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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(3): 727-733

www.thepharmajournal.com
Received: 10-12-2021
Accepted: 21-02-2022

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Effect of rootstock age, integrated nutrient management and seasonal variations on conventional propagation method of Khasi mandarin plants under polyhouse condition with respect to Nagaland

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Abstract
The experiment was conducted at Central Institute of Horticulture (CIH) farm, Nagaland during 2021-2022 to study the effect of rootstock age, INM and seasonal variations on conventional propagation method of Khasi mandarin plants under polyhouse condition with respect to Nagaland. Experiment was laid out in RBD with 16 treatments *viz*., T_1 (9 Months old rootstock +250gm FYM + T-budding on 3rd Aug), T_2 (9 Months old rootstock + 200gm Vermicompost + T-budding on 3rd Aug), T_3 (12 Months old rootstock + 250gm FYM + T-budding on 3rd Aug), T_4 (12 Months old rootstock +200gm Vermicompost + T-budding on 3rd Aug), T_5 (9 Months old rootstock + 250gm FYM + Wedge grafting on 3rd Aug), T_6 (9 Months old rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug), T_7 (12 Months old rootstock + 250gm FYM + Wedge grafting on 3rd Aug), T_8 (12 Months old rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug), T_9 (9 Months old rootstock + 250gm FYM + T-budding on 3rd Sept), T_{10} (9 Months old rootstock + 200gm Vermicompost + T-budding on 3rd Sept), T_{11} (12 Months old rootstock + 250gm FYM + T-budding on 3rd Sept), T_{12} (12 Months old rootstock + 200gm Vermicompost + T-budding on 3rd Sept), T_{13} (9 Months old rootstock + 250gm FYM+ Wedge grafting on 3rd Sept), T_{14} (9 Months old rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept), T_{15} (12 Months old rootstock + 250gm FYM + Wedge grafting on 3rd Sept) and T_{16} (12 Months old rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept) replicated three times with 5 plants in each replication. Pooled data after analysis shows that T_6 gave maximum number of leaves (34.12 nos.), fastest sprouting (15.33 days), highest graft success (83.67%) and plant survivality (85%). While other attributes like maximum plant height (38.38 cm) was recorded in T_7, rootstock diameter value (7.25 mm) and length of branch (6.50 cm) were recorded in T_8, number of branches per plant (7.00 nos.) in T_5 and T_8 were observed. On the other hand, the least values in plant height (33.62 cm) and length of branches (6.00 cm) were found in T_{13}, number of branches per plant (3.33 nos.) and graft success (57.0%) in T_7, number of leaves per plant (23.52 nos.) and no. of days for sprouting (32.67 days) in T_{15}, diameter value (5.57 mm) in T_9 and lowest plant survival (64.33%) in T_{16} were recorded. In all treatments, T-budding was not successful due to failure in union of scion and rootstock; this may be due to unfavorable time for budding.

Keywords: Khasi mandarin, wedge grafting, t-budding, rootstock age, sprouting

Introduction
In India, citrus is cultivated in an area about 1058 thousand ha with a total production of 14032 thousand MT. Out of which mandarin crop covers an area about 479 thousand ha with a production of 6397 thousand MT (Department of Agriculture, Cooperation & Farmers Welfare 3rd Advance Estimates, 2019-2020) [15] The North East region is also one of the hotspot centers of citrus having 17 species, 52 varieties and 7 natural hybrids. Among the various citrus species, loose-skinned khasi mandarin orange (*Citrus reticulata* Blanco) is one commercially important cultivar for North East region. Its cultivation is distributed in various pockets of Assam (41.22%), Arunachal Pradesh (14.11%), Nagaland (9.58%), Meghalaya (9.15%), Mizoram (8.91%), Manipur (8.07%), Tripura (5.12%) and Sikkim (3.84%) (Anonymous, 2018) [2]. Nagaland also lies in one of the mandarin growing belts covering an area of about 5446.00 ha with a production about 42903.00 MT. In Nagaland state, khasi mandarin is widely grown in the districts of Dimapur (120ha), Kohima (895ha), Mokokchung (620ha), Mon (448ha), Longleng (336ha), Phek (498ha), Peren (520ha), Tuensang (475ha), Wokha (410ha), Zunheboto (410ha) (Anonymous, 2021) [3].

Though Khasi mandarin is a major fruit crop for the farmers of Nagaland yet there is gradual decline in its area as the orchards in Nagaland are raised from nucellar seedlings and not through commercial methods (T-budding and wedge grafting) for which the orchards are unable to cope the biotic and abiotic stresses during their developmental phase and ultimately challenged with extreme citrus decline, greening, Phythopthora and Tristeza virus. Many mandarin growers across the country are now adopting budded and grafted orchards of appropriate rootstock as it has provided better performance compared to nucellar seedlings in terms of adaptability against both biotic and abiotic factors, precosity of bearing, uniform fruit size and higher yield (Kumar *et al*., 2016) [10]. One of the major reasons for not adopting commercial methods for Nagaland farmers may be due to unavailability of quality planting material for establishment of new orchards or replanting, lack of researches and awareness in this field. Thus to produce genuine quality planting materials, one should go for commercial method of multiplication with good rootstock performance ideal for the location coupled with Integrated Nutrient Management (INM) from an early stage to lay a strong foundation. Appropriate rootstock age also plays an important role in accelerating good success rate and lesser mortality rate in field condition. The right season for propagation has also helped in good success rate saving money and time.The advantages of integrated nutrients management generally superior over use of each component separately. Slow breakdown and release rate of nutrients from organic sources helps the plant to uptake nutrients for longer time (Choudhary and Kumar, 2013) [4]. Maximum fruit yield coupled with an adequate tree volume of sweet orange is attainable through combined use of organics plus inorganic or bio-fertilizers (Marathe and Bharambe, 2007) [11]. Introduction of initial integrated application of fertilizers and organic manures during developmental phase is another important factor to produce quality and sturdy plants. Thus to obtain genetically uniform true to type quality planting material and also to take advantage of adapted rootstocks, therefore, this research study is attempted to standardize the appropriate rootstock age, INM and seasonal variations on conventional propagation methods of Khasi mandarin, which is the need of hour for quality plants production under nursery stage for quality establishment of citrus orchards in Nagaland.

Materials and Methods

The present study was undertaken at Central Institute of Horticulture (CIH) farm, Medziphema, Nagaland during the month of August, 2021 to January, 2022. The experimental site is situated at an altitude about 360 m above msl and lies between 25.75º N latitude and 93.86ºE longitude. The mean minimum and maximum temperature in polyhouse during experimental period were also recorded to be 13.2 °C and 32.6 °C with a relative humidity of 76%.

For the experiment, T-budding and Wedge grafting was performed on 9 and 12 months old rough lemon (*C. jambhiri*) rootstock which have been raised in media with different treatments as shown in table 1.

Table 1: Treatment descriptions

T_1	9 Months old rootstock+250g FYM+T-budding on 3rd Aug
T_2	9 Months old rootstock+ 200g Vermicompost +T-budding on 3rd Aug
T_3	12 Months old rootstock+250g FYM + T-budding on 3rd Aug
T_4	12 Months old rootstock+200g Vermicompost + T-budding on 3rd Aug
T_5	9 Months old rootstock+250g FYM + Wedge grafting on 3rd Aug
T_6	9 Months old rootstock+200g Vermicompost + Wedge grafting on 3rd Aug
T_7	12 Months old rootstock+ 250g FYM + Wedge grafting on 3rd Aug
T_8	12 Months old rootstock+200g Vermicompost + Wedge grafting on 3rd Aug
T_9	9 Months old rootstock+250g FYM + T-budding on 3rd Sept
T_{10}	9 Months old rootstock+200g Vermicompost + T-budding on 3rd Sept
T_{11}	12 Months old rootstock+250g FYM + T-budding on 3rd Sept
T_{12}	12 Months old rootstock+200g Vermicompost + T-budding on 3rd Sept
T_{13}	9 Months old rootstock+250g FYM+ Wedge grafting on 3rd Sept
T_{14}	9 Months old rootstock+ 200g Vermicompost + Wedge grafting on 3rd Sept
T_{15}	12 Months old rootstock+250g FYM + Wedge grafting on 3rd Sept
T_{16}	12 Months old rootstock+200g Vermicompost + Wedge grafting on 3rd Sept

Experiment was laid out in simple Randomized Block Design comprising of sixteen (16) treatments. Each treatment was replicated three times with 5 plants in each replication and was kept under the polyhouse. The observation on days taken to sprouting (days) was recorded based on first bud sprout after budding or grafting. The bud or graft success (%) was measured using formula, i.e., {(No. of sprouted graft/Total plant grafted) × 100} and plant survival (%) after 120 days was measured using formula i.e., {(Survived plant/Graft success plant) × 100} (Deshmukh *et al*., 2017) [5]. Morphological traits, *viz*., plant height (cm), rootstock diameter (mm), number of leaves per plant and number of branches per plant were recorded after first bud sprout. The average data were recorded and subjected to further statistical analysis of variance (ANOVA) and the means were compared using statistical software SPSS version 17.0 difference were considered statistically significant at P = 0.05.

Results and Discussion

1. Plant height (cm)

Performance of plant height from the date of grafting till plant survivality is presented in Table 2. Maximum plant height (38.38 cm) was found in T_7 (12M rootstock + 250gm FYM + Wedge grafting on 3rd Aug) followed by T_{15} (12M rootstock + 250gm FYM + Wedge grafting on 3rd Sept) which was 37.15 cm while minimum plant height (33.62 cm) was recorded in T_{13} (9M rootstock +250gm FYM + Wedge grafting on 3rd Sept) followed by T_{14} (9M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept) which was 34.02 cm. Increased plant height was observed in wedge grafting performed on 3rd August on 12 months old rootstocks. Favorable climatic condition and appropriate rootstock age may have aided in quicker union of rootstock and scion and thus showed more plant height. A similar finding was opined by Singh *et al.* (2012) [20] where highest plant height (34.58 cm) in Nagpur

mandarin was recorded on twelve months old rough lemon rootstock. Patel *et al.* (2010) [16] also found highest plant height (28.90 cm) in Khasi mandarin on last week of July grafting. The plant height increase might be due to nutrient supply from INM which have influenced the physical, chemical and biological properties of soil through supplying macro and micronutrients leading to better plant growth and development. Kimi and Hazarika (2018) [9] also observed maximum plant height (5.83 m and 5.66 m) on application of FYM + Cow Pat Pit + Bio dynamics 500 + Bio dynamics 501. Tarai and Ghosh (2016) [21] also reported maximum growth of sweet orange plant on receiving half dose of NPK + full dose of neem cake. Similar findings have been opined by Singh *et al.* (2000) [19] on application of chemical fertilizers and biofertilisers in sweet orange.

2. Diameter of rootstock (mm)

From table 3, it is evident that there is a significant difference on all treatments. Highest rootstock diameter value (7.25 mm) was found in T_8 (12M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug) which was at par with T_4, T_7, T_{15} and T_{16} while the lowest value (5.57 mm) was observed in T_9 (9M rootstock + 250 gm FYM + T-budding on 11th Sept) and was found to be at par with T_1, T_2, T_3, T_5, T_6, T_9, T_{10}, T_{13} and T_{14}. 12 months old rootstock plants showed more value of diameter which may be due to expansion of cambium with age. The nutrient supply on application of vermicompost also encouraged increased value of diameter rootstock. Increase in plant growth with the application of nitrogen may be explained from the fact that the nitrogen is the major constituent of many compound of great physiological importance in the metabolism such as amino acids, proteins, nucleic acids, porphyrins, enzymes and coenzymes (Agarwala and Sharma, 1976) [1].

3. Length of branches (cm)

The maximum length of branch (6.50 cm) was recorded in treatment T_8 (12M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug) and was at par with T_{16} (12M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept) while the minimum length of branches (6.00 cm) was found in treatment T_{13} (9M rootstock + 250gm FYM + Wedge grafting on 3rd Sept) and was found to be at par with T_{14} (9M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept), T_8 (12M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug) and T_7 (12M rootstock + 250gm FYM + Wedge grafting on 3rd Aug). Increase in length of branches may be due to influence of maturity of rootstock age, nutrients and seasonal variations on grafting. Matured rootstock (12 months old) having bigger root system aided in better absorption of nutrients supplied from the manures which have lead to faster elongation of the branches length. The findings from Srivastava *et al.* (1994) [22], Mei *et al.* (2011) [12] and Deshmukh *et al.* (2017) [5] reported the higher root-scion ratio the more numerous lateral roots was found important in improving nutritional deficiencies in citrus and have contributed in better development of the plant stand.

4. Number of branches per plant

The highest number of branches per plant (7.00 nos.) was recorded in T_5 (9M rootstock + 250gm FYM + Wedge grafting on 3rd Aug) and T_8 (12M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug) which was at par with T_{13} and T_{16}. The lowest number of branches per plant (3.33 nos.) was recorded in T_7 (12M rootstock + 250gm FYM + Wedge grafting on 3rd Aug) which was at par with T_6, T_{14} and T_{15}. Ibe *et al.* (2011) [8] found that the complementary use of organic and inorganic fertilizers holds the key to sustainable citrus production and improved plant height and spread through a sound fertility management strategy.

Table 2: Effect of rootstock age, INM and seasonal variations on plant height of Khasi mandarin plants under polyhouse condition

Treatments	Plant height (cm)									
	3rd Aug	24th Aug	31st Aug	7th Sept	14th Sept	21st Sept	28th Sept	5th Oct	12th Oct	19th Oct
T_1: (9M rootstock + FYM + T- budding on 3rd Aug)	32.31	32.31	32.31	32.77	32.77	32.77	33.11	33.11	33.11	33.11
T_2: (9M rootstock + Vermicompost + T-budding on 3rdAug)	31.47	31.47	31.47	32.38	32.38	32.38	32.38	32.38	32.38	32.38
T_3: (12M rootstock + FYM +T- budding on 3rd Aug)	36.28	36.28	36.28	36.49	36.49	36.49	36.66	36.66	36.66	36.66
T_4: (12M rootstock + Vermicompost +T-budding on 3rd Aug)	35.55	35.55	35.62	35.92	35.92	35.92	35.92	35.92	35.92	35.92
T_5: (9M rootstock + FYM +Wedge grafting on 3rd Aug)	32.05	32.05	32.54	33.18	33.47	33.59	33.99	34.33	34.95	35.09
T_6: (9M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	32.66	32.66	32.66	33.80	34.10	34.90	35.07	35.07	35.52	35.88
T_7: (12M rootstock + FYM+ Wedge grafting on 3rd Aug)	35.98	35.98	36.21	36.69	37.10	37.36	37.55	37.75	37.96	38.14
T_8: (12M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	34.03	34.03	34.03	35.32	35.47	35.69	36.21	36.21	36.25	36.55
T_9: (9M rootstock + FYM+ T-budding on 3rd Sep)	32.01	32.01	32.61	32.61	33.32	33.60	33.60	33.60	33.60	32.22
T_{10}: (9M rootstock + Vermicompost +T-budding on 3rd Sept)	30.73	30.73	31.62	31.62	32.61	32.92	32.92	32.92	32.92	33.21
T_{11}: (12M rootstock + FYM+ T-budding on 3rd Sep)	35.60	35.60	35.89	35.89	36.81	37.46	37.46	37.46	37.46	35.38
T_{12}: (12M rootstock + Vermicompost +T-budding on 3rd Sept)	35.08	35.08	35.08	35.08	35.69	35.98	35.98	35.98	35.98	35.03
T_{13}: (9M rootstock + FYM + Wedge grafting on 3rd Sept)	31.65	31.65	32.16	33.28	33.84	34.99	35.50	36.50	36.69	33.17
T_{14}: (9M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	32.64	32.64	32.98	33.76	34.99	35.26	35.55	35.92	35.92	33.42
T_{15}: (12M rootstock + FYM + Wedge grafting on 3rd Sept)	35.06	35.06	35.60	36.09	37.34	38.07	39.06	40.40	40.48	36.45
T_{16}: (12M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	33.37	33.37	34.31	34.82	35.74	36.89	37.59	38.06	39.01	34.15
S.Em±	1.02	1.02	1.03	0.99	1.02	0.89	0.90	0.87	0.89	0.96
CD (P=0.05)	2.93	2.93	2.96	2.86	2.95	2.58	2.61	2.51	2.56	2.77

Table 3: Effect of rootstock age, INM and seasonal variations on diameter of rootstock of Khasi mandarin plants under polyhouse condition

Treatments	Diameter of rootstock (mm)									
	3rd Aug	24th Aug	31st Aug	7th Sept	14th Sept	21st Sept	28th Sept	5th Oct	12th Oct	19th Oct
T1: (9M rootstock + FYM + T- budding on 3rd Aug)	5.00	5.22	5.30	5.42	5.50	5.57	5.65	5.70	5.78	5.82
T2: (9M rootstock + Vermicompost + T-budding on 3rdAug)	5.10	5.27	5.37	5.46	5.54	5.60	5.67	5.72	5.80	5.85
T3: (12M rootstock + FYM +T- budding on 3rd Aug)	5.50	5.65	5.73	5.84	5.90	5.98	6.02	6.08	6.12	6.16
T4: (12M rootstock + Vermicompost +T-budding on 3rd Aug)	5.94	6.05	6.12	6.20	6.28	6.35	6.40	6.47	6.52	6.56
T5: (9M rootstock + FYM +Wedge grafting on 3rd Aug)	5.36	5.53	5.60	5.68	5.74	5.82	5.88	5.94	6.00	6.05
T6: (9M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	4.93	5.23	5.40	5.50	5.58	5.65	5.70	5.76	5.80	5.84
T7: (12M rootstock + FYM+ Wedge grafting on 3rd Aug)	6.10	6.30	6.45	6.52	6.60	6.67	6.72	6.78	6.82	6.86
T8: (12M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	6.53	6.70	6.82	6.90	7.00	7.05	7.10	7.16	7.20	7.25
T9: (9M rootstock + FYM+ T-budding on 3rd Sep)	4.76	5.00	5.12	5.22	5.31	5.37	5.42	5.47	5.52	5.57
T10: (9M rootstock + Vermicompost +T-budding on 3rd Sept)	4.89	5.17	5.24	5.32	5.40	5.47	5.54	5.60	5.65	5.70
T11: (12M rootstock + FYM+ T-budding on 3rd Sep)	5.57	5.79	6.00	6.12	6.20	6.26	6.30	6.37	6.42	6.46
T12: (12M rootstock + Vermicompost +T-budding on 3rd Sept)	5.63	6.07	6.15	6.22	6.29	6.35	6.40	6.45	6.50	6.55
T13: (9M rootstock + FYM + Wedge grafting on 3rd Sept)	5.07	5.34	5.43	5.52	5.60	5.67	5.72	5.77	5.80	5.86
T14: (9M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	4.62	5.00	5.14	5.22	5.30	5.38	5.42	5.48	5.54	5.60
T15: (12M rootstock + FYM + Wedge grafting on 3rd Sept)	5.90	6.18	6.28	6.34	6.42	6.47	6.52	6.56	6.60	6.65
T16: (12M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	6.20	6.53	6.64	6.70	6.76	6.82	6.86	6.90	6.94	7.00
S.Em±	0.15	0.18	0.22	0.22	0.23	0.26	0.25	0.25	0.25	0.25
CD (P=0.05)	0.44	0.52	0.63	0.65	0.65	0.74	0.72	0.72	0.72	0.71

Table 4: Effect of rootstock age, INM and seasonal variations on length of branch per plant of Khasi mandarin plants under polyhouse condition

Treatments	Length of branch per plant (cm)									
	3rd Aug	24th Aug	31st Aug	7th Sept	14th Sept	21st Sept	28th Sept	5th Oct	12th Oct	19th Oct
T1: (9M rootstock + FYM + T- budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T2: (9M rootstock + Vermicompost + T-budding on 3rdAug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T3: (12M rootstock + FYM +T- budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T4: (12M rootstock + Vermicompost +T-budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T5: (9M rootstock + FYM +Wedge grafting on 3rd Aug)	2.20	2.58	3.13	3.77	4.49	4.87	5.26	5.40	5.59	6.14
T6: (9M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	1.83	2.49	2.83	3.43	4.07	4.68	5.02	5.30	5.78	6.18
T7: (12M rootstock + FYM+ Wedge grafting on 3rd Aug)	2.90	3.52	3.90	4.20	4.80	5.18	5.34	5.64	5.93	5.93
T8: (12M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	1.77	2.57	3.23	4.00	4.68	5.19	5.54	5.85	6.30	6.50
T9: (9M rootstock + FYM+ T-budding on 3rd Sep)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T10: (9M rootstock + Vermicompost +T-budding on 3rd Sept)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T11: (12M rootstock + FYM+ T-budding on 3rd Sep)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T12: (12M rootstock + Vermicompost +T-budding on 3rd Sept)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T13: (9M rootstock + FYM + Wedge grafting on 3rd Sept)	1.92	2.00	2.53	3.22	4.00	4.40	5.14	5.24	5.45	6.00
T14: (9M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	2.04	2.33	2.88	3.67	4.24	4.47	5.13	5.20	5.62	6.05
T15: (12M rootstock + FYM + Wedge grafting on 3rd Sept)	1.32	2.50	2.99	3.79	4.56	4.80	5.52	5.60	5.84	6.25
T16: (12M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	1.77	2.63	3.24	3.77	4.74	4.87	5.50	5.72	6.17	6.38
S.Em±	0.16	0.18	0.14	0.14	0.11	0.12	0.11	0.09	0.07	0.04
CD (P=0.05)	0.46	0.52	0.39	0.41	0.32	0.34	0.33	0.27	0.19	0.13

Table 5: Effect of rootstock age, INM and seasonal variations on number of branches per plant of Khasi mandarin plants under polyhouse condition

Treatments	Number of branches per plant (nos.)									
	3rd Aug	24th Aug	31st Aug	7th Sept	14th Sept	21st Sept	28th Sept	5th Oct	12th Oct	19th Oct
T1: (9M rootstock + FYM + T- budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T2: (9M rootstock + Vermicompost + T-budding on 3rdAug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T3: (12M rootstock + FYM +T- budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T4: (12M rootstock + Vermicompost +T-budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T5: (9M rootstock + FYM +Wedge grafting on 3rd Aug)	0.33	1.00	1.33	2.33	2.67	4.00	4.67	5.33	6.67	7.00
T6: (9M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	0.67	1.00	1.33	2.00	2.33	2.00	2.33	2.67	3.33	4.00
T7: (12M rootstock + FYM+ Wedge grafting on 3rd Aug)	0.67	0.67	1.00	1.67	1.67	1.67	2.00	2.33	3.00	3.33
T8: (12M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	0.67	1.00	2.00	3.00	3.67	4.33	5.00	5.67	6.67	7.00
T9: (9M rootstock + FYM+ T-budding on 3rd Sep)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T10: (9M rootstock + Vermicompost +T-budding on 3rd Sept)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T11: (12M rootstock + FYM+ T-budding on 3rd Sep)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T12: (12M rootstock + Vermicompost +T-budding on 3rd Sept)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T13: (9M rootstock + FYM + Wedge grafting on 3rd Sept)	0.33	1.00	1.00	1.67	2.00	3.00	3.33	4.33	5.33	6.00
T14: (9M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	0.33	0.67	1.00	1.33	2.00	2.33	2.33	3.00	3.67	4.00
T15: (12M rootstock + FYM + Wedge grafting on 3rd Sept)	0.67	0.67	0.67	1.33	1.67	2.00	2.33	3.00	3.67	3.67
T16: (12M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	0.33	0.67	1.00	2.00	2.33	3.00	3.67	4.00	5.67	6.33
S.Em±	0.19	0.16	0.24	0.37	0.45	0.46	0.58	0.68	0.68	0.65
CD (P=0.05)	0.55	0.47	0.70	1.06	1.29	1.34	1.69	1.97	1.95	1.88

5. Number of leaves per plant

Highest number of leaves per plant (34.12 nos.) was recorded in treatment T_6 (9M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug) while the least number of leaves per plant (23.52 nos.) was noted in treatment T_{15} (12M rootstock + 250gm FYM + Wedge grafting on 3rd Sept). The above finding must be due to influence of rootstock age, effect of higher content of nutrients in vermicompost and seasonal timing of grafting that might have contributed to more production of leaves per plant. Patel *et al.* (2010) [16] also reported maximum number of leaves (25.40 nos.) on 2nd week of July grafting on *C. grandis* rootstock. Deshmukh *et al.* (2017) [5] also found better morphological traits when Khasi mandarin was grafted on 6th months old rootstock of rough lemon. Due to rapid and strong formation of union between rootstock and scion, successively influencing greater absorption of nutrients (Skene *et al.*, 1983) [21].

6. Number of days for sprouting

As presented in Table 7, number of days taken for sprouting showed significant differences in all the subjected treatments. The sprouting of bud was fastest (15.33 days) in T_6 (9M rootstock +200gm Vermicompost + Wedge grafting on 3rd Sept) and was at par with T_5 (9M rootstock + 250gm FYM + Wedge grafting on 3rd Aug) which was 16.67 days followed by T_8 (12M rootstock + 200gm Vermicompost + Grafting on 3rd Oct) which was 21 days. While slowest spouting of bud (32.67 days) took place in T_{15} (12M rootstock + 250gm FYM + Wedge grafting on 3rd Sept) which was at par with T_{16} (29 days) followed by T_{14} (16M rootstock + 200gm Vermicompost + Wedge grafting on 11th Sept) which was 26.67 days. Earlier initiation of sprouting buds was observed on plants where grafting was performed on 3rd August compared to performance of 3rd September. This may be due to rapid callus formation and union of xylem and cambium tissue of the scion and rootstock favored better survival of the sprout (Hartmann *et al.*, 1997) [7]. Our findings are in line with the results of Muralidhara *et al*. (2019) [13] in Coorg mandarin.

7. Graft or bud Success (%)

Effect of rootstock age, INM and seasonal variations showed significant effect on graft and bud success (Table 7). Highest percentage of graft success (83.67%) was noted in treatment T_6 (9M rootstock + 200gmVermicompost + Wedge grafting on 3rd Aug) followed by T_{14} (9M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept) which was 72.67% while the least success (57.0%) was observed in treatment T_7 (12M rootstock + 250gm FYM + Wedge grafting on 3rd Aug) which was at par with T_8 and T_{16}. The budding and grafting success is highly influenced by physical factors, *viz*., temperature, relative humidity, soil moisture and plant factors, *viz*., plant water content and retention, growth stage of scion, age of rootstock and method of propagation. The appropriate rootstock age having higher sugars and moderate C: N ratio must have attributed to the higher percentage of graft success (Deshmukh *et al*., 2017) [5]. While the rapid decline in graft success in some treatments may be due to non-availability of active buds, physiological condition of the rootstock and decreased sap flow or quick cell dehydration, proliferation of callus tissues by both the graft components leading to vascular discontinuity arising from inadequate physiological maturity of rootstock which ultimately interfered with the process of graft/bud union formation (Wang and Kollmann, 1996) [24]. Similar results were also reported in Coorg mandarin (Sankar *et al*., 2014 [16]), Khasi mandarin (Dubey *et al*., 2004 [6] and Patel *et al.*, 2010 [16]).

Table 6: Effect of rootstock age, INM and seasonal variations on number of leaves per plant of Khasi mandarin plants under polyhouse condition

Treatments	Number of leaves per plant (nos.)									
	3rd Aug	24th Aug	31st Aug	7th Sept	14th Sept	21st Sept	28th Sept	5th Oct	12th Oct	19th Oct
T_1: (9M rootstock + FYM + T- budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2: (9M rootstock + Vermicompost + T-budding on 3rdAug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_3: (12M rootstock + FYM +T- budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_4: (12M rootstock + Vermicompost +T-budding on 3rd Aug)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_5: (9M rootstock + FYM +Wedge grafting on 3rd Aug)	15.64	18.32	22.33	24.61	27.14	27.21	28.67	30.25	31.05	31.86
T_6: (9M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	15.58	17.90	22.43	24.95	26.74	26.88	29.07	31.53	33.48	34.12
T_7: (12M rootstock + FYM+ Wedge grafting on 3rd Aug)	14.08	17.17	21.70	22.46	25.29	26.42	27.93	28.90	29.58	30.20
T_8: (12M rootstock + Vermicompost + Wedge grafting on 3rd Aug)	15.74	16.62	22.85	24.45	25.81	26.80	27.70	28.55	29.37	30.07
T_9: (9M rootstock + FYM+ T-budding on 3rd Sep)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_{10}: (9M rootstock + Vermicompost +T-budding on 3rd Sept)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_{11}: (12M rootstock + FYM+ T-budding on 3rd Sep)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_{12}: (12M rootstock + Vermicompost +T-budding on 3rd Sept)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_{13}: (9M rootstock + FYM + Wedge grafting on 3rd Sept)	12.83	17.04	18.00	18.93	20.47	21.35	22.35	23.55	24.87	25.78
T_{14}: (9M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	14.88	17.13	18.09	19.76	20.52	21.79	22.92	23.45	25.03	25.96
T_{15}: (12M rootstock + FYM + Wedge grafting on 3rd Sept)	13.50	15.14	15.83	16.72	17.84	18.95	19.82	20.56	22.59	23.52
T_{16}: (12M rootstock + Vermicompost + Wedge grafting on 3rd Sept)	15.77	16.98	17.29	18.44	19.33	20.82	21.15	21.78	23.40	24.22
S.Em±	0.98	0.75	0.60	0.68	0.62	0.71	0.67	0.72	0.72	0.78
CD (P=0.05)	2.83	2.18	1.74	1.98	1.79	2.04	1.93	2.07	2.09	2.24

Table 7: Effect of rootstock age, INM and seasonal variation on number of days for sprouting, graft or bud success and plant survival of Khasi mandarin plants under polyhouse condition

Treatments	Number of days for sprouting (nos.)	Graft or bud Success (%)	Plant survival (%)
T_1: (9M rootstock + 250 gm FYM + T- budding on 3rd Aug)	0.00	0.00	0.00
T_2: (9M rootstock + 200gm Vermicompost + T-budding on 3rdAug)	0.00	0.00	0.00
T_3: (12M rootstock + 250gm FYM +T- budding on 3rd Aug)	0.00	0.00	0.00
T_4: (12M rootstock + 200gm Vermicompost +T-budding on 3rd Aug)	0.00	0.00	0.00
T_5: (9M rootstock + 250gm FYM +Wedge grafting on 3rd Aug)	16.67	74.33	76.33
T_6: (9M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug)	15.33	83.67	85.00
T_7: (12M rootstock + 250gm FYM+ Wedge grafting on 3rd Aug)	22.33	57.00	71.00
T_8: (12M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Aug)	21.00	59.67	69.33
T_9: (9M rootstock + 250gm FYM+ T-budding on 3rd Sep)	0.00	0.00	0.00
T_{10}: (9M rootstock + 200gm Vermicompost +T-budding on 3rd Sept)	0.00	0.00	0.00
T_{11}: (12M rootstock + 250gm FYM+ T-budding on 3rd Sep)	0.00	0.00	0.00
T_{12}: (12M rootstock + 200gm Vermicompost +T-budding on 3rd Sept)	0.00	0.00	0.00
T_{13}: (9M rootstock + 250gm FYM + Wedge grafting on 3rd Sept)	23.33	69.33	67.33
T_{14}: (9M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept)	26.67	72.67	78.67
T_{15}: (12M rootstock + 250gm FYM + Wedge grafting on 3rd Sept)	32.67	60.33	69.00
T_{16}: (12M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept)	29.00	59.67	64.33
S.Em±	1.93	1.72	1.66
CD (P=0.05)	5.58	4.96	4.79

8. Plant survivality (%)

The plant survivality was recorded at 120 days after grafting or budding. The results as tabulated in Table 6 indicates that the treatment T_6 (9 M rootstock + Vermicompost + Wedge grafting on 3rd Aug) recorded highest plant survival (85%) followed by T_{14} (9M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept) which was 78.67%. However, lowest plant survival (64.33%) was noticed in treatment T_{16} (12M rootstock + 200gm Vermicompost + Wedge grafting on 3rd Sept) (64.33%) followed by T_{13} (12M rootstock + 250gm FYM + Wedge grafting on 3rd Sept) which was 67.33%. The right rootstock age, season for grafting and nutrients supplied through INM must have encouraged better stock-scion interactions assimilating better movement of water and nutrient flow influencing in higher plant survalility (Perez-alfocea *et al*., 2010) [17]. Muralidhara *et al.* (2019) [13] reported maximum plant survivality (98.00%) on three and four month's old rootstock in Coorg mandarin. Highest plant survival (80.2%) was recorded in last week of August grafting of Khasi mandarin in *C. grandis* as reported by Patel *et al.* (2010) [16].

Conclusion

From this research study, it can be concluded that from all the treatments, T_6 (9M rootstock + Vermicompost + Wedge grafting on 3rd Aug) is the most feasible under Nagaland condition followed by T_5 (9M rootstock + FYM +Wedge grafting on 3rd Aug).

Budding was not successful in all treatments. This may be due to the unfavorable timing for budding which have lead to failure in union of scion and rootstock. Further researches can be done on this aspect to discover the most apt time for budding in Nagaland.

Acknowledgement

Authors gratefully acknowledge the Director, Central Institute of Horticulture (CIH), Medziphema, Nagaland, for providing all experimental facilities during the course of research study and Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India, New Delhi, for financial support under the project entitled "Network Project for Establishment of Disease Free Elite Khasi mandarin and Sweet orange genetic stocks through shoot tip grafting (STG) and mass production of quality planting material for Northeastern states of India"

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