Original Research Article

Study of different aged Jackfruit (*Artocarpus heterophyllus* L.) rootstocks on softwood grafting success under different environmental conditions

ABSTRACT

An investigation was conducted to find out the optimum Jackfruit rootstock age for softwood grafting and to find out the suitable environmental condition for the success of Jackfruit grafts was conducted at Department of Biotechnology and Crop Improvement, College of Horticulture, Kolar, Karnataka during the year 2023. Six different aged Jackfruit rootstocks (15, 30, 45, 60, 75 and 90 days old) were softwood grafted and evaluated under three environmental conditions (Shadenet, Polytunnel and Polyhouse) in a factorial completely randomised design with four replications.

The morpho-physiological results revealed that, 15 days old rootstock grown under shadenet took highest number of days for sprout initiation (24.02 days) compared to others. Significantly highest graft success (50.20 %) was recorded in 90 days old rootstock grafts grown under polyhouse condition 30 days after grafting. Maximum number of leaves per graft (4.95, 6.95 and 9.15) and maximum RWC % (83.63, 86.98, and 90.61 %) was recorded in 90 days old rootstock grown under polyhouse at 30, 60 & 90 days after grafting respectively. Similarly, significantly highest chlorophyll (4.70 mg/g FW), root length (18.52 cm), root fresh weight (9.43 g/plant), root dry weight (1.35 g/plant) and root biomass (3.64 g/plant) found in 90 days old rootstock grafts grown under polyhouse conditions. The maximum root-to-shoot ratio was recorded on fresh weight (0.73 g) and dry weight (0.56 g) in 90 days old rootstock grown under polyhouse condition. Significant maximum graft survival (44.71 %) recorded in 90 days old rootstock grafts grown under polyhouse. Significantly highest graft dry matter (3.95 g/plant) was recorded in 90 days old rootstocks grafts grown under polyhouse whereas least in shadenet (2.99 g/plant).

In conclusion, it is found that grafting of 90 days old Jackfruit rootstocks performed better under polyhouse conditions for most of the traits.

Keywords: Jackfruit, Softwood grafting, Age of rootstocks and Environmental conditions.

1. INTRODUCTION

The species of Jackfruit (*Artocarpus heterophyllus* Lam.) originates to the Moraceae family. This enormous tree produces the largest fruit among the edible fruits. It exists in Central and Eastern Africa, South-Eastern Asia, the Caribbean, Florida, Brazil, Australia, Puerto Rico, and numerous Pacific Island nations. It is native from the Western Ghats of India and Malaysia. Jackfruit is the national fruit of Bangladesh and is also known as "poor man's fruit" in eastern and southern India. According to (Bose and Mitra, 2002) jackfruit is extensively grown in Bangladesh, Sri Lanka, Vietnam, Malaysia, Myanmar, Indonesia, Bangladesh, Brazil, West Indies, Pakistan, and other tropical nations. It is widely grown in Kerala, Karnataka, Andhra Pradesh, Tamil Nadu, West Bengal, Maharashtra, Assam, the Andaman Islands, and the Nicobar Islands. It is highly popular in Eastern and Southern India.

In India, which it is cultivated in an area of 1.95 L hectares with a produced of 33, 01,000 MT by 2021-2022, (Agricoop). Jackfruit tree is a monoecious, medium to large (7–10 m) tall growing tropical tree, evergreen, latex-producing tree whose fruit usually reaches 10–25 kg in weight, maturing in the summer when staple food grains are often in short supply. The bearing habit is cauliflorous, as it is borne on the main trunk and on primary and secondary branches. Inflorescence is catkin and fruit is botanically sorosis. Leaves are 10–20 cm long, elliptic in shape, acute at the apex, narrowed at the base, leathery and stiff in structure and shining above with deep green while rough and pale beneath (Santapau, 1966).

In Jackfruit, seed propagation is common, however because of the high heterozygosity, seed propagation is not often acknowledged. Due to its high levels of heterozygosity and cross-pollination, populations have vastly different yields, sizes, shapes, flesh colors, fruit quality, and maturity times. With vegetative propagation, it is generally known that an elite clone or cultivar can preserve its genetic consistency and identity. This case is prevalent in Jackfruit hence, it is necessary to multiply the superior materials greatly and provide them to the farmers who are in need. Therefore, in order to satisfy the increasing demand for planting material, suitable vegetative propagation techniques need to be standardized. Whereas approach grafting and other attached grafting techniques have demonstrated more effectiveness in grafting Nazeem *et al.* (1984), this method is time-consuming, expensive, and labor-intensive. With varying levels of effectiveness, detached scion grafting techniques like as veneer, wedge, side, and splice grafting have been explored in jack in various growing tracts, as follows in cashew and mango. The process of growing seedling root stocks and then maintaining them until they reach graftable size is quite expensive and risky in today's nursery methods. A higher success rate can likely be accomplished with proper grafting techniques and healthy rootstock growth (Swamy, 1993).

2. MATERIALS AND METHODS

The investigation was carried out in the year 2023-24 at Department of Biotechnology and Crop Improvement, College of Horticulture, Kolar, Karnataka. Jackfruit seeds were collected from mature trees at Jackfruit orchard, College of Horticulture, Kolar, Karnataka, India.
Yellow flesh Jackfruit tree seeds were selected and were dipped to fungicide solution for overnight. Seeds were sown in the polythene bag (15×20 cm) with sufficient holes for good aeration in the month of January 2023. The polybags were filled with a potting mixture (red soil, sand and FYM in the ratio of 1:1:1). Watering and weeding were done regularly as per the requirement. Vigorously grown, healthy rootstocks with uniform size were selected for grafting. Scions were collected from Chandra Halasu mother trees and tipped off healthy scion with 2-3 leaves with unopened bud. Scions were dipped in water at 24 hours' treatment. Uniform sized scions of 25 – 30 cm length were used for this study.

This experiment was laid out with Factorial Completely Randomized Design with four replications each with each replication was comprising 10 plants. It consists of two factors *viz,* different age of rootstock (Factor A) and different environmental conditions (Factor B) with softwood grafting. Six different age of rootstocks *viz.*, 15 days old rootstock (A_1), 30 days old rootstock (A_2), 45 days old rootstock (A_3), 60 days old rootstock (A_4), 75 days old rootstock (A_5), 90 days old rootstock (A_6) were grafted and allowed to grow under different environmental conditions shadenet (B_1), polytunnel (B_2) and polyhouse (B_3) (Fig 1). The softwood grafting operation was performed at 15 days' intervals using locally ruling Chandra Halasu scion sticks of Jack on the raised rootstock. The morpho-physiological growth parameters were recorded in different days intervals and were subjected to fisher's method of statistical "Analysis of variance" (ANOVA).

3. RESULTS AND DISCUSSION

3.1 Number of days taken for first sprouting

The number of days taken for the sprouting of grafting was influenced significantly by the age of rootstocks and different environmental conditions in shadenet (B_1). Grafting done on 90 days old rootstock with polyhouse (A_6B_3) took the minimum number of days taken for the sprouting of grafting (13.40 days) at 30 DAG and 15 days old rootstock with shadenet (A_1B_1) recorded the maximum number of days taken sprout at 30 DAG (24.02 days). These similar results were obtained by Bhaskaran *et al.* (2008). The maturity of the scion is also another important key factor in deciding the success of grafting in any fruit crop. More success in a shorter period could be recorded with softwood scion than hardwood scion (Table 1).

3.2 Graft success percentage (%)

In case of the effect of different grafting times on per cent of graft success at 90 DAG, significantly highest graft success percentages were noticed in 90 days old rootstock (A_6) with polyhouse condition (B_3) (50.20%). The delayed sprouting during the 15 days old rootstock (A_1) probably was caused by to late initiation of sprouting. Such a wide variation in sprouting and graft success may passively be attributed to variation in temperature and relative humidity during the period of study. These factors influence the sprouting and graft success (Awasthi and Shukla, 2003). Possibly, the optimum thickness of the rootstocks, and optimum environmental conditions influence the graft union formation satisfactorily. The variation in grafting may be attributed due to the differences in the quantity of endogenous phenolic compounds (Reddy and Melanata, 1988) and due to the differential capacity of rootstocks in the production of undifferentiated mass of parenchyma cells when grafting is performed. Tanushree *et al.,* (2019) stated that graft success percentage was observed highest when 90 days after grafting due to cells differentiating of callus cells in Jackfruit grafts plants (Fig 3).

3.3 Graft height (cm)

In the case of the effect of different ages of rootstock on graft height at 30, 60, and 90 DAG, significantly the highest graft height was noticed in 90 days old rootstock (A_6) (20.46, 21.29, and 22.20 cm). Different environmental conditions also exhibited a significant difference with respect to graft height per graft. At 30, 60, and 90 DAG significantly, the maximum graft height per graft was noticed in polyhouse (B_3) (16.85, 17.84, and 18.72 cm). Pawar *et al.* (2003) influenced as a higher cell activity and early healing of graft union during the optimum season of graft results in early sprouting and faster growth of leaves (Table 2).

3.4 Number of sprouts

Regarding the different ages of the rootstocks, a significantly maximum number of sprouts per graft at 30, 60, and 90 DAG was recorded in grafted plants at 90 days old rootstock (A_6) (4.13, 4.20, and 4.33, respectively), followed by grafted plants at 75 days old rootstock (A_5) (3.54, 3.61, and 3.74, respectively). Among different environmental conditions, a significantly maximum number of sprouts at 30, 60, and 90 DAG was recorded in polyhouse (B_3) (2.91, 2.98, and 3.11, respectively), followed by polytunnel (B_2) (2.64, 2.71, and 2.84, respectively). However, shadenet (B_1) recorded the minimum number of sprouts per graft at 30, 60, and 90 DAG (2.44, 2.51, and 2.64, respectively). As a result, the warmer climate within the polyhouse responsible for early formation of leaves that will affect sprout length. The beneficial effects of polyhouse could be attributed to high humidity for longer period, which prevents desiccation of the tissues at scion and stock interface and favours rapid callus tissue development and leading to better graft union. The results are in line with the work of Selvi *et al.* (2008) in jackfruit (Table 3).

3.5 Girth of graft (cm)

The girth of graft union at 30, 60, and 90 DAG among different age of rootstocks was recorded. Significantly, the maximum girth of graft union was found in plants grafted on 90 days old rootstock (A_6) (1.89, 2.11, and 2.37 cm, respectively), while minimum girth of graft union at 30, 60, and 90 DAG was observed when grafting was performed on 15 days old rootstock (A_1) (1.04, 1.26, and 1.52 cm, respectively).Among different environmental conditions, significantly higher maximum girth of graft union at 30, 60, and 90 DAG was noticed in polyhouse condition (B_3) (1.66, 1.88, and 2.14 cm, respectively) and was statistically on par with polytunnel condition (B_2) (1.60, 1.82, and 2.08 cm, respectively). However, the lowest girth of graft union at 30, 60, and 90 DAG was recorded in shadenet condition (B_1)

(1.56, 1.78, and 2.04 cm, respectively). Bharad *et al.* (2006) states that grafts performed during the optimum season having congenial condition for graft growth results in better leaf growth and higher photosynthetic activity leading to formation of more food material that facilitates the increase in girth of grafts. Priyanka *et al*. (2023) indicated that enhanced moisture and nutrient availability in the scion stick positively influences the grafting girth (Table 4).

3.6 Number of leaves

A significant effect was exhibited by different age of rootstocks on the number of leaves per graft. The maximum number of leaves at 30, 60, and 90 DAG were recorded in 90 days old rootstock grafted plants (A_6) (4.80, 6.80, and 9.00, respectively), whereas the minimum number of leaves at 30, 60, and 90 DAG were recorded in 15 days old rootstock grafted plants (A_1) (0.65, 2.65, and 4.85, respectively). Different environmental conditions also exhibited a significant difference with respect to the number of leaves per graft. At 30, 60, and 90 DAG, the maximum number of leaves per graft was noticed in polyhouse (B_3) (3.14, 5.14, and 7.34). However, shadenet (B_1) recorded the minimum number of leaves per graft (2.68, 4.68, and 6.88). The quick and strong union formation, better nutrient uptake and ample growing period might have caused better plant growth and more number of leaves per plant. The results are in the same line as reported by Chovatia and Singh (2000) and Singh *et al.* (2003). Dewangan *et al.* (2023) noted that favourable environmental conditions promote quick callus formation and early cambial contact in grafted plants, allowing for fast healing and strong unions which leads to improved strength and accelerated growth (Fig 2 and Table 5).

3.7 Leaf area (cm^2)

Overall, 90 days old rootstocks (A_6) have the highest leaf area at 30, 60, and 90 DAG (39.45, 46.35, and 57.44 cm^2) in 15 days intervals rootstock of jackfruit grafting. Different environmental conditions also exhibited a significant difference with respect to leaf area. At 30, 60, and 90 DAG significantly, the maximum number of leaf areas per graft was noticed in polyhouse (B_3) (25.52, 30.57, and 39.57 cm^2). The favourable condition prevailing inside the structure stimulating rapid callusing and early contact of cambial layers, which enables the graft to heal quickly and make a strong union ultimately leading to better strength and faster growth. Hema Nair *et al.* (2002) they recorded the maximum leaf area under red polyhouse which was significantly superior to open conditions in epicotyls mango. Harshavardhan (2011) obtained maximum leaf area under polyhouse condition during the month of October in jack fruit. Sivudu *et al.,* (2014) recorded maximum leaf area in the natural ventilated poly house in mango. Similar finding was observed by Anushma *et al.* (2014), Mulla *et al.* (2011) and Angadi and Karadi (2012) in Jamun (Table 6).

3.8 Specific leaf weight (mg/cm^2)

As per the data, there was a significant difference among the different age rootstocks with respect to specific leaf weight. Specific leaf weight at 30, 60, and 90 DAG was recorded more in 90 days old rootstock (A_6) (4.67, 4.89, and 5.27 mg/cm^2, respectively), whereas, 15 days old rootstock (A_1) exhibited less specific leaf weight at 30, 60, and 90 DAG (1.73, 1.95, and 2.33 mg/cm^2, respectively). There were also significant differences registered among the different environmental conditions with respect to specific leaf weights. Maximum specific leaf weight at 30, 60, and 90 DAG was noticed in polyhouse (B_3) (3.50, 3.72, and 4.10 mg/cm^2). The higher specific leaf weight provides a greater number of layers of mesophyll cells for high rate of apparent photosynthesis during growth. The improvement in apparent leaf attributes and related photosynthesis was recorded in soybean with proportionate increase in specific leaf weight Thompson *et al.,* (1996). These results were obtained from Deshmukh *et al.* (2017) Influence of rootstock age and propagation methods on scion physiology and root morphology of Khasi mandarin (Table 7).

3.9 Relative leaf water content

The effect of different age of rootstocks and different environmental conditions on relative leaf water content was found significant. Relative leaf water content at 30, 60 and 90 DAG was significantly highest percentage in 90 days old rootstock (A_6) with polyhouse (B_3) (83.63, 83.36 and 84.19 % respectively), whereas, the lowest percentage of relative leaf water content at 30, 60 and 90 DAG was recorded in 15 days old rootstock (A_1) with shadenet (B_1) (66.29, 66.18 and 66.16 % respectively). Higher water retention in the plant may be due to increased water use efficiency which has a direct relation with overall health and biomass accumulation (Passioura, 1986). The higher relative water content of the leaves was observed in wedge grafting on seven- and six-months old rootstock may be attributed to higher water uptake and retention which is directly related to better root growth and proliferation Schroeder *et al.* 2001. These results were obtained from Deshmukh *et al.* 2017. Influence of rootstock age and propagation methods on scion physiology and root morphology of Khasi mandarin (Table 8).

3.10 Chlorophyll content (mg/g FW)

As per the data, there was a significant difference among the different ages of rootstock with respect to chlorophyll content. Chlorophyll content at 30, 60, and 90 DAG was recorded as higher in 90 days old rootstock (A_6) (6.15, 6.28, and 6.46 mg/g FW, respectively), whereas, 15 days old rootstock (A_1) exhibited less chlorophyll content at 30, 60, and 90 DAG (2.04, 2.18, and 2.35 mg/g FW, respectively). There were also significant differences registered among the different environmental conditions with respect to chlorophyll content. Maximum chlorophyll content at 30, 60, and 90 DAG was noticed in polyhouse (B_3) (4.39, 4.52, and 4.70 mg/g FW, respectively). This was followed by polytunnel (B_2) (3.97, 4.11, and 4.28 mg/g FW, respectively). DMSO reading is higher in polyhouse compared to shade net and other environmental conditions. Under the polyhouse conditions, about 75 percentage of sun light were expected, graft canopy with higher or optimum temperature which result in higher metabolic rate and therefore chlorophyll condition. But chlorophyll content is poor in shade net (B_1), similarly under the environmental condition the quantum of light could be high that results in yellowing of leaves Richard *et al.* (1990). These results were obtained from Praveenakumar *et al.* (2018) seasonal variability and environmental condition of softwood grafting in Jamun. Nitrogen is a major constituent of amino acids, the building blocks of proteins. Further, nitrogen is a constituent of energy transfer compounds, which include ATP (adenosine triphosphate) which permits cell to preserve and utilize energy released in metabolism. These results are in line with Basalo *et al.* (2020) (Table 9).

3.11 Length of the longest root (cm)

The effect of different grafting rootstocks and different environmental conditions on the length of the longest root was also found to be significant. The maximum length of the longest root at 90 DAG was recorded in 90 days old rootstock (A_6) with polyhouse condition (B_3) (18.52 cm). The four months rootstocks recorded maximum root length and root spread due to the synthesis of a required number of secondary metabolites like phenols and alkaloid compounds which are most important for the protection of rootstock by less root infestation by soil-borne pathogens (Motty *et al.,* 2010 and Qiang *et al.* 2010) in citrus seedlings. Deshmukh *et al.* 2017 also observed maximum root length (385.36 cm) on six months old rootstocks of rough lemon. This may result from the availability of scions with active buds, healthy rootstock, and favorable environmental conditions. These factors lead to quick healing of grafts, promoting strong unions and improved vegetative and root growth (Kumar *et al.* (2020)) (Table 10).

3.12 Root dry weight (g)

Significance differences attributed by among between the interaction effect of different aged rootstocks and different environmental conditions on the dry weight of the root. Maximum dry weight of root at 90 DAG was noticed in 90 days old rootstock with polyhouse conditions (1.35 g/plant). Because, a higher vascular connection between the scion and rootstock, leading to the translocation of food material to the root zone through the phloem, which increases the stored food in the roots, might have helped, which in turn may have resulted in an increased dry weight of the root. Dry weight is determined by means of drying processes that would remove water and nutrient contents of the roots. The results are supported by the works of Sarada *et al.* (1991) in Cashew, Dhutraj *et al.* (2018) and Pawar *et al.* (2018) in Custard apple (Table 10).

3.13 Graft survival percentage (%)

The effect of different grafting rootstocks and different environmental conditions on graft survival percentage was also significantly varied at 90 DAG. The maximum graft survival percentage was recorded when grafting was carried out on 90 days old rootstock (A_6) with polyhouse (B_3) (44.71%). This happens because the grafting time might have favoured the information of a new cambial layer in the cambium bridge at the right time and laying down a new secondary xylem toward the inside and phloem toward the outside in deriving the vascular connection. This process of completion before the new bud and leaf formation ensured the highest survival percentage. This study was attributed by Naik *et al.* 2018 to jackfruit. This may be because an optimum temperature of about 26º C to 29º C and specific environmental conditions during the grafting season which may be ideal for callus tissue development that leads to better union of the scion and rootstock helping in faster developmental processes like cell division and cell elongation. Further favourable internal conditions like a high C: N ratio and external conditions like optimum humidity and moderate temperature result in more graft success and less survivability per cent in the grafts as stated by Hartman and Kestar (1979) and the results are supported by Kulkarni (1990) in custard apple and jamun, Shinde *et al*. 2015, Dhutraj *et al.* 2018 in custard apple, Nayaka. D. G. 2006 in aonla, Mulla *et al.,* 2007 and Ghojage *et al.,* 2011 in jamun, Raghavendra *et al.,* 2011 in wood apple and Anjana *et al.,* 2017 in guava. (Fig 4).

3.14 Total plant dry mater (g)

The interaction effect of different ages of rootstocks and different environmental conditions on total plant dry matter was also found to be significant. Total plant dry matter at 30, 60, and 90 DAG was significantly highest in 90 days old rootstock (A_6) with polyhouse (B_3) (3.86, 3.90, and 3.95 g/plant, respectively), whereas, the lowest total plant dry matter at 30, 60, and 90 DAG was recorded in 15 days old rootstock (A_1) with shadenet (B_1) (1.06, 1.11, and 1.16 g/plant, respectively). Because, that have shown that increased salinity of the nutrient solution improves graft firmness by increasing the dry matter. This study was investigated from Del Amor *et al.* (1999) and Navarro *et al.* (1999) (Table 11).

Table 1. Influence of rootstock age and environmental conditions on days to first sprouting of jackfruit grafts.

Age of the rootstock (A)	Number of days taken for first sprouting (days)			
	Environmental conditions (B)			
	B_1	B_2	B_3	Mean (A)
A_1	24.02	23.24	23.30	23.52
A_2	23.10	23.30	23.20	23.20
A_3	22.85	22.60	22.65	22.70
A_4	21.25	20.65	20.40	20.77
A_5	20.30	19.15	17.85	19.10

A_6	16.55	14.90	13.40	14.95
Mean (B)	21.35	20.64	20.13	
Interaction	A	B	AxB	
S. Em ±	0.13	0.09	0.22	
C.D @ 5%	0.36	0.25	0.62	

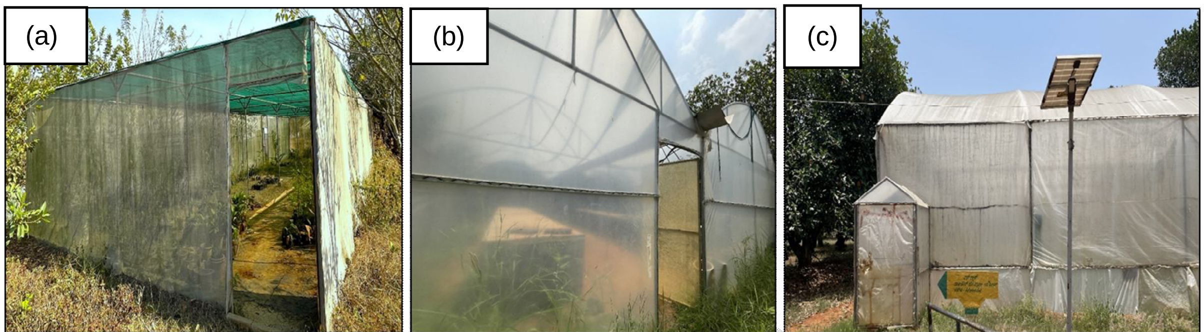

Fig 1: Jackfruit grafts growing under different environmental conditions (a) Shade net (b) Polytunnel and (c) Polyhouse

Fig 2: Jackfruit grafts with different aged rootstocks kept under different environmental conditions. A_1 – 15 days old rootstock, A_2 – 30 days old rootstock, A_3 – 45 days old rootstock, A_4 – 60 days old rootstock, A_5 – 75 days old rootstock, A_6 – 90 days old rootstock, B_1 – Shadenet, B_2 – Polytunnel, B_3 – Polyhouse

Table 2: Effect of age of rootstocks and environmental conditions on graft height (cm).

Age of the rootstock (A)	Graft height (cm)													
	30 DAG				60 DAG					90 DAG				
	Environmental conditions (B)													
	B_1	B_2	B_3	Mean (A)		B_1	B_2	B_3	Mean (A)		B_1	B_2	B_3	Mean (A)
A_1	9.84	11.34	12.54	11.24	A_1	11.49	12.99	14.19	12.89	A_1	12.47	13.97	15.17	13.87
A_2	13.44	14.32	15.12	14.29	A_2	15.09	15.46	15.95	15.50	A_2	16.07	16.29	16.59	16.31
A_3	15.51	15.96	16.02	15.83	A_3	16.42	16.67	16.76	16.62	A_3	16.74	17.20	17.60	17.18
A_4	15.86	16.45	17.25	16.52	A_4	17.17	17.53	18.03	17.58	A_4	17.95	18.26	19.31	18.51

A_5	18.27	18.96	19.50	18.91	A_5	19.06	20.10	20.13	19.76	A_5	20.41	20.70	20.98	20.70
A_6	20.17	20.53	20.70	20.46	A_6	20.67	21.18	22.01	21.29	A_6	21.53	22.40	22.68	22.20
Mean (B)	15.51	16.26	16.85		Mean (B)	16.65	17.32	17.84		Mean (B)	17.52	18.13	18.72	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.20	0.14	0.35		S. Em ±	0.18	0.13	0.31		S. Em ±	0.19	0.13	0.33	
C.D @ 5%	0.57	0.40	NS		C.D @ 5%	0.51	0.36	NS		C.D @ 5%	0.54	0.38	NS	

Table 3: Effect of age of rootstocks and environmental conditions on number of sprouts

Age of the rootstock (A)	Number of sprouts													
	30 DAG				60 DAG					90 DAG				
	Environmental conditions (B)													
	B_1	**B_2**	**B_3**	**Mean (A)**		**B_1**	**B_2**	**B_3**	**Mean (A)**		**B_1**	**B_2**	**B_3**	**Mean (A)**
A_1	0.75	0.85	0.95	0.85	A_1	0.82	0.92	1.02	0.92	A_1	0.95	1.05	1.15	1.05
A_2	1.25	1.65	2.15	1.68	A_2	1.32	1.72	2.22	1.75	A_2	1.45	1.85	2.35	1.88
A_3	2.50	2.65	2.85	2.67	A_3	2.57	2.72	2.92	2.74	A_3	2.70	2.85	3.05	2.87
A_4	2.95	3.05	3.35	3.12	A_4	3.02	3.12	3.42	3.19	A_4	3.15	3.25	3.55	3.32
A_5	3.41	3.55	3.65	3.54	A_5	3.48	3.62	3.72	3.61	A_5	3.61	3.75	3.85	3.74
A_6	3.80	4.10	4.50	4.13	A_6	3.87	4.17	4.57	4.20	A_6	4.00	4.30	4.70	4.33
Mean (B)	2.44	2.64	2.91		Mean (B)	2.51	2.71	2.98		Mean (B)	2.64	2.84	3.11	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.08	0.05	0.13		S. Em ±	0.08	0.05	0.13		S. Em ±	0.08	0.05	0.13	
C.D @ 5%	0.22	0.15	NS		C.D @ 5%	0.22	0.15	NS		C.D @ 5%	0.22	0.15	NS	

Table 4. Influence of rootstock age and environmental conditions on days to girth of graft (cm).

Age of the rootstock (A)	Girth of graft (cm)													
	30 DAG				60 DAG					90 DAG				
	Environmental conditions (B)													
	B_1	**B_2**	**B_3**	**Mean (A)**		**B_1**	**B_2**	**B_3**	**Mean (A)**		**B_1**	**B_2**	**B_3**	**Mean (A)**

A1	0.94	1.04	1.14	1.04	A1	1.16	1.26	1.36	1.26	A1	1.42	1.52	1.62	1.52
A2	1.44	1.50	1.60	1.51	A2	1.66	1.72	1.82	1.73	A2	1.92	1.98	2.08	1.99
A3	1.65	1.69	1.70	1.68	A3	1.87	1.91	1.92	1.90	A3	2.13	2.17	2.18	2.16
A4	1.71	1.73	1.75	1.73	A4	1.93	1.95	1.97	1.95	A4	2.19	2.21	2.23	2.21
A5	1.77	1.78	1.81	1.79	A5	1.99	2.00	2.03	2.01	A5	2.25	2.26	2.29	2.27
A6	1.85	1.88	1.94	1.89	A6	2.07	2.10	2.16	2.11	A6	2.33	2.36	2.42	2.37
Mean (B)	1.56	1.60	1.66		Mean (B)	1.78	1.82	1.88		Mean (B)	2.04	2.08	2.14	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.02	0.02	0.04		S. Em ±	0.02	0.02	0.04		S. Em ±	0.02	0.02	0.04	
C.D @ 5%	0.07	0.05	NS		C.D @ 5%	0.07	0.05	NS		C.D @ 5%	0.07	0.05	NS	

Table 5. Influence of rootstock age and environmental conditions on number of leaves.

Age of the rootstock (A)	Number of leaves per plant													
	30 DAG				60 DAG					90 DAG				
	Environmental conditions (B)													
	B1	**B2**	**B3**	**Mean (A)**		**B1**	**B2**	**B3**	**Mean (A)**		**B1**	**B2**	**B3**	**Mean (A)**
A1	0.45	0.55	0.95	0.65	A1	2.45	2.55	2.95	2.65	A1	4.65	4.75	5.15	4.85
A2	1.25	1.55	1.90	1.57	A2	3.25	3.55	3.90	3.57	A2	5.45	5.75	6.10	5.77
A3	2.55	2.75	3.15	2.82	A3	4.55	4.75	5.15	4.82	A3	6.75	6.95	7.35	7.02
A4	3.50	3.60	3.50	3.53	A4	5.50	5.60	5.50	5.53	A4	7.70	7.80	7.70	7.73
A5	3.75	4.05	4.40	4.07	A5	5.75	6.05	6.40	6.07	A5	7.95	8.25	8.60	8.27
A6	4.60	4.85	4.95	4.80	A6	6.60	6.85	6.95	6.80	A6	8.80	9.05	9.15	9.00
Mean (B)	2.68	2.89	3.14		Mean (B)	4.68	4.89	5.14		Mean (B)	6.88	7.09	7.34	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.08	0.06	0.14		S. Em ±	0.08	0.06	0.14		S. Em ±	0.08	0.06	0.14	
C.D @ 5%	0.23	0.16	NS		C.D @ 5%	0.23	0.16	NS		C.D @ 5%	0.23	0.16	NS	

Table 6. Influence of rootstock age and environmental conditions on leaf area (cm^2).

Age of the rootstock (A)	Leaf area (cm^2)													
	30 DAG				60 DAG					90 DAG				
	Environmental conditions (B)													
	B_1	**B_2**	**B_3**	**Mean (A)**		**B_1**	**B_2**	**B_3**	**Mean (A)**		**B_1**	**B_2**	**B_3**	**Mean (A)**
A_1	4.53	6.12	6.88	5.84	A_1	5.95	7.81	8.68	7.48	A_1	10.69	13.02	14.11	12.61
A_2	8.36	10.50	13.21	10.69	A_2	10.32	12.64	17.61	13.52	A_2	16.22	19.23	25.12	20.19
A_3	20.65	22.61	25.32	22.86	A_3	25.35	26.83	29.22	27.13	A_3	33.85	35.56	38.33	35.91
A_4	26.29	27.23	29.24	27.59	A_4	30.86	33.23	34.91	33.00	A_4	40.16	42.80	44.71	42.56
A_5	30.13	33.69	35.87	33.23	A_5	36.15	38.78	40.72	38.55	A_5	46.07	49.05	51.23	48.78
A_6	36.91	38.84	42.59	39.45	A_6	41.89	44.90	52.27	46.35	A_6	52.55	55.84	63.91	57.44
Mean (B)	21.15	23.16	25.52		Mean (B)	25.09	27.37	30.57		Mean (B)	33.26	35.92	39.57	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.93	0.66	1.61		S. Em ±	0.66	0.46	1.14		S. Em ±	0.74	0.52	1.27	
C.D @ 5%	2.64	1.86	NS		C.D @ 5%	1.87	1.32	NS		C.D @ 5%	2.09	1.48	NS	

Table 7. Influence of rootstock age and environmental conditions on Specific Leaf Weight (mg/cm^2).

Age of the rootstock (A)	Specific Leaf Weight (mg/cm^2)													
	30 DAG				60 DAG					90 DAG				
	Environmental conditions (B)													
	B_1	**B_2**	**B_3**	**Mean (A)**		**B_1**	**B_2**	**B_3**	**Mean (A)**		**B_1**	**B_2**	**B_3**	**Mean (A)**
A_1	1.60	1.73	1.86	1.73	A_1	1.82	1.95	2.08	1.95	A_1	2.20	2.33	2.46	2.33
A_2	2.25	2.37	2.68	2.43	A_2	2.47	2.59	2.90	2.65	A_2	2.85	2.97	3.28	3.03
A_3	2.92	3.05	3.34	3.10	A_3	3.14	3.27	3.56	3.32	A_3	3.52	3.65	3.94	3.70
A_4	3.49	3.56	4.01	3.68	A_4	3.71	3.78	4.23	3.90	A_4	4.09	4.16	4.61	4.28
A_5	4.09	4.16	4.24	4.16	A_5	4.31	4.38	4.46	4.38	A_5	4.69	4.76	4.84	4.76
A_6	4.47	4.68	4.87	4.67	A_6	4.69	4.90	5.09	4.89	A_6	5.07	5.28	5.47	5.27
Mean (B)	3.13	3.26	3.50		Mean (B)	3.35	3.48	3.72		Mean (B)	3.73	3.86	4.10	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.03	0.02	0.06		S. Em	0.03	0.02	0.06		S. Em	0.03	0.0	0.06	

				±				±		2	
C.D @ 5%	0.10	0.07	NS	C.D @ 5%	0.10	0.07	NS	C.D @ 5%	0.10	0.07	NS

Table 8: Effect of age of rootstocks and environmental conditions on relative leaf water content (%)

Age of the rootstock (A)	Relative leaf water content (%)														
	30 DAG				60 DAG					90 DAG					
	Environmental conditions (B)														
	B_1	B_2	B_3	Mean (A)		B_1	B_2	B_3	Mean (A)		B_1	B_2	B_3	Mean (A)
A_1	66.29	69.08	70.87	68.75	A_1	66.18	68.97	70.76	68.64	A_1	66.16	68.94	70.73	68.61
A_2	71.76	72.71	77.38	73.95	A_2	71.65	72.60	79.44	74.56	A_2	71.62	72.58	76.74	73.64
A_3	76.24	77.14	78.38	77.25	A_3	76.24	77.32	78.80	77.45	A_3	78.61	78.57	79.68	78.95
A_4	79.04	80.67	75.23	78.31	A_4	78.97	80.05	72.70	77.24	A_4	78.87	81.51	76.68	79.02
A_5	80.55	80.50	80.86	80.64	A_5	79.66	78.91	81.10	79.89	A_5	80.30	80.25	81.76	80.77
A_6	82.34	82.00	83.63	82.66	A_6	81.19	81.30	83.36	81.95	A_6	82.01	84.54	84.19	83.58
Mean (B)	76.04	77.02	77.72		Mean (B)	75.65	76.53	77.69		Mean (B)	76.26	77.73	78.29	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.46	0.32	0.79		S. Em ±	0.47	0.33	0.81		S. Em ±	0.49	0.34	0.84	
C.D @ 5%	1.29	0.91	2.24		C.D @ 5%	1.33	0.94	2.31		C.D @ 5%	1.38	0.97	2.39	

Table 9: Effect of age of rootstocks and environmental conditions on Chlorophyll content (mg/g FW).

Age of the rootstock (A)	Chlorophyll content (mg/g FW)														
	30 DAG				60 DAG					90 DAG					
	Environmental conditions (B)														
	B_1	B_2	B_3	Mean (A)		B_1	B_2	B_3	Mean (A)		B_1	B_2	B_3	Mean (A)
A_1	1.93	2.03	2.16	2.04	A_1	2.0	2.1	2.2	2.18	A_1	2.2	2.3	2.4	2.35

						7	7	9			4	4	7	
A_2	2.28	2.46	3.20	2.65	A_2	2.42	2.60	3.33	2.78	A_2	2.59	2.77	3.51	2.96
A_3	3.43	3.45	3.50	3.46	A_3	3.57	3.59	3.63	3.60	A_3	3.74	3.76	3.81	3.77
A_4	4.52	4.83	4.84	4.73	A_4	4.66	4.97	4.98	4.87	A_4	4.83	5.14	5.15	5.04
A_5	5.08	5.29	5.69	5.35	A_5	5.21	5.42	5.83	5.49	A_5	5.39	5.60	6.00	5.66
A_6	5.73	5.79	6.93	6.15	A_6	5.86	5.92	7.07	6.28	A_6	6.04	6.10	7.24	6.46
Mean (B)	3.83	3.97	4.39		Mean (B)	3.96	4.11	4.52		Mean (B)	4.14	4.28	4.70	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.13	0.09	0.22		S. Em ±	0.13	0.09	0.22		S. Em ±	0.13	0.09	0.22	
C.D @ 5%	0.37	0.26	NS		C.D @ 5%	0.37	0.26	NS		C.D @ 5%	0.37	0.26	NS	

Table 10: Effect of age of rootstocks and environmental conditions on root length (cm)

Age of the rootstock (A)	Length of longest root (cm)				Root dry weight (g)			
	Environmental conditions (B)							
	B_1	**B_2**	**B_3**	**Mean (A)**	**B_1**	**B_2**	**B_3**	**Mean (A)**
A_1	9.22	10.20	11.17	10.20	0.17	0.19	0.20	0.19
A_2	11.86	12.17	12.54	12.19	0.22	0.29	0.40	0.30
A_3	12.70	13.22	13.71	13.21	0.47	0.48	0.48	0.48
A_4	14.21	14.66	14.96	14.61	0.50	0.52	0.56	0.53
A_5	15.33	15.50	16.18	15.67	0.58	0.80	0.88	0.75
A_6	17.32	18.34	18.52	18.06	1.21	1.28	1.35	1.28
Mean (B)	13.44	14.01	14.51		0.52	0.59	0.64	
Interaction	A	B	AxB		A	B	AxB	
S. Em ±	0.05	0.03	0.08		0.01	0.01	0.03	
C.D @ 5%	0.14	0.10	0.23		0.04	0.03	0.07	

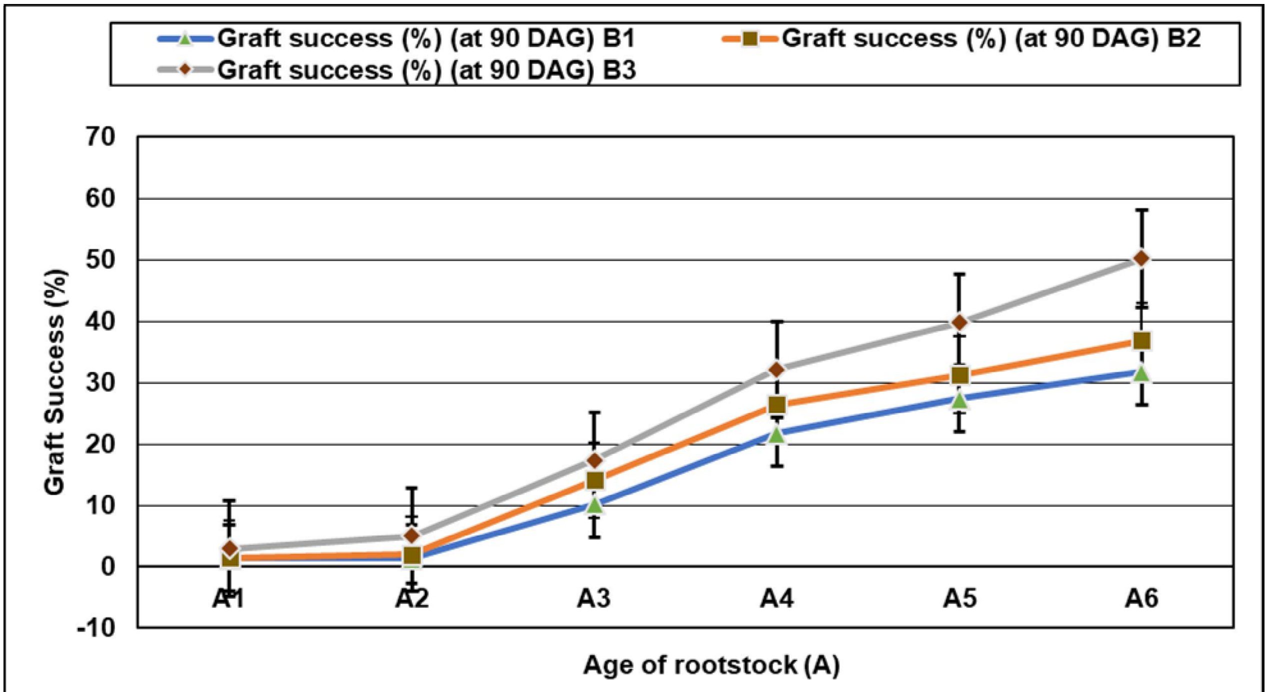

Fig. 3: Influence of different aged rootstocks and different environmental conditions on graft success in Jackfruit softwood grafting

Table 11: Effect of age of rootstocks and environmental conditions on plant dry matter (g)

Age of the rootstock (A)	Total plant dry matter (g)													
	30 DAG				60 DAG					90 DAG				
	Environmental conditions (B)													
	B_1	B_2	B_3	Mean (A)		B_1	B_2	B_3	Mean (A)		B_1	B_2	B_3	Mean (A)
A_1	1.06	1.07	1.09	1.07	A_1	1.11	1.13	1.14	1.13	A_1	1.16	1.17	1.19	1.17
A_2	1.10	1.14	1.19	1.14	A_2	1.15	1.20	1.25	1.20	A_2	1.20	1.25	1.29	1.25
A_3	1.24	1.27	1.45	1.32	A_3	1.29	1.32	1.49	1.37	A_3	1.34	1.37	1.55	1.42
A_4	1.47	1.52	1.54	1.51	A_4	1.51	1.57	1.59	1.56	A_4	1.57	1.63	1.64	1.61
A_5	1.68	1.80	1.87	1.78	A_5	1.73	1.84	1.92	1.83	A_5	1.79	1.90	1.97	1.88
A_6	2.79	3.80	3.86	3.48	A_6	2.89	3.85	3.90	3.55	A_6	2.99	3.90	3.95	3.61
Mean (B)	1.56	1.77	1.83		Mean (B)	1.62	1.82	1.88		Mean (B)	1.67	1.87	1.93	
Interaction	A	B	AxB			A	B	AxB			A	B	AxB	
S. Em ±	0.01	0.01	0.02		S. Em ±	0.01	0.01	0.02		S. Em ±	0.02	0.01	0.03	
C.D @ 5%	0.04	0.03	0.07		C.D @ 5%	0.04	0.03	0.07		C.D @ 5%	0.04	0.03	0.07	

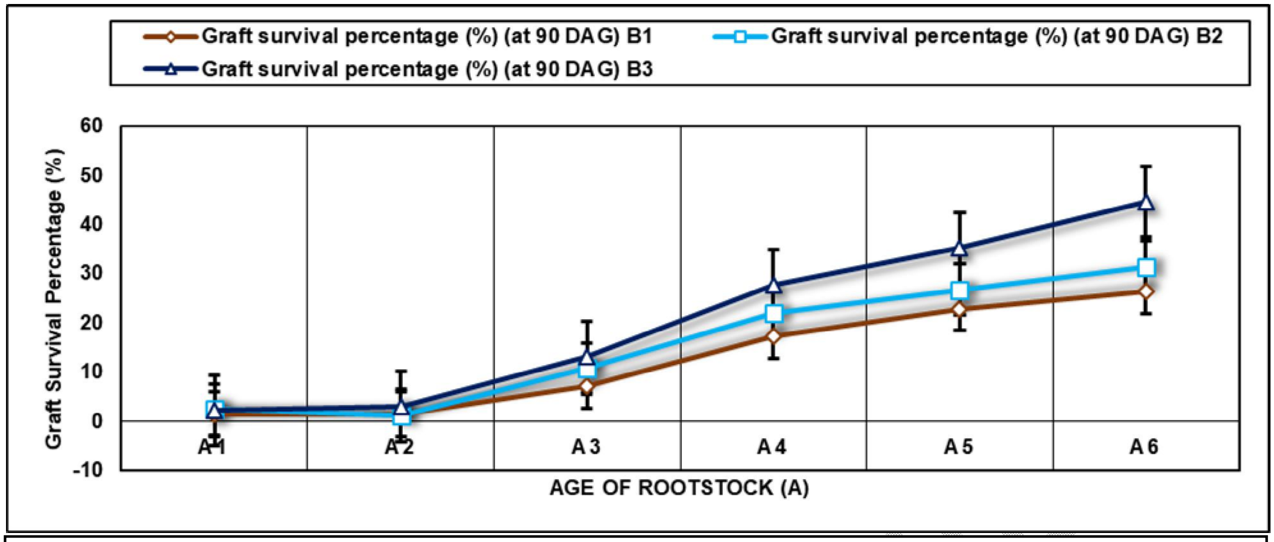

Fig. 4: Influence of different aged rootstocks and different environmental conditions on graft survival percentage (%) in jackfruit softwood grafting

4 CONCLUSION

Effect of Jackfruit softwood grafting between different age of rootstocks and different environmental conditions had a vital positive association and was significantly associated with days taken for sprouting, graft success, length of longest root, relative leaf water content (%), graft survival percentage (%), root volume (cm^3), root biomass (g) and total plant dry matter (g). However, among the different combinations of age of rootstock and environmental conditions, the grafts performed using 90 days old rootstock when they allowed to grow under polyhouse environmental condition were performed better growth and development for most of the traits studied. Whereas, 15 days old rootstock under shadenet condition showed comparatively poor growth performance.

Disclaimer (Artificial intelligence):

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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