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EFFECT OF BIOSTIMULANTS AND PGPR ON ROOTING SUCCESS AND SURVIVAL OF LAYERS IN FIG (*Ficus carica*) cv. POONA AFTER TRANSPLANTING INTO POLYBAGS

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ABSTRACT

An experiment was conducted at the Main Horticultural Research and Extension Centre (MHREC), University of Horticultural Sciences, Bagalkot, Karnataka, during 2025–26 to study the effect of indole-3-butyric acid (IBA), biostimulants and plant growth promoting rhizobacteria (PGPR) on rooting success, growth and survival of fig cv. Poona air layers after transplanting in polybags. Air layers raised with fourteen treatments (IBA at 3000 ppm combined with seaweed extract, humic and fulvic acids, vesicular arbuscular mycorrhiza (VAM) and PGPR in the sphagnum moss rooting medium; IBA alone as control) were detached 60 days after layering, transplanted in polybags containing red soil, farmyard manure and vermicompost (1:1:1) and observed up to 90 days after transplanting (DAT) in a randomized block design with three replications. At 90 DAT, T_{11} (IBA + VAM + *Azotobacter* + *Bacillus subtilis*) recorded the highest number of primary (42.00) and secondary roots (317.33), the longest (66.28 cm) and thickest (1.78 mm) root, the highest root fresh (6.73 g) and dry weight (1.83 g) and the highest rooting success (97.00%), compared with 16.00, 156.67, 23.27 cm, 0.65 mm, 3.80 g, 0.70 g and 81.44 per cent, respectively, in the control. T_{12} (IBA + seaweed extract + VAM + *Azotobacter* + *Azospirillum*) was the best for earliness of sprouting (7.78 days), sprouting (98.10%), leaf production (14.89), shoot number (4.55), shoot length (21.84 cm), shooting (95.90%) and survival (95.00%), whereas survival was lowest in the control (77.22%). Omission of IBA (T_{13}) gave the lowest rooting (79.22%). Integrating IBA with a VAM–PGPR consortium thus improved rooting success and survival of fig layers in the nursery.

Key words : Fig, Poona, Air layering, Polybags, Rooting success, Survival, VAM, PGPR.

Introduction

Air layering is a simple and rapid method of clonal propagation of fig that yields well-rooted, true-to-type plants (Paul and Aditi, 2009). The success of a layer, however, is not decided at detachment alone. After the rooted layer is severed from the mother plant and transplanted, it must regenerate roots, absorb water and nutrients and put out new shoots in the nursery, and losses at this stage through root damage and transplanting shock reduce the number of saleable plants. Rooting success and survival after transplanting are therefore important criteria for judging layering treatments in guava, litchi and pomegranate (Bhandulkar, 2017; Sarita *et al*., 2019; Simpi, 2016; Kushwah *et al*., 2022).

Biological inputs can support the establishment of transplanted layers. A medium of orchard soil, FYM and rhizobacteria gave the highest survival (93.51%) of air-layered litchi (Sarita *et al*., 2019) and PGPR with FYM improved survival (90.00%) and growth of transplanted litchi layers (Chawla and Mehta, 2015). In guava air

layers, *Azotobacter* with GA_3 in soil and vermicompost gave 87.33 per cent survival (Kushwah *et al*., 2022). A consortium of *Azospirillum*, *Pseudomonas fluorescens* and VAM improved growth and establishment of cashew grafts under nursery conditions (Shankarappa *et al*., 2017), combined inoculation of PGPR and arbuscular mycorrhizal fungi improved root length, survivability and growth of litchi air layers (Visen *et al*., 2021). PGPR were also reported to reduce mortality and to be economical in the production of litchi air layers (Thakur *et al*., 2024).

In the first part of this study (Kichadi *et al*., companion paper), combinations of IBA with VAM and PGPR hastened root initiation and increased root number and biomass of fig air layers at the time of detachment. Whether this advantage persists after transplanting into polybags and translates into rooting success and survival was not known. The present investigation therefore evaluated the effect of IBA, biostimulants and PGPR on sprouting, growth, root development, rooting success and survival of fig cv. Poona layers after transplanting in polybags.

Materials and methods

Experimental site and climate

The experiment was carried out in the fruit block of the Main Horticultural Research and Extension Centre (MHREC), University of Horticultural Sciences, Bagalkot, Karnataka, during 2025–26. The centre lies in the Northern Dry Zone (Zone 3) of Karnataka at 16°10′ N latitude and 75°42′ E longitude, at 542 m above mean sea level and receives an average annual rainfall of 552 mm. During the nursery period (October–December 2025) the mean monthly minimum temperature was 17.0–20.0°C, the morning and afternoon relative humidity ranged from 80 to 97 per cent and 33 to 69 per cent, and rainfall was 46 mm in October with none in November and December (MHREC meteorological observatory).

Experimental design and treatments

The experiment was laid out in a randomized block design (RBD) with fourteen treatments (Table 1) and three replications, with ten layers per treatment in each replication. The treatments were combinations of IBA (3000 ppm) with seaweed extract, humic acid, fulvic acid, VAM and the PGPR *Azospirillum*, *Azotobacter*, *Pseudomonas fluorescens*, *Bacillus subtilis* and phosphate solubilizing bacteria (PSB), mixed with the sphagnum moss rooting medium at the time of layering. IBA at 3000 ppm alone (T_{14}) served as control, while T_{13} received the biostimulant–PGPR combination without IBA.

Layering, detachment and transplanting

Air layering was carried out on 30 July 2025 on one-year-old, pencil-thick branches by removing a 2 cm ring of bark, applying the IBA solution to the cut surface and

Table 1 : Treatment details.

Treatment	Details (applied per kg of sphagnum moss rooting medium)
T_1	IBA (3000 ppm) + seaweed extract (5 g of RM)
T_2	IBA (3000 ppm) + humic acid (5 g of RM) + fulvic acid (5 g of RM)
T_3	IBA (3000 ppm) + VAM (50 g of RM) + *Azospirillum* (20 ml of RM)
T_4	IBA (3000 ppm) + VAM (50 g of RM) + *Azotobacter* (20 ml of RM)
T_5	IBA (3000 ppm) + VAM (50 g of RM) + *Azotobacter* (20 ml of RM) + *Azospirillum* (20 ml of RM)
T_6	IBA (3000 ppm) + VAM (50 g of RM) + *Pseudomonas fluorescens* (20 ml of RM)
T_7	IBA (3000 ppm) + VAM (50 g of RM) + *Bacillus subtilis* (20 ml of RM)
T_8	IBA (3000 ppm) + VAM (50 g of RM) + PSB (20 ml of RM)
T_9	IBA (3000 ppm) + VAM (50 g of RM) + *Azotobacter* (20 ml of RM) + PSB (20 ml of RM)
T_{10}	IBA (3000 ppm) + VAM (50 g of RM) + *Azotobacter* (20 ml of RM) + *Pseudomonas fluorescens* (20 ml of RM)
T_{11}	IBA (3000 ppm) + VAM (50 g of RM) + *Azotobacter* (20 ml of RM) + *Bacillus subtilis* (20 ml of RM)
T_{12}	IBA (3000 ppm) + seaweed extract (5 g of RM) + VAM (50 g of RM) + *Azotobacter* (20 ml of RM) + *Azospirillum* (20 ml of RM)
T_{13}	Seaweed extract (5 g of RM) + VAM (50 g of RM) + *Pseudomonas fluorescens* (20 ml of RM) + *Bacillus subtilis* (20 ml of RM) (no IBA)
T_{14}	IBA (3000 ppm) alone – control

RM: rooting medium (sphagnum moss); VAM: vesicular arbuscular mycorrhiza (*Glomus fasciculatum)*; PSB (*Bacillus megaterium*): phosphate solubilizing bacteria, *Azatobacter chrococcum* Amounts are per kg of RM; the 20 ml doses refer to liquid cultures.

the 2 cm of stem above it and wrapping a ball of moist treated sphagnum moss with 200-gauge transparent polythene secured with jute thread. The layers were detached 60 days after layering and the successfully rooted layers were transplanted in polybags filled with red soil, farmyard manure and vermicompost (1:1:1) according to the layout. The treatments were thus applied only at the time of layering and the polybag medium was the same for all treatments. The polybags were irrigated, weeded and cleaned at weekly intervals and plant protection measures were adopted as required.

Observations recorded

Five sprouted layered plants were selected at random from each treatment in each replication and labelled for recording observations. The number of days taken for first sprouting after transplanting was noted by daily observation. Sprouting (%) was calculated as the number of sprouted layers divided by the number of layers planted, multiplied by 100 and shooting (%) as the number of shoots divided by the total number of sprouts, multiplied by 100. The number of leaves and shoots per layer, the cumulative leaf area of five randomly selected leaves (leaf area meter, cm^2), shoot length (scale, cm) and shoot fresh and dry weight (g) were recorded at 30, 60 and 90 DAT. Root parameters were recorded at 90 DAT: number of primary and secondary roots, length of the longest root (cm), its girth (digital vernier calliper, mm), and root fresh and dry weight (g; dry weight after oven drying at 60°C for 12 hours to constant weight). Rooting (%) was calculated as the number of successfully rooted layers divided by the total number of layers planted, multiplied by 100, and survival (%) as the number of surviving layers divided by the number of sprouted layers, multiplied by 100.

Statistical analysis

The data were analysed by analysis of variance appropriate for RBD (Panse and Sukhatme, 1985). Treatment differences were tested by the F-test at the 5 per cent level, and the standard error of the mean (S.Em±) and critical difference (CD) at 5 per cent were worked out for comparing treatment means. NS indicates non-significant.

Results and Discussion

The treatments, applied at layering, significantly influenced sprouting, shoot growth, root development, rooting success and survival of the layers after transplanting in polybags (Tables 2 and 3, Fig. 1 and Plate 1).

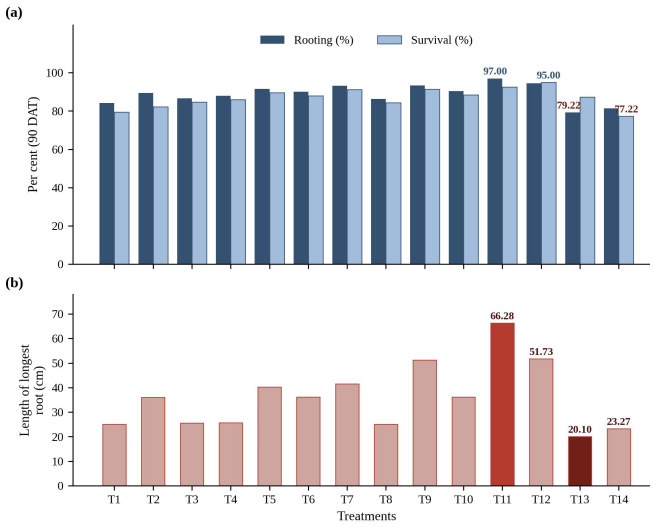


Fig. 1 : Effect of IBA, biostimulants and PGPR on (a) rooting and survival per cent and (b) length of longest root at 90 days after transplanting in fig cv. Poona layers.

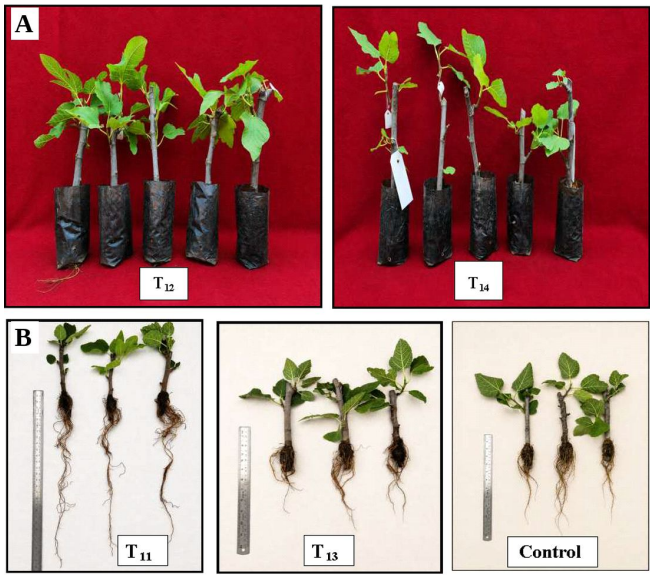


Plate 1 : Fig cv. Poona layers 90 days after transplanting in polybags. (A) Layers in polybags in T_{12} (best for sprouting, shoot growth and survival) and control (T_{14}); (B) uprooted layers at 90 DAT showing the root system in T_{11} (best for rooting), T_{13} (lowest rooting) and control (T_{14}).

Sprouting behaviour

Layers of T_{12} sprouted earliest (7.78 days), which was at par with T_{11} (8.45 days), whereas the control took 19.11 days, more than 11 days longer (Table 2). T_{12} also recorded the highest sprouting (98.10%), at par with T_{11} (95.00%) and T_9 (93.66%) and the control the lowest (69.86%). Even T_{13}, which lacked IBA, sprouted sooner (11.78 days) than the control.

Seaweed extracts are a natural source of cytokinins, betaines and polyamines that stimulate bud break and shoot initiation (Dutta *et al.*, 2023; Loconsole *et al.*, 2022),

Table 2 : Effect of IBA, biostimulants and PGPR on sprouting and shoot growth of fig cv. Poona layers at 90 days after transplanting.

Treatment	Days to first sprouting	Sprouting (%)	Number of leaves	Leaf area (cm^2)	Number of shoots	Shoot length (cm)	Shooting (%)
T_1	15.78	72.16	8.45	298.50	2.55	16.63	65.23
T_2	15.33	72.80	8.89	308.40	2.55	18.85	66.26
T_3	12.56	78.40	9.78	328.60	2.99	19.40	75.20
T_4	11.78	80.76	10.22	348.80	3.00	19.64	83.20
T_5	10.78	88.03	12.89	381.60	3.55	20.34	84.83
T_6	11.33	86.46	11.67	374.50	3.22	19.65	83.76
T_7	10.56	89.46	12.50	386.20	3.55	20.87	86.46
T_8	12.67	76.06	9.56	318.70	2.78	19.37	71.26
T_9	9.22	93.66	13.11	389.80	3.55	21.18	86.63
T_{10}	10.78	86.46	11.78	378.90	3.44	20.18	84.46
T_{11}	8.45	95.00	13.22	394.20	3.89	21.59	91.30
T_{12}	**7.78**	**98.10**	**14.89**	**400.00**	**4.55**	**21.84**	**95.90**
T_{13}	11.78	85.66	10.89	360.80	3.11	19.65	83.36
T_{14}	19.11	69.86	6.56	250.00	1.89	16.48	64.90
S.Em±	**0.44**	**4.66**	**0.50**	**7.80**	**0.25**	**0.49**	**2.38**
CD at 5%	**1.29**	**13.55**	**1.45**	**23.40**	**0.72**	**1.43**	**7.15**

Number of leaves, leaf area, number of shoots and shoot length are at 90 DAT. Values in bold indicate the best performance. Treatment details are given in Table 1.

and *Azospirillum* produces cytokinin- and gibberellin-like substances besides fixing nitrogen (Muthusamy *et al*., 2023); their combination with VAM and *Azotobacter* in T_{12} is likely to have hastened release of reserves and bud break. The strong root system already formed in T_{11} and T_{12} would also have ensured a steady supply of water and nutrients to the buds. The long delay in the control shows that layers raised with IBA alone depend heavily on additional growth-promoting inputs for prompt establishment.

Shoot growth and canopy development

Shoot growth increased progressively from 30 to 90 DAT in all treatments, and T_{12} was consistently superior. At 90 DAT, T_{12} produced the highest number of leaves (14.89; 9.56 and 12.78 at 30 and 60 DAT), followed by T_{11} (13.22) and T_9 (13.11), the largest leaf area (400.00 cm^2), which was at par with T_{11} (394.20 cm^2) and T_9 (389.80 cm^2). It also had the most shoots (4.55, at par with T_{11} at 3.89) and the longest shoots (21.84 cm, at par with T_{11} at 21.59 cm). Against these, the control recorded only 6.56 leaves (2.11 and 3.33 at 30 and 60 DAT), 250.00 cm^2 leaf area, 1.89 shoots and 16.48 cm shoot length. Shoot fresh and dry weight were highest in T_{12} (81.37 and 44.33 g), followed by T_{11} (79.67 and 41.00 g), and lowest in the control (45.70 and 15.67 g). Shooting was also highest in T_{12} (95.90%, at par with T_{11} at 91.30%) against 64.90 per cent in the control.

Leaf number, leaf area and shoot number follow bud break, and the cytokinin-like activity of seaweed extract and *Azospirillum*, which relieves apical dominance and favours lateral shoot growth, together with the improved nitrogen and micronutrient supply from VAM and *Azotobacter*, would have supported sustained leaf initiation and expansion in T_{12} (Loconsole *et al*., 2022; Muthusamy *et al*., 2023; Shruti *et al*., 2025). Shoot biomass is the cumulative result of shoot number, shoot length and leaf area, and so reflects the superiority of T_{12} in those traits.

Root development at 90 days after transplanting

Root development at 90 DAT was significantly influenced by the treatments (Table 3, Plate 1). T_{11} recorded the highest number of primary roots (42.00), at par with T_{12} (39.00), T_9 (38.67), and of secondary roots (317.33), at par with T_{12} (309.00). The longest root was recorded in T_{11} (66.28 cm), significantly longer than in T_{12} (51.73 cm) and T_9 (51.17 cm), and it also had the greatest girth (1.78 mm). Root fresh weight (6.73 g) and dry weight (1.83 g) were highest in T_{11} and at par with T_{12} (6.27 and 1.70 g). The poorest root system was in T_{13} (13.33 primary roots, 116.33 secondary roots, 20.10 cm, 0.59 mm, 2.97 g and 0.67 g), closely followed by the control (16.00, 156.67, 23.27 cm, 0.65 mm, 3.80 g and

Table 3 : Effect of IBA, biostimulants and PGPR on root parameters, rooting success and survival of fig cv. Poona layers at 90 days after transplanting.

Treatment	Primary roots (No.)	Secondary roots (No.)	Length of longest root (cm)	Girth of longest root (mm)	Root fresh weight (g)	Root dry weight (g)	Rooting (%)	Survival (%)
T_1	17.67	181.33	25.00	0.69	4.07	0.83	84.22	79.44
T_2	25.33	208.00	36.00	0.89	4.63	1.30	89.33	82.22
T_3	23.67	187.00	25.60	0.81	4.60	1.13	86.66	84.66
T_4	24.00	187.33	25.70	0.89	4.63	1.23	88.00	86.00
T_5	30.00	249.33	40.27	1.04	5.40	1.33	91.56	89.55
T_6	27.00	212.00	36.11	0.90	4.97	1.33	90.00	88.00
T_7	36.33	271.33	41.50	1.05	5.83	1.40	93.22	91.22
T_8	20.67	184.00	25.03	0.78	4.53	0.87	86.33	84.33
T_9	38.67	279.33	51.17	1.26	5.93	1.50	93.33	91.33
T_{10}	28.67	212.67	36.13	0.94	5.20	1.33	90.44	88.44
T_{11}	**42.00**	**317.33**	**66.28**	**1.78**	**6.73**	**1.83**	**97.00**	92.55
T_{12}	39.00	309.00	51.73	1.31	6.27	1.70	94.55	**95.00**
T_{13}	13.33	116.33	20.10	0.59	2.97	0.67	79.22	87.33
T_{14}	16.00	156.67	23.27	0.65	3.80	0.70	81.44	77.22
S.Em±	**1.28**	**8.38**	**3.03**	**0.07**	**0.39**	**0.10**	**0.39**	**0.07**
CD at 5%	**3.72**	**24.37**	**8.80**	**0.22**	**1.13**	**0.30**	**1.15**	**0.22**

Values in bold indicate the best performance. Treatment details are given in Table 1.

0.70 g). T_{11} thus had 2.6 times as many primary roots, 2.0 times as many secondary roots and a 2.8 times longer longest root than the control.

The superiority of T_{11} in root traits, already evident at detachment (Kichadi *et al.*, companion paper) was thus maintained and consolidated in the nursery. Since the polybag medium was uniform, this suggests that the root system formed under the IBA–VAM–*Azotobacter*–*B. subtilis* treatment and possibly the inoculants carried with the root ball, continued to promote root growth, probably through continued synthesis of auxins and improved rhizosphere nutrient cycling (Sagar *et al*., 2022; Shruti *et al*., 2025). Improved microbial biomass and enzyme activity in the rhizosphere have been reported in litchi air layers treated with mycorrhizal fungi and *Azotobacter* (Kumar *et al*., 2024). The length of the longest root in T_{11} rose from 10.47 cm at detachment to 66.28 cm at 90 DAT, reflecting free growth in the loose medium of red soil, FYM and vermicompost. The number of primary roots at 90 DAT was lower than at detachment in all treatments (T_{11}: 42.00 against 70.22), probably because some roots were lost or damaged during detachment and transplanting, whereas secondary roots increased (T_{11}: 264.44 to 317.33), indicating continued root branching in the polybags.

Rooting success and survival percentage

Rooting at 90 DAT was highest in T_{11} (97.00%), followed by T_{12} (94.55%), T_9 (93.33%) and T_7 (93.22%), while T_{13} (79.22%) and the control (81.44%) recorded the lowest values (Table 3, Fig. 1). Survival was highest in T_{12} (95.00%), followed by T_{11} (92.55%), T_9 (91.33%) and T_7 (91.22%), and lowest in the control (77.22%). Compared with IBA alone, T_{11} therefore increased rooting success by 15.6 percentage points (19 per cent) and T_{12} increased survival by 17.8 percentage points (23 per cent).

Rooting per cent integrates root initiation, root proliferation and persistence of the roots after transplanting, and its superiority in T_{11} is consistent with the role of IBA in rooting of fig (Sheikh *et al*., 2022; Nale *et al*., 2024) and with the improved rooting of *Ficus elastica* layers given IBA together with *Bacillus subtilis* and mycorrhizal fungi (Mousa *et al*., 2019). Survival, on the other hand, was highest in T_{12}, which also showed the best sprouting and shoot growth. A larger leaf area and more leaves provide photosynthates to the developing roots during acclimatisation and help the layer overcome transplanting shock, while T_{11}, with the strongest roots, ranked next. The higher survival of T_{13} (87.33%) than of the control, despite its poor rooting, may indicate that seaweed extract and the microbial inoculants helped the sprouted layers to establish even without IBA; as survival was calculated on sprouted layers, this should be read together with the low rooting of T_{13}. Similar benefits of bio-inoculants for survival of transplanted air layers have

been reported in litchi and guava (Sarita *et al*., 2019; Chawla and Mehta, 2015; Kushwah *et al*., 2022).

T_{11} and T_{12} share IBA, VAM and *Azotobacter* and differ in the second PGPR (*B. subtilis* in T_{11}; *Azospirillum* plus seaweed extract in T_{12}). T_{11} may be preferred where root-system quality and rooting success are the main aim and T_{12} where early sprouting, shoot vigour and survival matter more; both were clearly better than IBA alone. The cost of the treatments was not evaluated.

Conclusion

Transplanted fig cv. Poona air layers responded significantly to the IBA, biostimulant and PGPR treatments applied at layering. IBA 3000 ppm with VAM (50 g), *Azotobacter* (20 ml) and *Bacillus subtilis* (20 ml) per kg of sphagnum moss (T_{11}) gave the best root development at 90 DAT and the highest rooting success (97.00%), while IBA with seaweed extract (5 g), VAM, *Azotobacter* and *Azospirillum* (T_{12}) gave the earliest and highest sprouting (7.78 days; 98.10%), the best shoot growth and the highest survival (95.00%). IBA alone recorded 81.44 per cent rooting and 77.22 per cent survival, and omission of IBA gave the lowest rooting (79.22%). Integrating IBA with a compatible VAM–PGPR consortium at layering can therefore improve rooting success and survival of fig layers in polybag nurseries; evaluation across seasons and locations and a cost–benefit analysis are warranted.

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