
M1	:	Sand : Silt: Clay: Cocopeat = 2: 1:1:1
M2	:	Sand : Silt: Clay: Vermicompost : Sphagnum moss = 2:1:1:1:1
M3	:	Sand : Silt: Clay: FYM= 2:1:1:1
M4	:	Sphagnum moss
Control	:	Pond silt, rottened jute bags/ leaf mould, neem cake, FYM, DAP, bone meal

The procedure involved removal of a ring of bark 2-3 cm width from a branch of 2-3 cm diameter, till the white cambium layer was clear. Then applied hormonal treatment with a brush, covered it with the rooting media and wrapped with polythene. Then the rooted airlayerings were detached after 60 days, and 3/4thfoliage was removed for hardening and planted in pots till the onset of next planting season under shade.

Experimental Results

The results (Table 2) revealed that overall rooting percentage during the pre-monsoon season was 66 per cent as compared to38per cent during the monsoons. During the pre-monsoon season, treatment combination T4M2 with phyto-hormones in higher concentration (IBA: NAA: Kinetin as 3000:1500:150 ppm) with media (sand: silt: clay: vermi compost: Sphagnum moss@2:1:1:1:1) resulted in cent per cent rooting. This was followed by T3M4 combination

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with IBA: NAA: Kinetin @ 2000:1000:100 ppm and Sphagnum moss with 90 per cent rooting, which also resulted in highest rooting percentage (90 %) during the monsoon season. Better rooting was observed while using black polythene (71%) over the transparent (55%) during the pre-monsoon and 42 % versus 31% (in transparent) during the monsoon season. During the pre-monsoon season, cent per centcallus formation was observed in T1M4, T3M2, T4M1, T4M2, besides control wherein rooting was very less unlike others. During the monsoon season, more callus formation was observed but less rooting resulted (Plates1-5)

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Table 2: Pooled data for the percentage of callus formation and successful rooting from different treatment combinations through air layering (B=Black; T = Transparent)

Comment [KP43]: recheck the format for the table's caption and include the percentage as a unit for data in the table

	Pre-monsoon season						During Monsoon season					
Treatment	Callus			Rooting			Callus			Rooting		
	B	T	Overall	B	T	Overall	B	T	Overall	B	T	Overall
T1M1	90	80	85	80	30	55	100	80	90	60	70	65
T1M2	100	90	95	90	80	85	100	100	100	0	0	0
T1M3	100	90	95	60	10	35	100	100	100	0	40	20
T1M4	100	100	100	70	80	75	100	100	100	20	0	10
T2M1	100	70	85	100	70	85	100	90	95	60	60	60
T2M2	90	50	70	90	40	65	100	100	100	0	0	0
T2M3	100	90	95	20	50	35	90	70	80	40	0	20
T2M4	90	10	50	80	10	45	70	90	80	50	40	45
T3M1	100	60	80	80	60	70	90	50	70	60	40	50
T3M2	100	100	100	100	50	75	100	100	100	90	30	60
T3M3	60	50	55	60	40	50	100	100	100	10	10	10
T3M4	100	80	90	100	80	90	100	100	100	90	90	90
T4M1	100	100	100	60	90	75	90	100	95	80	60	70
T4M2	100	100	100	100	100	100	90	40	65	80	40	60
T4M3	100	70	85	70	20	45	100	100	100	0	0	0
T4M4	80	100	90	50	90	70	100	100	100	40	50	45
Control	100	100	100	0	40	20	100	100	100	30	0	15
Average	95	79	87	71	55	66	96	89	93	42	31	38
CD $_{0.05}$	NS	8.71	8.95	9.66	9.97	7.79	NS	3.61	6.95	8.94	7.38	9.03

Differential effect of different phyto-hormonal treatments and media used was also studied (Table 3). It was observed that higher rooting was observed for media with higher concentration T4 (IBA: NAA: Kinetin @ 3000:1500:150 ppm) and M2 (sand: silt: clay: vermicompost: Sphagnum moss @2:1:1:1:1) during the pre-monsoon season. However, during the monsoons, T3 (IBA: NAA: Kinetin @2000:1000:100) and M1 (Sand : Silt: Clay: Cocopeat

= 2: 1:1:1) resulted in more rooting. Desired combinations can be used for more successful air layering generation. The air layering seedlings raised were hardened in the tree shade with survival percentage 32.76 per cent (Plate-6).

Table 3: Differential effect of different phyto-hormonal treatments and media used in successful air layering

	Pre-monsoon season		**During Monsoons**	
Treatment	Rooting	Callus	Rooting	Callus
T1…	63	94	24	98
T2…	58	75	31	89
T3…	70	81	53	93
T4…	73	94	44	90
…M1	71	88	61	88
…M2	80	91	30	91
…M3	41	83	13	95
…M4	70	83	48	95

Discussion

Air layering has been used as a vegetative propagation technique to produce true to type planting stock from long. The success of rooting through air layering depends on the species, rooting media, phyto-hormones, time of the year, and thickness of branch among others. So the different factors were considered for evaluating the success of air layering in kusum. For the accumulation of the nutritive substances and sap flow, bark plays an important role, which subsequently effects the cellular differentiation towards the rhizogenesis (Harivel et al., 2006). So, optimum sized branch 2-3 cm diameter was selected for both the years and both the seasons.Rabiou*et al* (2017), while attempting the aerial layering of *Pterocarpuserinaceus*also considered multiple factors for the standardization of the technique in the species. Rymbai and Reddy (2010) also considered different factors like the effect of plant hormones, time of layering and rooting media on air-layers and plantlets survival under different growing nursery conditions in guava.

From our study on the vegetative propagation through air layering of kusum, significantly better rooting percentage(66 %)was obtained during the pre-monsoon season. Using black polythene, the rooting percentage and callus formation was significantly better during both the years and both the seasons, which may be the due to no light penetration inside the rooted air layering. During the pre-monsoon season, treatment combination with phyto-hormones in higher concentration (IBA: NAA: Kinetin as 3000:1500:150) with media (sand: silt: clay: vermi

Comment [KP44]: Strengths:
The discussion successfully integrates findings from the study with prior research. Comparisons with studies on *Pterocarpus erinaceus*, guava, litchi, and teak provide a broader context and scientific validity.

Key results, such as the significantly better rooting percentage (66%) during the pre-monsoon season and the role of black polythene in enhancing rooting and callus formation, are clearly highlighted. This specificity strengthens the discussion.

The discussion suggests improvements, such as using polyhouse or mist chamber conditions, to address the low survival rate (32.76%), providing actionable insights for practitioners.

Weaknesses:
Certain points, such as the mention of multiple factors affecting rooting (e.g., media, phytohormones, and season), are repeated unnecessarily, making the discussion feel verbose.

While results are stated, there is limited analysis of *why* specific treatments, like higher phytohormone concentrations or black polythene, performed better. The discussion could delve deeper into the underlying mechanisms.

The low survival rate (32.76%) is acknowledged but not adequately analyzed. The reasons for this issue, such as environmental stresses or the hardening process, are not explored thoroughly.

Some sentences are overly long and lack clarity, such as "The differential effect of different phyto-hormonal treatments and media used in successful air layering revealed that higher concentrations of the phyto-hormones and the media with better water retention provided better results in callus formation and rooting." Breaking this into simpler sentences would improve readability.

While practical recommendations are mentioned, there is limited emphasis on how these findings could specifically impact large-scale propagation or the economic benefits for lac cultivators.

Suggestion:
Eliminate repetitive statements and focus on unique findings. For instance, the role of black polythene could be discussed once, with a concise explanation of its advantages.

Expand on why certain treatments worked better. For example:
- Why did higher concentrations of IBA, NAA, and Kinetin result in better rooting?
- Why does black polythene outperform transparent polythene in promoting rooting and callus formation?

Include a detailed analysis of factors contributing to the low survival rate and potential strategies to improve it. For example, discuss the role of environmental stresses, the hardening process, or plant physiology.

Break down long, complex sentences into shorter, clearer ones. Avoid redundant phrases like "different factors were considered for evaluating the success of air layering," which adds little value. ... [1]

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compost: Sphagnum moss = 2:1:1:1:1) resulted in cent per cent rooting. This was followed by combination with IBA: NAA: Kinetin as 2000:1000:100 and Sphagnum moss (90 %), which also resulted in highest rooting percentage (90 %) during the monsoon season. The application of a rooting hormone for vegetative propagation is widely recognized, examples include (Husen and Pal (2006) in teak, Kumar (2012) in litchi, Jannat et al. (2016) in kusum, Ansari and Gupta (2000) for their role in different tropical species. Different rooting media and time of air layering has responded differently in other species also like in guava where IBA concentrations of 2000 ppm, 3000 ppm and 4000 ppm were used in three time of layering viz., 15th June, 15th July and 15th August with two rooting media viz., sphagnum moss and coco peat (Rymbai and Reddy, 2010).The differential effect of different phyto-hormonal treatments and media used in successful air layering revealed that higher concentrations of the phyto-hormones and the media with better water retension provided better results in callus formation and rooting. Subsequently, the suitable factors may be considered for successful air layering in a species.

The air layering seedlings raised were hardened in the tree shade with survival percentage 32.76 per cent. The survival percentage can further be improved provided poly house or mist chamber conditions, due to congenial environmental conditions as compared to uncontrolled environmental conditions of open nursery. This finding is in agreement with the results obtained by Ahmad et al. (2007) in patch budding of walnut, Singh et al. (2007) on Wedge method of grafting in guava (*Psidium guajava*) and Rymbai and Reddy (2010) in air layering of guava (*Psidium guajava*).

Conclusions

Keeping in view the importance of *kusum* as a premiere lac host, production of elite genetic stock is important, which requires true-to-type production and mass multiplication of genotypes with higher productivity potential. Though many vegetative methods have been tried in the species, but air layering offers the best option for the same. During our experimentation for the three years, we concluded that phyto-hormone combinations constituting IBA, NAA and kinetin in higher concentration resulted in better rooting and production of seedlings, significantly higher in the pre-monsoon season with black polytheneuses to wrap the growing media. Growing media with higher water holding capacity resulted in better rooting; especially the sphagnum moss.The technique can be helpful in mass propagation of planting stock from plus trees or elite trees identified for lac production.

References

Comment [KP46]: The conclusion does not address challenges, such as the low survival rate of air-layered seedlings, or suggest specific directions for future research.

The conclusion focuses heavily on specific findings but does not place them in a broader context of their potential impact on agricultural practices, conservation, or socioeconomic benefits.

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Plates1-5: Rooting under different treatment combinations

Plate 6: a seedling raised through air layering

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	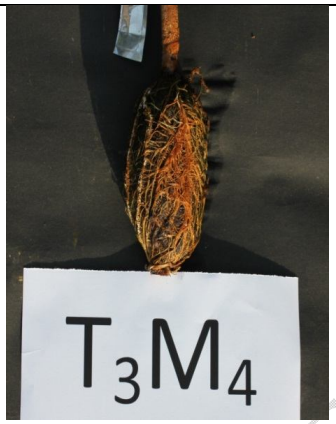	
Plate 1	**Plate 2**	**Plate 3**
		
Plate 4	**Plate 5**	**Plate 6**

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Break down long, complex sentences into shorter, clearer ones. Avoid redundant phrases like "different factors were considered for evaluating the success of air layering," which adds little value.

Emphasize how the findings can be scaled up for commercial or conservation purposes. For example, discuss how these results might benefit lac cultivators or be applied to other species with propagation challenges.

Organize the discussion into clear subsections, such as:

- Overview of Results
- Comparison with Previous Studies
- Mechanisms Behind Observed Trends
- Practical Implications
- Recommendations for Future Research