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Ashok Kumar
M.Sc. Student, Department of Horticulture, COA, CCS HAU, Hisar, Haryana, India

Devender Chahal
Associate Professor, Krishi Vigyan Kendra, Ambala City, Haryana, India

Arvind Malik
Assistant Professor, Department Horticulture, RDS - Seed Farm, CCS HAU, Hisar, Haryana, India

Sarita Devi
Assistant Scientist, Plant Physiology), Department of Bot. & Pl. Phy, CCS HAU, Hisar, Haryana, India

OP Bishnoi
Assistant Scientist (Plant Breeding), Department of Genetics & PB, CCS HAU, Hisar, Haryana, India

Corresponding Author:
Devender Chahal
Associate Professor, Krishi Vigyan Kendra, Ambala City, Haryana, India

Effect of rootstock thickness on wedge grafting in guava (*Psidium guajava* L.) under different growing conditions

Ashok Kumar, Devender Chahal, Arvind Malik, Sarita Devi and OP Bishnoi

Abstract
The present investigation was conducted during the propagation season of 2017 at Centre for Quality Planting Material, RDS Seed Farm, CCS HAU, Hisar, and Haryana. The experiment comprised of 18 treatment combinations laid in RBD (factorial) design [3 rootstock sizes in terms of thickness (<0.8 cm, 0.8-1.2 cm & >1.2 cm); 6 growing conditions (polyhouse of 200 µ size with and without polycap, green shade-net '50% shade' with and without polycap, open-field plus polycap and open-field only)], each replicated thrice. The results revealed that scion grafted on rootstock having thickness of 0.8-1.2 cm took minimum days for bud sprouting as well as first leaf opening and had maximum success percentage of grafts. Shoot length and its diameter, and the number of leaves as well as leaf area per graft were registered maximum with rootstock thickness of >1.2 cm and it was closely followed by rootstock thickness of 0.8-1.2 cm. However, the chlorophyll content of leaves was again recorded maximum with the rootstock thickness of 0.8-1.2 cm and closely followed by rootstock thickness of >1.2 cm, while the fresh and dry weight of shoot as well as roots were observed maximum with rootstock thickness of >1.2 cm followed by rootstock thickness of 0.8-1.2 cm. Considering the growing conditions, days for graft sprouting and first leaf opening were recorded minimum under polyhouse with polycap. The success percentage of grafts, shoot length and its diameter, number of leaves, leaf area per plant, and the fresh and dry weight of shoot as well as roots were also observed maximum in polyhouse with polycap over the grafts. Almost similar chlorophyll content of leaves was registered under polyhouse as well as open field conditions with and without polycap. Overall, the grafts with rootstock thickness 0.8-1.2 cm performed better and it was closely followed by thickness of >1.2 cm. Moreover, most of the growth traits of graft were observed significantly superior under polyhouse (200 µ) followed by the shade-net condition (50% shade) in comparison to open-field condition. Grafts covered with polycap performed better than the uncovered grafts under all the growing conditions.

Keywords: Guava, wedge grafting, rootstock thickness, polycap, polyhouse, shade-net

Introduction
Guava (*Psidium guajava* L.), a member of Myrtaceae family, is one of the most common horticultural crops in India. Guava is indigenous to tropical America, but it is cultivated in all the tropical and subtropical countries of the world. It is commonly known as 'Apple of tropics' because of having high vitamin A and B and being exceptionally rich in vitamin C (Rai *et al*., 2010) [17]. The fruit is also a good source of pectin, calcium and phosphorus. In terms of area (2.55 lakh ha) and production (40.48 lakh tonnes), it is occupying fourth and fifth place in India, respectively (Anonymous, 2017) [2]. It is one of the most important fruit crops of North India because of its high adaptability to wide range of climate and soil conditions. Haryana is producing 1, 52, 180 tonnes of guava fruit from 11,210 hectares (ha) of land with an average yield of 13.58 tonnes/ha (Anonymous, 2017) [2]. The major guava producing belts of Haryana are Mewat, Palwal, Faridabad, Sonepat, Jind, Hisar and Fatehabad.
Guava is quite hardy, prolific bearer and highly remunerative crop. However, its cultivation is surrounded with several identified constraints like- propagation problems, guava wilt, fruit fly infestation and availability of quality planting material. There is tremendous scope for bringing substantial additional area under guava crop in the state as well as in country. So, the demand of quality planting material will upsurge in coming years and in lieu of this, to ensure the supply of quality guava planting material round the year, rapid multiplication techniques need to be developed. Guava is usually propagated from seed and the species is highly cross pollinated in nature.

If propagated through seed, it exhibits a great variation due to inevitable heterozygosity. Moreover, seed propagated plants come into bearing much later than the vegetatively propagated plants. Through seed propagation, unique characters of certain variety cannot be preserved or multiplied and it does not permit the utilization of superior important characters of a certain rootstock such as disease tolerance, adaptability to varying agro-ecological conditions, manipulation of tree growth and better influence of certain rootstock. So, vegetative propagation is inevitable in guava. Wedge grafting is one of the most popular, easiest and modern technique of vegetative propagation. Success in grafting, subsequent growth of scion shoot and development of the successful graft depend on number of factors including variety, time of grafting, method of grafting, selection and preparation of scion, rootstock material and environmental conditions.

In Northern India, generally guava is propagated by inarching with a very high percentage of success during rainy season. But inarching is cumbersome and limited number of plants are produced from the mother plant. Patch budding is another ideal among various methods of budding but it can be done only during May-June. The scenario is changing from traditional propagation with incorporation of science and technology to nursery management and trade (Singh and Bajpai, 2003) [20]. Conventional methods of propagation as air layering, inarching or stooling cannot fully meet the increasing demand of planting stock because of dependence on weather conditions and low success rate (Gautam *et al*., 2010) [5]. So, there is a demand to prepare the quality guava saplings throughout the year by involving a rapid and successful multiplication technique.

Wedge grafting technique has been found possible throughout the year even in extreme climatic conditions such as severe cold (Singh *et al.*, 2005) [22]. Wedge method of grafting utilizing polycap (PC) has been recommended by Singh *et al*. (2007) [21] for enhancing the production of quality planting material throughout the year. Beer *et al*. (2013) [4] found that controlled environment (when scion shoot covered with polytube) was best for wedge grafts. Joshi *et al*. (2014) [8, 9] recorded the highest graft-take in guava when wedge grafting was done in February and grafts were covered with polycap by using local guava as a rootstock under polyhouse condition. Kukshal (2016) [10] also reported that grafting performed during second fortnight of February with capping of grafts under open field conditions gave higher graft success, whereas, grafting performed during second fortnight of January without capping of grafts under open field conditions gave minimum graft success in guava.

In the present contest, improvement in quality of planting material raised through grafting has become very important when planting materials are limited due to scarcity of a clone or varieties or due to sudden expansion in acreage. The demand of guava hybrid 'Hisar Safeda' (Allahabad Safeda x Seedless) as developed by CCSHAU, Hisar is increasing among the growers due to its superiority over standard cultivars in term of yield and quality. Therefore, present study was aimed to standardize the thickness of recommended rootstock (L-49) for wedge grafting and to find out the most suitable growing condition to raise the nursery of this most promising cultivar, Hisar Safeda, successfully in semi-arid zone of Haryana.

Materials and Methods

The present investigation was carried out at Centre for Quality Planting Material, RDS Seed Farm, CCS HAU, Hisar (Haryana) during the year 2017. The experimental site has a semi-arid subtropical climate with hot, dry and desiccating winds during summer season and severe cold during winter season. The mean monthly maximum temperature during summer (May to July) is around 42 to 45 ^{o}C, while the minimum temperature during winter months of December and January and sometimes goes as low as 0 ^{o}C or less than that. The rainfall of area is highly erratic and variable. The average rainfall is about 425 mm and about 75 per cent of which is received during July to September. The soil of district Hisar has been derived from Indo-Gangetic alluvial plain, which is sandy loam in texture and has some amount of calcium carbonate in the profile. Experiment was laid out on one-year-old guava seedlings of cultivar L-49 raised and nurtured in black polyethylene bags (7″ x 9″) filled with sand (2 parts) plus FYM (1 part) as a potting mixture in Randomized Block Design (factorial) with three replications and eighteen treatment combinations, comprising of three rootstock thickness (<0.8 cm, 0.8-1.2 cm and >1.2 cm) and six growing conditions [polyhouse (200 µ) with polycap, polyhouse (200 µ) without polycap, green shade-net (50% shade) with polycap, green shade-net (50% shade) without polycap, open-field condition with polycap and open-field condition without polycap]. Vigorous and uniform, middle and basal scion sticks of cultivar 'Hisar Safeda' were wedge grafted on guava seedlings of cultivar 'L-49' selected according to variation in stem thickness at grafting point in the last week of February 2017 and after that grafts were placed under the different growing conditions. Various horticultural practices were applied according to the 'Package of practice for horticultural crops' as recommended by CCSHAU, Hisar.

The scion shoots 15 to 18 cm long with 3 to 4 healthy buds were selected for grafting. All the selected scion shoots were defoliated on the mother plants about one week prior to detachment. At the same time, the apical growing portion of selected shoots was also beheaded, which helped in forcing the dormant buds to swell and to sprout after the grafting. The scion sticks with swollen buds were detached from mother plants and then wrapped in newspaper with moist sphagnum moss and tied in gunny bag to avoid the desiccation of buds. Grafting operation was performed immediately after the collection of scion sticks. After the selection of scion material, the rootstock was headed back, leaving 12 to 15 cm long stem above the polyethylene bag. The beheaded rootstock was split open about 4.0 to 4.5 cm deep through the center from the cut end of rootstock with grafting knife. A grafting wedge-shaped cut, slanting from both the sides 4.0-4.5 cm long was made on lower side of the scion shoot. The scion stick was inserted into split of the stock and pressed properly so that the cambium tissues of rootstock and scion stick could align properly. The stock and scion were then tied with the help of 150-gauge, 2 cm wide and 25 to 30 cm long polyethylene strip and then covered with polycap according to above mentioned treatments. Grafts were watered as per requirement and weeding in the poly bags was done regularly. New sprouts (side shoots) arising from any portion of rootstock were removed at the interval of 15 days. After sprouting, 1-2 healthy shoots were maintained on scion stem. Adequate care was taken to protect the tender growing grafts from pests and diseases by maintaining sanitation.

All the experimental grafts were observed daily critically for recording the data on bud sprouting, first leaf opening, success percentage of grafts, shoot length, diameter of

sprouted shoot and number of leaves on graft (scion). Date of bud sprouting was recorded when the first sign of bud sprout was visible with naked eyes on the grafted scion stick, and such varied dates were recorded on all the experimental grafts per treatment and average date was worked out for each replication. After that, days taken for bud sprouting were calculated from the date of grafting to the average date on which the first bud sprouted. The first leaf opening was counted upto the date when first leaf fully opened on a scion stick. Days taken for first leaf opening were calculated from the date of grafting to the average date on which the first leaf fully opened. The number of successful grafts in each treatment were counted after the 60 days of grafting. Emergence of healthy shoots from the lateral auxiliary buds of scion stick was considered as the success of a graft. Results were calculated and expressed on percentage basis. Success percentage of individual treatment was calculated by using the standard mathematical formula. Length of sprouted shoot (cm) having maximum growth on scion was recorded at 60, 90 and 120 days of grafting (DOG) with the help of a meter rod from the base of sprouted shoot at scion stem to the top of the sprouted shoot of five healthy plants, and then averaged. The diameter of sprouted shoot (mm) at scion stem was recorded at 60, 90 and 120 DOG with the help of a digital Vernier Caliper at one centimeter above the base of sprouted shoot of five healthy plants, and then averaged. The total number of leaves in each sprouted shoot of each scion stem in each graft were counted at 60, 90 and 120 DOG of five healthy plants and mean number of leaves per graft were calculated. For calculating leaf area/plant (cm^2), ten leaves from five selected plants were collected randomly at 120 DOG in each treatment. The leaf area of these ten leaves was measured with the help of digital Leaf Area Meter model no. CL-203. Average data was worked out by multiplying measured area with average number of leaves per plant in each treatment.

For taking observations on chlorophyll contents ('a', 'b' & total) of leaves (mg/g fw), two leaves from five selected plants in each treatment were collected randomly at 120 DOG. Leaves were washed, dried with filter paper, then cut into pieces and weighed (0.25 g/treatment), and then dipped in test tubes containing 5 ml of dimethyl sulfoxide (DMSO) for overnight as described by Sawhney and Singh (2002). The extracted chlorophyll in DMSO was estimated by recording its absorbance at 663 and 645 nm, respectively, with the help of Spectronic-120 and its content was calculated by following the standard formula. Fresh weight (g) of complete shoots (scion shoot + scion stem + rootstock stem) and fresh weight (g) of roots of five selected plants were recorded in each treatment at 120 DOG and average weight of each graft was worked out replication-wise for each treatment with the help of an electronic weighing balance. Dry weight (g) of the complete shoots (scion shoot + scion stem + rootstock stem) and dry weight (g) of roots of five selected plants were recorded in each treatment at 120 DOG by putting them in hot-air-oven at 55 ^oC until a constant weight is achieved and average weight of each graft was worked out replication-wise for each treatment with the help of an electronic weighing balance. The statistical analysis of data collected during the study was done by applying the technique of analysis of variance (Rai and Grover, 2006). All the statistical analysis was carried out by using OPSTAT statistical software design developed by CCSHAU, Hisar to find out the significance of variation resulting from the experimental treatments. All tests of significance were made at 5% level of the significance.

Results and Discussion

Effect of rootstock thickness on growth parameters of wedge grafted nursery plants

The data recorded on number of days to bud sprouting, number of days to first leaf opening and success percentage of grafts were significantly influenced by rootstock thickness (table 1). Scion grafted on rootstock with the thickness of 0.8-1.2 cm (S_2) took minimum days (27.84) for bud sprouting and minimum days (33.05) for first leaf opening on scion sticks, whereas the maximum number of days (31.21) to bud sprouting and first leaf opening (36.41 days) were recorded with rootstock thickness of >1.2 cm (S_3). The percentage of successful grafts was also recorded maximum (78.89) with rootstock thickness of 0.8-1.2 cm (S_2), whereas the minimum percentage (72.78) of successful grafts was recorded with rootstock thickness of >1.2 cm (S_3). Such results might be due to the thickness of scion sticks which may be almost similar to the thickness of rootstock stems during that period of grafting which ultimately resulted in proper alignment of the scion and rootstock cambium tissues. Contrary to our results, Mng'omba and coworkers (2010) [11] observed the higher survival percentage (> 75%) and reduced time to graft-take (19 days) with the thicker rootstocks than thinner rootstocks when conducted an experiment to study the effects of rootstock diameter (at root collar) on mango grafting. However, the present findings also got support from the findings of Pina and Errea (2005) [15] who reported the proper alignment of scion and rootstock cambium tissues is required for better graft success during the vegetative propagation of plants through grafting technique.

Shoot length and diameter of shoot at 60, 90 and 120 DOG (days of grafting) was found to be significantly influenced by rootstock thickness (table 1). Shoot length (16.26, 24.21 & 32.35 cm) and diameter of shoot (1.97, 3.15 & 4.26 mm) at 60, 90 and 120 DOG, respectively, was registered maximum (fig. 1 & 2) with rootstock thickness of >1.2 cm (S_3) and closely followed by rootstock thickness of 0.8-1.2 cm (S_2), while the minimum was observed with rootstock thickness of <0.8 cm (S_1). Higher length and diameter of shoot in S_3 might be due to the early graft-take in thicker rootstock. The above findings are also in agreement with the results obtained by Parente and Maciel (1973) [14] during the study on propagation of cashew fruit plants.

The data presented in table 2 clearly indicate that the rootstock thickness significantly influenced the chlorophyll 'a', 'b' & 'total' contents of leaves in graft. Among the rootstock thickness, maximum content 'a' (0.736 mg), content 'b' (0.285 mg) and total chlorophyll (1.021 mg) in leaves was recorded with S_2 (0.8-1.2 cm), which was at par with S_3 (>1.2 cm), whereas the minimum chlorophyll 'a', 'b' & total content in leaves was registered with S_1 (<0.8 cm). It might be due to the faster metabolic activities in grafts with proper alignment of scion and rootstock cambium tissues in thicker rootstock.

The fresh and dry weight of shoot and roots were also significantly influenced by the rootstock thickness in wedge grafted guava saplings (table 2). However, the maximum fresh (68.52 g) and dry (35.61 g) weight of shoot as well as fresh (34.38 g) and dry (21.06 g) weight of roots were obtained with rootstock thickness of >1.2 cm (S_3), but S_2 (0.8-1.2 cm) was also observed at par with S_3 in fresh (66.52 g)

and dry (34.69 g) weight of shoot, whereas, the minimum fresh and dry weight of shoot as well as roots was recorded with rootstock thickness of <0.8 cm (S_1). Such results might be due to more thickness of shoot, more length of shoot and a greater number of leaves in grafts with rootstock thickness of >1.2cm which directly adds to the fresh and dry weight of shoot and roots.

Table 1: Effect of rootstock thickness and growing conditions on days taken to bud sprout, days taken to first leaf opening, success percentage of grafting, length and diameter of sprouted shoot on scion stick

Treatments	Days taken to bud sprouting	Days taken to first leaf opening	Success percentage of grafting	Shoot length			Diameter of shoot		
				60 DOG	90 DOG	120 DOG	60 DOG	90 DOG	120 DOG
	Rootstock thickness (S)								
S_1 (<0.8 cm)	29.22	34.42	73.33	11.67	18.43	27.82	1.79	3.05	3.83
S_2 (0.8 - 1.2 cm)	27.84	33.05	78.89	14.12	22.84	31.62	1.85	3.10	4.21
S_3 (>1.2 cm)	31.21	36.41	72.78	16.26	24.21	32.35	1.97	3.15	4.26
CD @ 5%	0.76	0.74	4.93	0.86	1.09	1.25	0.04	0.04	0.05
	Growing conditions (G)								
G_1 (Polyhouse + polycap)	25.69	30.84	86.67	19.39	29.82	40.81	1.95	3.71	4.62
G_2 (Polyhouse)	27.24	32.50	78.89	17.02	27.17	38.26	1.93	3.56	4.36
G_3 (Shade-net + polycap)	29.11	34.26	77.78	17.39	24.61	34.30	1.94	3.52	4.43
G_4 (Polyhouse)	30.53	35.78	70.00	14.50	21.77	30.53	1.90	3.45	4.21
G_5 (Open field + polycap)	31.29	36.47	73.33	9.42	15.80	22.54	1.77	2.20	3.53
G_6 (Open field)	32.68	37.91	63.33	6.37	11.78	17.15	1.73	2.15	3.44
CD @ 5%	1.08	1.05	6.98	1.21	1.54	1.77	0.05	0.05	0.08
	Rootstock thickness x Growing conditions (S x G)								
S_1G_1 (Polyhouse + polycap)	25.50	30.67	83.33	16.23	26.85	37.74	1.85	3.68	4.51
S_1G_2 (Polyhouse)	27.00	32.23	76.67	14.34	24.56	35.61	1.81	3.51	4.29
S_1G_3 (Shade-net + polycap)	28.67	33.83	76.67	14.46	20.40	32.69	1.81	3.46	4.25
S_1G_4 (Polyhouse)	30.13	35.37	70.00	12.23	17.89	28.77	1.79	3.41	3.86
S_1G_5 (Open field + polycap)	31.33	36.57	73.33	7.20	12.50	19.85	1.75	2.15	3.11
S_1G_6 (Open field)	32.70	37.87	60.00	5.54	8.35	12.29	1.72	2.10	2.95
S_2G_1 (Polyhouse + polycap)	23.73	28.90	90.00	19.58	29.61	41.30	1.91	3.72	4.65
S_2G_2 (Polyhouse)	25.20	30.47	80.00	17.39	26.63	38.67	1.89	3.55	4.38
S_2G_3 (Shade-net + polycap)	27.50	32.63	83.33	17.22	24.88	34.58	1.93	3.51	4.50
S_2G_4 (Polyhouse)	28.97	34.20	76.67	14.74	21.98	31.19	1.88	3.44	4.37
S_2G_5 (Open field + polycap)	30.13	35.30	76.67	9.37	19.45	24.52	1.77	2.19	3.71
S_2G_6 (Open field)	31.53	36.80	66.67	6.40	14.50	19.45	1.73	2.15	3.67
S_3G_1 (Polyhouse + polycap)	27.83	32.97	86.67	22.36	33.01	43.39	2.09	3.75	4.70
S_3G_2 (Polyhouse)	29.53	34.80	80.00	19.32	30.31	40.50	2.08	3.60	4.42
S_3G_3 (Shade-net + polycap)	31.17	36.30	73.33	20.50	28.55	35.63	2.07	3.57	4.54
S_3G_4 (Polyhouse)	32.50	37.77	63.33	16.54	25.45	31.62	2.01	3.51	4.41
S_3G_5 (Open field + polycap)	32.40	37.53	70.00	11.70	15.45	23.25	1.80	2.27	3.77
S_3G_6 (Open field)	33.80	39.07	63.33	7.16	12.49	19.70	1.73	2.19	3.70
CD @ 5%	NS	NS	NS	NS	2.66	NS	0.09	NS	0.13

Where; DOG: Days of Grafting

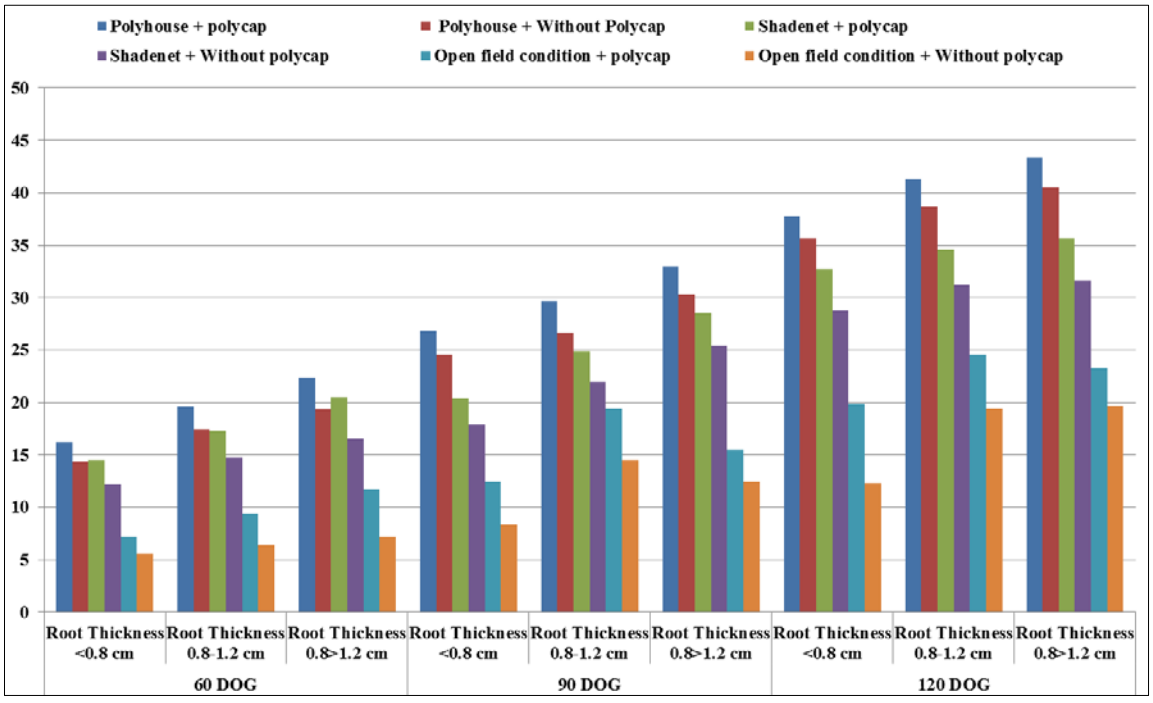

Fig 1: Shoot length (cm) at 60, 90 and 120 days of grafting vs. rootstock thickness under different growing conditions

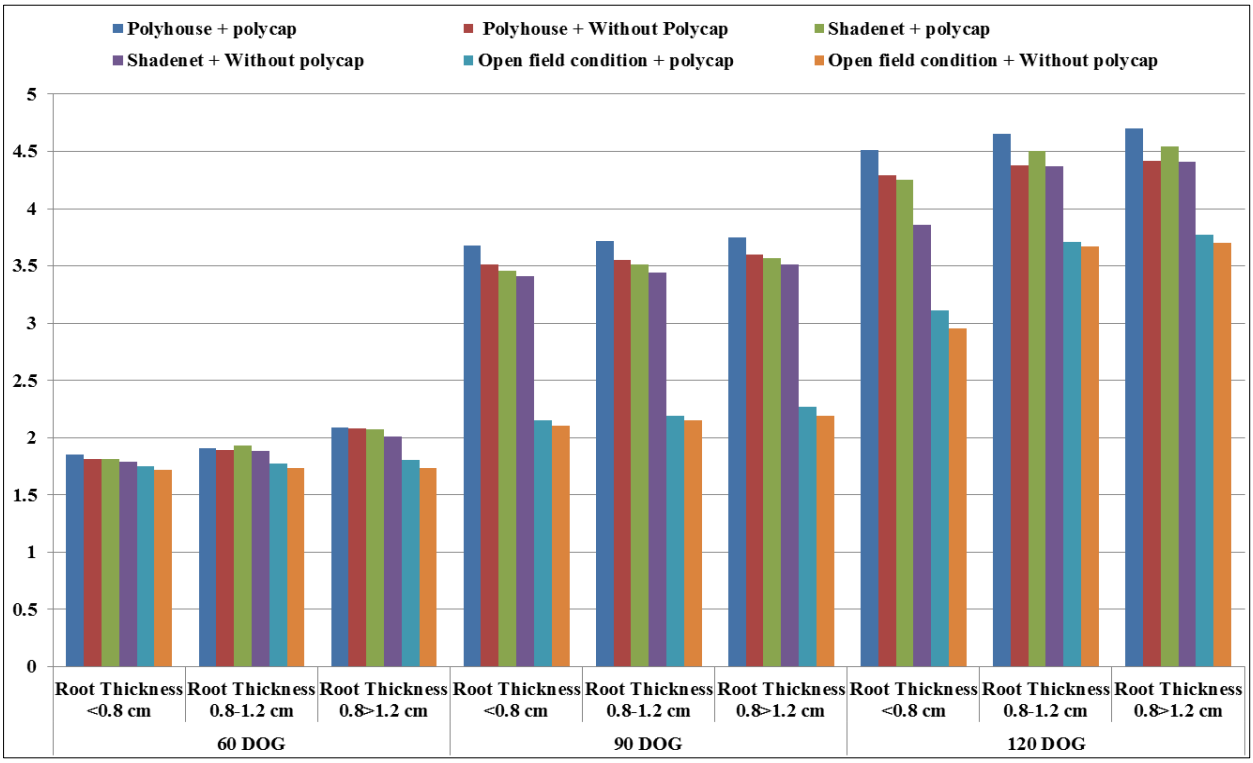

Fig 2: Diameter of sprouted shoot (mm) at 60, 90 and 120 days of grafting vs. rootstock thickness under different growing conditions

Table 2: Effect of rootstock thickness and growing conditions on number of leaves per graft, leaf area per graft, chlorophyll content of leaves, shoot weight and root weight of grafts

Treatments	No. of leaves/graft			Leaf area/graft (cm^2)	Chlorophyll content of leaves (mg/g fw)			Shoot weight (g)		Root weight (g)	
	60 DOG	90 DOG	120 DOG		Chlorophyll 'a'	Chlorophyll 'b'	Total	Fresh	Dry	Fresh	Dry
	Rootstock thickness (S)										
S_1 (<0.8 cm)	8.57	15.45	21.87	836.05	0.705	0.275	0.980	51.42	27.00	24.18	14.92
S_2 (0.8 - 1.2 cm)	9.58	17.91	27.33	1024.52	0.736	0.285	1.020	66.52	34.69	28.11	17.18
S_3 (>1.2 cm)	11.13	19.90	28.13	1037.33	0.728	0.283	1.010	68.52	35.61	34.38	21.06
CD @ 5%	0.30	0.55	0.62	11.81	0.011	0.004	0.015	2.38	1.06	0.95	0.72
	Growing conditions (G)										
G_1 (Polyhouse + polycap)	13.87	23.50	31.56	1179.44	0.788	0.302	1.090	79.17	41.43	32.36	19.96
G_2 (Polyhouse)	12.07	21.81	30.11	1145.32	0.782	0.300	1.082	67.11	34.56	32.06	19.94
G_3 (Shade-net + polycap)	11.22	19.33	28.96	1070.01	0.606	0.244	0.849	67.18	33.97	28.77	17.73
G_4 (Polyhouse)	10.43	17.16	25.92	969.29	0.596	0.240	0.836	57.97	30.34	28.52	17.50
G_5 (Open field + polycap)	6.21	13.33	20.11	737.59	0.786	0.301	1.087	55.17	29.08	25.89	15.67
G_6 (Open field)	4.74	11.39	18.01	694.14	0.780	0.299	1.079	46.33	25.23	25.76	15.53
CD @ 5%	0.43	0.78	0.88	16.70	0.016	0.005	0.021	3.36	1.50	1.34	1.04
	Rootstock thickness x Growing conditions (S x G)										
S_1G_1 (Polyhouse + polycap)	12.05	21.33	28.33	1035.83	0.760	0.293	1.053	66.37	35.50	28.27	17.40
S_1G_2 (Polyhouse)	10.51	19.30	27.47	994.40	0.757	0.292	1.048	57.40	28.63	28.83	17.27
S_1G_3 (Shade-net + polycap)	10.20	17.10	24.33	864.27	0.610	0.245	0.855	56.80	29.20	24.10	15.40
S_1G_4 (Polyhouse)	9.93	14.70	20.60	808.53	0.607	0.244	0.851	47.60	25.33	24.13	15.33
S_1G_5 (Open field + polycap)	4.59	11.10	16.10	689.43	0.750	0.290	1.040	44.83	23.53	20.13	12.10
S_1G_6 (Open field)	4.12	9.17	14.37	623.83	0.747	0.289	1.035	35.53	19.80	19.60	12.03
S_2G_1 (Polyhouse + polycap)	13.59	24.03	32.97	1246.70	0.793	0.303	1.097	84.52	43.97	31.47	19.07
S_2G_2 (Polyhouse)	12.28	22.90	30.00	1206.73	0.787	0.301	1.088	71.01	37.10	30.50	19.37
S_2G_3 (Shade-net + polycap)	11.00	19.20	31.07	1169.00	0.637	0.253	0.890	71.33	35.87	28.10	17.33
S_2G_4 (Polyhouse)	10.46	17.33	28.40	1043.50	0.633	0.252	0.886	62.19	32.37	27.30	17.00
S_2G_5 (Open field + polycap)	5.18	12.60	21.93	757.20	0.787	0.301	1.088	59.31	31.37	25.37	15.37
S_2G_6 (Open field)	4.95	11.40	19.63	723.97	0.780	0.299	1.079	50.78	27.50	25.93	14.97
S_3G_1 (Polyhouse + polycap)	15.98	25.13	33.37	1255.80	0.811	0.309	1.120	86.62	44.83	37.33	23.40
S_3G_2 (Polyhouse)	13.42	23.23	32.87	1234.83	0.804	0.307	1.111	72.93	37.93	36.83	23.20
S_3G_3 (Shade-net + polycap)	12.46	21.70	31.47	1176.77	0.571	0.232	0.803	73.41	36.83	34.10	20.47
S_3G_4 (Polyhouse)	10.90	19.43	28.77	1055.83	0.547	0.225	0.772	64.11	33.33	34.13	20.17
S_3G_5 (Open field + polycap)	8.87	16.30	22.30	766.13	0.821	0.312	1.133	61.35	32.33	32.17	19.53
S_3G_6 (Open field)	5.16	13.60	20.03	734.63	0.814	0.310	1.124	52.68	28.40	31.73	19.60
CD @ 5%	0.74	NS	1.53	28.92	0.028	0.009	0.037	NS	NS	NS	NS

Where; DOG: Days of Grafting

Effect of growing conditions on growth parameters of wedge grafted nursery plants

The observations recorded on the number of days to bud sprouting, number of days to first leaf opening and success percentage were significantly influenced by the different growing conditions (table 1). Grafts kept under Polyhouse + polycap (G_1) took minimum days (25.69) for bud sprouting and minimum days (30.84) for first leaf opening on scion stick, and G_1 was followed by G_2 (Polyhouse without polycap), whereas the maximum days for sprouting of bud (32.68) and first leaf opening (37.91) were recorded under open field condition without polycap (G_6). The percentage of successful grafts was also recorded maximum (86.67) under polyhouse with polycap (G_1), whereas the minimum percentage (63.33) was observed under open field condition without polycap (G_6). Interestingly, grafts covered with polycap took significantly less time to bud sprout as well as first leaf opening and higher percentage of successful grafts as compared to the uncovered grafts under all the growing conditions (table 1). These results are in accordance with the findings of Singh *et al.* (2007) [21] who reported that the wedge grafting under greenhouse condition significantly reduced the time taken (11-13 days) for bud sprouting in guava grafts. Furthermore, the wedge grafting performed in greenhouse gave significantly higher success of grafts (64.56-94.33%) as compared to open field condition (51.30-78.63%) in Allahabad Safeda and Sardar (L-49). Syamal *et al.* (2012) [24] also reported that polyhouse gave better results than open field condition with respect to number of days taken to sprout and survival percentage of grafts in three guava cultivars. The present findings also got support from the findings of Singh *et al*. (2007) [21], Rani (2010) [18], Singh *et al.* (2011) [23], Joshi *et al*. (2014) [8, 9], Kukshal (2016) [10] and Gotur *et al.* (2017) [6]. Further, Pandey and Singh (2002) [13], Anil (2013) [1] and Beer *et al.* (2013) [4] also reported the similar reduction in time taken for bud sprouting and the enhancement in survival percentage of guava grafts when the wedge grafting operation was performed at different dates under different growing conditions.

Shoot length and its diameter at 60, 90 and 120 DOG was found to be significantly influenced by different growing conditions (table 1). Shoot length (19.39, 29.82 & 40.81 cm) and diameter of shoot (1.95, 3.71 & 4.62 mm) at 60, 90 and 120 DOG, respectively, was observed maximum (fig. 1 & 2) in graft kept under polyhouse with polycap (G_1), and it was followed by grafts kept under G_2 (polyhouse without polycap) and G_3 (shade-net with polycap), while the minimum shoot length (6.37, 11,78 & 17.15 cm) and diameter of shoot (1.73, 2.15 & 3.44 mm) at 60, 90 and 120 DOG, respectively, was observed under open-field condition without polycap (G_6). Interestingly, grafts covered with polycap (G_1, G_3 & G_5) produced significantly longer shoot with more diameter as compared to uncovered grafts under all the growing conditions (table 1). These results are in accordance with the findings of Syamal *et al.* (2012) [24] who reported that polyhouse gave better results than open field condition with respect to number of leaves and length of sprouted shoot in guava cultivars. Similar enhancement in growth parameters of guava grafts under modified atmosphere were also reported by Nair *et al*. (2002) [12], Rani (2010) [18], Anil (2013) [1], Joshi *et al*. (2014) [8, 9] and Gotur *et al.* (2017) [6].

Number of leaves and leaf area per graft were found significantly influenced by the different growing conditions (table 2). The maximum number of leaves (13.87, 23.50 & 31.56) at 60, 90 & 120 DOG, respectively, and the maximum leaf area (1179.44 cm^2) was recorded in graft kept under Polyhouse with polycap (G_1), and it was followed by grafts kept under G_2 (polyhouse without polycap) and G_3 (shade-net with polycap), while the minimum number of leaves (4.74, 11.39 & 18.01) at 60, 90 & 120 DOG, respectively, and leaf area (694.14 cm^2) per graft was observed under open field condition without polycap (G_6). Further, grafts covered with polycap (G_1, G_3 & G_5) attained significantly a greater number of leaves as well as leaf area per graft as compared to uncovered grafts under all the growing conditions (table 2). These results are also in accordance with the findings of Joshi *et al*. (2014) [8, 9] who reported that 'Local guava' rootstock + wedge grafting + polyhouse with polycap combination produced higher number of leaves and more leaf area per graft than the treatment combination of 'L-49' rootstock + shield budding + open field condition lacking polycap. The present findings also got support from other findings of Nair *et al*. (2002) [12], Rani (2010) [18], Syamal *et al.* (2012) [24] and Anil (2013) [1].

The chlorophyll 'a', 'b' & 'total' contents of leaves in graft were also significantly influenced by different growing conditions (table 2). The maximum chlorophyll 'a' (0.788 mg), 'b' (0.302 mg) and total (1.090 mg) contents in leaves were accumulated under polyhouse with polycap (G_1), which were observed at par with G_2 (polyhouse without polycap), G_5 (open field with polycap) and G_6 (open field without polycap),, whereas minimum accumulation of chlorophyll 'a' (0.596 mg), 'b' (0.240 mg) and total (0.836 mg) contents in leaves were recorded under shade-net without polycap (G_4) Furthermore, grafts covered with polycap accumulated significantly more chlorophyll 'a', 'b' & total content in leaves as compared to uncovered grafts under all the growing conditions. The present findings also got support from other findings of Joshi and Syamal (2014) [8, 9] who reported that among different methods of budding/grafting, the highest chlorophyll content was recorded in treatment combination of 'Local guava' rootstock plus wedge grafting covered with polycap and kept under the polyhouse condition for February grafted plants. Furthermore, there was significant variation in chlorophyll 'a', chlorophyll 'b', total chlorophyll and total sugar contents in leaf due to the methods of propagation, different rootstocks and growing seasons as well as growing conditions.

The fresh and dry weight of shoot and roots were also significantly influenced by different growing conditions in wedge grafted guava saplings (table 2). The maximum fresh (79.17 g) and dry (41.43 g) weight of shoot and as well as fresh (32.36 g) and dry (19.96 g) weight of roots were recorded under polyhouse with polycap (G_1), but grafts grown under polyhouse without polycap (G_2) were also observed at par with G_1 in fresh and dry weight of roots, whereas, the minimum fresh (46.33 g) and dry (25.23 g) weight of shoot as well as fresh (25.76 g) and dry (15.53 g) weight of roots were obtained under open field condition without polycap (G_6). Grafts covered with polycap accumulated significantly more fresh and dry weight of shoot and roots as compared to uncovered grafts under all the growing conditions (table 2). The higher fresh and dry weight of graft shoot and roots as observed under polyhouse with polycap might be due to the longer as well as thicker shoot, a greater number of leaves, more stable environment and comparatively higher concentration of carbon dioxide inside the polyhouse. In addition to these, higher level of humidity inside the polycap

also created more favourable microclimatic condition for scion growth.

Interaction effect of rootstock thickness and growing conditions on growth parameters of graft

The interaction among the rootstock thickness and growing conditions was found non-significant inferring that both acted independently to influence the number of days to bud sprouting and first leaf opening, success percentage of grafts, length of sprouted shoot at 60 & 120 days of grafting (DOG) as well as diameter of sprouted shoot at 90 DOG, number of leaves on scion at 90 D0G, and the fresh and dry weight of shoot as well as roots of graft. However, the shoot length of graft at 90 DOG, diameter of sprouted shoot at 60 and 120 DOG, number of leaves at 60 and 120 DOG, leaf area per graft and the chlorophyll 'a', 'b' & 'total' content of leaves in graft were found to be significantly influenced by the interaction of rootstock thickness and growing conditions (table 1 & 2). Rootstock thickness >1.2 cm in combination with polyhouse with polycap (S_3G_1) resulted in maximum shoot length (33.01 cm) at 90 DOG (fig. 1), diameter of shoot (2.09 & 4.70 mm) as well as number of leaves on graft (15.98 & 33.37) at 60 & 120 DOG, respectively, and also the highest leaf area per graft (1255.80 cm^2), and it was closely followed by S_3G_2 (rootstock thickness >1.2 cm + polyhouse without polycap), S_2G_1 (rootstock thickness 0.8-1.2 cm + polyhouse with polycap) and S_3G_3 (rootstock thickness >1.2 cm + shade-net with polycap), while all the above parameters were observed minimum with S_1G_6 (rootstock thickness <0.8 cm + open-field without polycap) combination. On the other hand, chlorophyll 'a' (0.821 mg), chlorophyll 'b' (0.312 mg) and ultimately 'total' chlorophyll (1.133 mg) content in leaves was accumulated maximum under S_3G_5 (rootstock thickness >1.2 cm + open-field with polycap) combination, which was closely followed by S_3G_6 (rootstock thickness >1.2 cm + open-field without polycap), S_3G_1 (rootstock thickness >1.2 cm + polyhouse with polycap), S_3G_2 (rootstock thickness >1.2 cm + polyhouse without polycap) and S_2G_1 (rootstock thickness 0.8-1.2 cm + polyhouse with polycap) combinations (table 2), whereas the minimum chlorophyll content was recorded under S_3G_4 (rootstock thickness >1.2 cm + shade-net without polycap) combination. It might be due to the faster metabolic activities in grafts with proper alignment of scion and rootstock cambium tissues in thicker rootstock. The present findings also got support from the other findings of Mng'omba *et al*. (2010) [11], Avdiu *et al.* (2014) [3] and Joshi and Syamal (2014) [8, 9].

Conclusion

It has been concluded from the present investigation that scion grafted on the rootstock with thickness of 0.8-1.2 cm took minimum days for bud sprouting and first leaf opening. Success percentage of grafts was recorded maximum with rootstock thickness of 0.8-1.2 cm. Shoot length and its diameter, and the number of leaves as well as leaf area per graft were registered maximum with rootstock thickness of >1.2 cm and closely followed by rootstock thickness of 0.8-1.2 cm. However, the chlorophyll contents of leaves were again observed maximum with rootstock thickness of 0.8-1.2 cm and closely followed by rootstock thickness of >1.2 cm, while, the fresh and dry weight of shoot as well as roots were observed maximum with rootstock thickness of >1.2 cm. The grafts grown under polyhouse with polycap took minimum number of days for bud sprouting as well as first leaf opening on scion stick. The success percentage of grafts was also recorded maximum when grafts covered with polycap and kept under polyhouse. Overall, the grafts with rootstock thickness of 0.8-1.2 cm performed better and it was closely followed by rootstock thickness of >1.2 cm. Moreover, most of the growth traits of graft were observed significantly superior under polyhouse followed by the shade-net condition in comparison to open-field condition. Grafts covered with polycap performed better than the uncovered grafts under all the growing conditions.

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