Asian Journal of Plant Sciences

ISSN 1682-3974

OPEN ACCESS
Asian Journal of Plant Sciences
ISSN 1682-3974
DOI: 10.3923/ajps.2021.590.600

Research Article
Estimated Compatibility of IRR 400 Series as Promising Rubber Clones with GT1 Rootstock Based on Growth Characters

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Abstract
Background and Objective: The scion and rootstock compatibilities of rubber plants affect their yield potential by ±40% due to the low nutritional intake needed by plants to produce latex. This research was related to the effect of compatibility on IRR 400 series scion and GT1 rootstock. **Materials and Methods:** The rubber stadia were carried out on two whorls of polybag plants from March to June, 2020, in the greenhouse of the Sungei Putih Research Centre, Indonesia Rubber Research Institute. The research was arranged based on a non-factorial randomised block design. The factors of treatment involved five types of IRR 400 series clones (IRR 425, IRR 428, IRR 429, IRR 434 and IRR 440) and GT1 seeds as rootstock. Each treatment was repeated five times and each replication consisted of five samples. The characteristics observed were shoot height (cm), shoot diameter (mm), shoot angle (°), number of petioles, length of the petiole (cm), whorl distance (cm) and P-total (mg L^{-1}). Data such as correlations and heritability of the characters observed were analysed using Microsoft Office 2010 and MINITAB-16. **Results:** The characters with the greatest correlation (r>0.8) were shoot height vs. shoot angle, shoot height vs. petiole number, shoot height vs. whorl distance and petiole number vs. whorl distance. The heritability values (h^2>0.5) were shoot height, petiole length and whorl distance. **Conclusion:** The factors that can be used as predictors at the beginning of growth to assess compatibility are shoot height, petiole length and whorl distance.

Key words: IRR 400 series, GT 1, compatibility, scion, rootstock

Citation: Pasaribu, S.A., M. Basyuni, E. Purba, Y. Hasanah and R. Tistama, 2021. Estimated compatibility of IRR 400 series as promising rubber clones with GT1 rootstock based on growth characters. Asian J. Plant Sci., 20: 590-600.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The propagation of a rubber tree (*Hevea brasiliensis* Muell. Arg) is usually done through the seeds or vegetative parts. During the early years of rubber crops, only through seeds were propagated method instead, but after 1917, vegetative propagation via budding became very common. At present, seeds are mainly used for the production of rootstocks[1].

In the *Hevea* budding technique, the terms rootstock and scion (entries) are quite commonly known. The rootstock used must have vigorous roots so it can support plant growth, while the scion must come from superior clones that produce high latex yields[2]. The preparation of rootstocks is a separate activity performed to obtain planting material with good roots and nutrient absorption. To achieve this condition, rootstock nurseries that meet the technical requirements are needed, considering the seedling soil preparation, seed planting, germination, sprouting and efforts to maintain plants in the nursery[3]. Scion is recommended, but commercial clones of known potential latex yields from hybridisation or natural selection results that are diversified are also acceptable.

The success of propagation via this budding technique is highly dependent on the suitability and compatibility of the scion and rootstock, growth conditions of the rootstock during budding, implementation time and environmental conditions[4]. The scion compatibility affects the growth rate and length of the rubber shoot. Good compatibility between rootstock and scion will support the transport of nutrients and minerals; in other words, the use of several clones in this study was to study the differences in shoot length[5]. According to which the compatibility of rootstocks with the scion strongly supports the development of shoots[6].

The compatibility of GT1 (Gondang Tapen) rubber rootstocks with the scion of the IRR (Indonesia Rubber Research) 400 clone series and the percentage of grafted plants, growth characteristics and total phosphorus content have rarely have been studied. Therefore, the present study aimed to analyse the compatibility of GT1 rubber rootstocks with the scion of the IRR 400 clone series via budding techniques, research and assessment of the percentage of grafted plants, growth characteristics and total phosphorus content.

MATERIALS AND METHODS

Study area: The research was conducted for four months, namely from April to July, 2020. The area of the research was the green house of Experimental Garden Sungei Putih Research Center, Rubber Research Institute, North Sumatra, Indonesia at an altitude of 80 m above sea level.

Planting materials and tools: Five clones of the IRR 400 series constituted the planting material for the scion used, namely IRR 425, IRR 428, IRR 429, IRR 434 and IRR 440. GT1 seeds were used as the planting material for the rootstock. The tools and chemical materials used were 18×25 cm polybags, podsolic soil, sand, fertiliser NPK 16-16-16, dithane M-45, H_2SO_4, HNO_3, vanadate molybdate, distilled water, a UV-Vis spectrophotometer, a hot plate, a cloth meter, callipers, bows, hoes, soil sieves, buckets and a knapsack.

Plant materials preparation: The budwood garden (entries) of the IRR 400 series clones was planted at a distance of 1×1 m, located in block 2 of the Sungei Putih Experimental Garden, Rubber Research Institute. The budwood garden was used as a source for the scion, which was to be attached to the rootstock to prepare superior rubber planting material. The IRR 400 clone budwood garden was aged seven years, with both the branch age and rootstock age being eight months.

GT1 seeds were planted for rootstocks which were initially sown in the sand until they reached the fishing stage (about 21 days), then transferred to black polybags measuring 18×25 cm and maintained for eight months for brown budding. The rootstock seedlings were watered every day. Any weeds growing in the polybags were controlled manually and weeds in the area around the polybag were sprayed using a systemic herbicide with active ingredient glyphosate at a concentration of 0.2%. Rootstock and scion with stem diameters of $\geq$0.6 mm were budded.

Budding: Successful budding is indicated by the rootstock making the budding window, which involves cutting the scion, placing the shield and wrapping the budding. When performing budding, the stems are initially cleaned with a cloth and then incised with a sharp budding knife at a maximum width of 1/3 of the girth of the stem and length of 7.5 cm to form a window. Budding wood (entries) must be cleaned before the scion is cut. The scion containing the buds is taken from the budding wood by cutting it smaller than the

Table 1: Analysis model of clones and some budded characters

Variance sources	Degree of freedom	Mean square	Expected mean square
Clones	a-1	M1	$\delta^2e+\delta^2a$
Characters/clones	b-1	M2	δ^2e
Total	a+b		

size of the budding window. What needs to be considered is that the age of the tissue as a source of budding eyes is almost the same as the rootstock seedlings' age. When placing the shield, the tip of the window was opened and the prepared shield was carefully inserted to avoid friction with the cambium. The shutters were opened from above and cut to a height of 1.5-2 cm, then clipped to the shield and wrapped from the bottom to the top in a transparent plastic of length 40 cm, width 2-2.5 cm and thickness 0.08-0.09 mm. The success of budding was evidenced by the shield remaining fresh/green after removing the plastic budding, which was done 21 days after the budding process. One week after removing the budding plastic, re-examination was carried out to determine the definitive percentage. The rootstock, at a height of 10-15 cm from the grafting junction was cut using an oblique saw at an angle of 45° in the direction opposite to the budding eye.

Characters: The observed characteristics were shoot height (cm), diameter shoots (mm), shoot angle (°), number of petioles, length of the petiole (cm), whorl distance (cm) and total phosphorus content (P-total) (mg L^{-1}). The diameters of the shoots were measured at a height of 5 cm above the ground using a digital calliper. Shoot height was measured using a cloth meter from the ground to the top growing point. The shoot angle (°) was measured using a bow. The number of petioles was calculated by labelling each petiole and then measuring the length using a plastic ruler, starting from the base of the petiole to the tip of the leaf blade. The whorl distance (cm) was measured using a cloth meter from the top of the first whorl to the base of the second whorl. P-total was measured[7] and the sample weight was as much as 0.5 g. Subsequently, an ashing process was carried out with the addition of concentrated H_2SO_4 and concentrated HNO_3, after which it was heated on a hot plate. Specifically, 2.5 mL of concentrated H_2SO_4 was added to the sample so that it turned black like ash and then concentrated HNO_3 was gradually added until the smoke from the sample was no longer black. After the ashing process was complete, 50 mL of distilled water was added to the sample and then shaken. Following this, it was filtered and stored in a container and then 2.5 mL of vanadate molybdate was added to the container, producing a yellow colour. After this, the phosphorus levels were determined using a UV-Vis spectrophotometer at a maximum wavelength of 400 nm.

Data analysis: A correlation analysis was performed with the mentioned plant components (shoot height, shoot diameter, shoot angle, petiole number, petiole length, whorl distance and P-total). The software used for various analysis and discriminant analysis were Microsoft Excel 2010 and Minitab-16. The study was arranged using a non-factorial randomised block design with some type of scion clone, for five replications. When testing the variance obtained via significantly different treatments, the Tukey test was employed. Analysis of variance for some characters observed was done by Gunter[8], as shown in Table 1. Based on the variance in Table 1, the genotype variation (δ^2g) and phenotype variation (δ^2p) were formulated as follows:

$$\text{Genotype variation } (\delta^2 g)\text{: } \frac{\text{M1}}{\text{df-1}}$$

$$\text{Environment variation } (\delta^2 e)\text{: } \frac{\text{M2}}{\text{df-1}}$$

$$\text{Phenotype variation } (\delta^2 p)\text{: } \delta^2 g+\delta^2 e$$

The heritability criteria were used by Priyadarshan *et al.*[9], where high heritability value was $h^2>0.50$, moderate was $h^2 = 0.20\text{-}0.50$ and low was $h^2<0.20$.

RESULTS AND DISCUSSION

Shoot height (cm): The mean shoot height of the IRR 400 series clones was tested at 67.32 cm, with the lowest shoot height being 49.14 cm and the highest 88.73 cm. The height of the tested clones also had a good homogeneity value, as indicated by the coefficient of variation of 13.83%. The results of the analysis of shoot height characters showed a significant difference between the IRR 400 series clones that were budded. The highest shoot height was visible in the IRR 434 clone (79.62 cm), followed by the clones of IRR 429 (72.51 cm), IRR 440 (65.19 cm), IRR 428 (64.19 cm) and IRR 425 (55.10 cm) shown in Fig. 1. This indicated that shoot height can be used as a characteristic to determine whether a scion clone is compatible with the rootstock. Vegetative multiplication through budding is a practice accepted for planting material in *Hevea* production[2]. Vegetative propagation has an important role where it is necessary or desirable to reproduce trees true to type. The growth and development indicators of

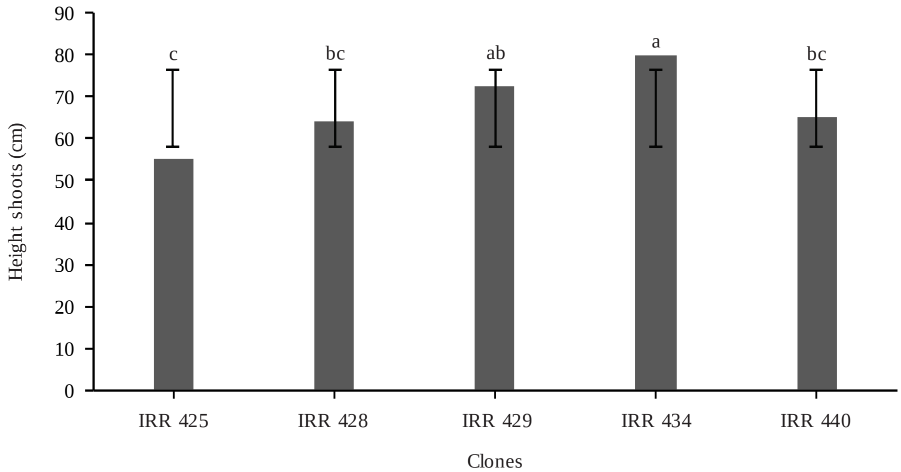

Fig. 1: Pattern of shoot height (cm) of IRR 400 series clones budded with GT1 seedlings
Data are represented Mean±SD. [abc]Same letter is not significantly different for each other ($p<0.05$) using the Tukey test

the seedlings of the six cocoa genotypes employed as a rootstock in a study reflected genotypic variations[10]. Additionally, plant height, girth and the number of leaves are essential for assessing plant vigour-related characteristics[10]. Vegetative propagation is used to obtain an exact copy of the mother plant genome[11]. The choice of rootstock for vegetative propagation, in most horticultural crops, is dependent on the vigour, precocity, yield and yield efficiency of stock and scion, among other factors[12]. The system of vegetative propagation is a means of capturing the additive genetic gain[13], where yield and vigour and are highly correlated[14,15]. Thus, the failure of the system root in meeting the evapotranspiration request of the shoot is an issue[16]. Rubber tree roots indicate a slope for potential growth. Taproots (primary) have unlimited fast growth and solid ramifications, unlike tertiary roots (third sequence) which have slow and short growth with few branches and secondary roots (second sequence) being split between many intermediate cases, depending on location and inception date[17]. The pattern of shoot height of the IRR 400 series clones can be seen in Fig. 1.

Shoot diameter (mm): The mean shoot diameter of the IRR 400 series clones was 7.92 mm, with the lowest shoot height at 6.28 mm and the highest at 8.90 mm. The shoot diameter of the clones also had a good homogeneity value, as indicated by the coefficient of variation value (6.17%). The analysis results of shoot diameter characters showed no significant difference between the IRR 400 series clones that were grafted. The largest shoot diameter was seen in the clone IRR 440 (8.38 mm), followed by the clones of IRR 428 (8.03 cm), IRR 434 (7.95 mm), IRR 429 (7.87 mm) and IRR 425 (7.39 mm). The intimate contact of cambial tissues at the union point favours the development of functional connectivity within the xylem and phloem tissues[18]. Physiologically, however, the process of cell recognition, callus formation, as well as vascular and parenchyma tissue differentiation are critical processes in bud development[19]. The diameter shoot patterns of the 400 series IRR clones can be seen in Fig. 2.

Shoot angle (°): The mean shoot angle of the tested IRR 400 series was 47°, with the smallest angle being 38° and the largest 58°. The angle of the growing shoots showed a small variation, namely 11.88%. This is indicative of considerable variation in the various shoot angles. The results of the analysis of shoot angles showed significant differences among the IRR 400 series clones that were grafted. The biggest shoot angle was seen in clone IRR 440 (52°), followed by the clones of IRR 425 (51°), IRR 428 (47°), IRR 429 (43°) and IRR 434 (44°). The analysis results (significantly different) of shoot angle showed that this characteristic can be used as a marker of compatibility between a scion and rootstock via budding. The rootstock-scion angle is highly related to the developmental stages and genetic relationship of scions, indicating that the smaller the angle, the better the affinity[20]. There was no regular pattern in budding success-there were a few successful buds and one or two unsuccessful ones. Also, there was a particular percentage of buds that were dormant. The growing time also did not show any correlation with bud position[21]. The pattern of shoot angle of the IRR 400 series can be seen in Fig. 3.

Petiole number: The mean petiole number for the first and second whorls was found to be 11. The minimum number of petioles was 9 and the maximum was 12. The number of

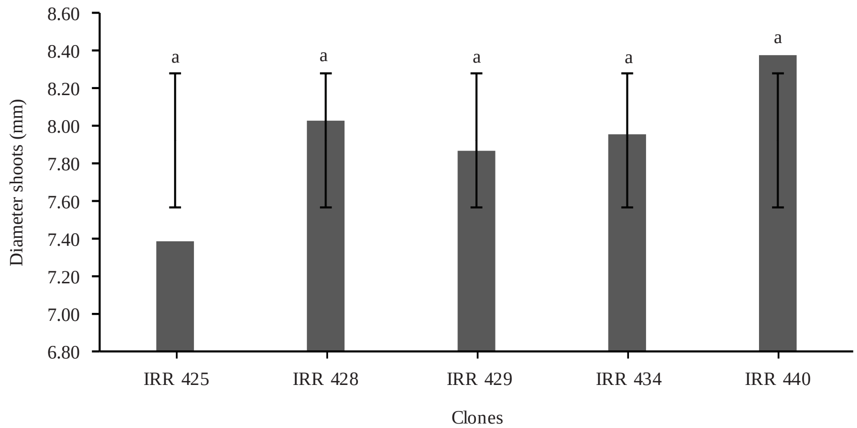

Fig. 2: Pattern of diameter shoots (mm) of IRR 400 series clones budded with GT1 seedlings
Data are represented as Mean±SD. [a]Same letter is not significantly different for each other ($p<0.05$) using the Tukey test

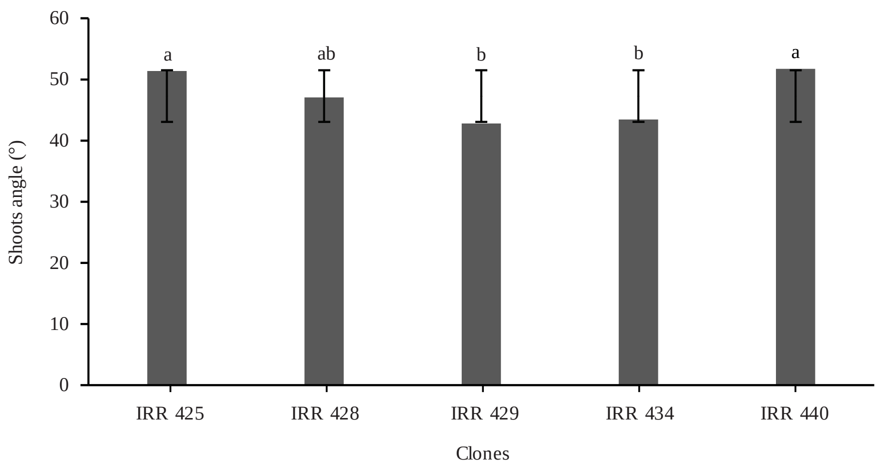

Fig. 3: Pattern of shoots angle (°) of IRR 400 series clones budded with GT1 seedlings
Data are represented as Mean±SD. [ab]Same letter is not significantly different for each other ($p<0.05$) using the Tukey test

petioles between the two whorls calculated was quite significant with a coefficient of variation of 7.13%. The results of the analysis on the number of petioles showed no significant difference between the IRR 400 series clones that were budded. Three clones had 11 petioles: IRR 429, IRR 434 and IRR 440. Two other clones, IRR 425 and IRR 428 had 10 petioles each. In the phloem vessel network, unfavourable environmental conditions (temperature and/or humidity) and the incapacity to fuse the vessel network of the two connectors have been identified as issues. Compatibility between rootstock and scion, being the right size and accurate splicing can trigger the unification of the network between the two parts of the plant. A successful tissue fusion can lead to the expression of certain genes; prevent the accumulation of phenolic compounds and a phytohormone balance, until the post-grafting tissue unification becomes perfect. The perfect grid integration would support the translocation of hormones, nutrients and carbohydrates, which further lead to normal plant growth[22]. The pattern of petioles in the clones of the IRR 400 series can be seen in Fig. 4.

Petiole length (cm): The mean petiole length of the tested IRR 400 series clones was 9.0 cm, with the shortest petiole length being 6.2 cm and the longest being 12.7 cm. The variation in petiole length was large at 16.3%; when viewed visually, each petiole of the analysed clones had a different size from the base of the whorl to the tip. The results of the petiole length (cm) analysis showed significant differences among the IRR 400 series clones that were budded. The longest petiole length was found in clones of IRR 434 (9.9 cm), followed by clones of IRR 428 (9.8 cm), IRR 440 (9.4 cm), IRR 425 (8.1 cm)

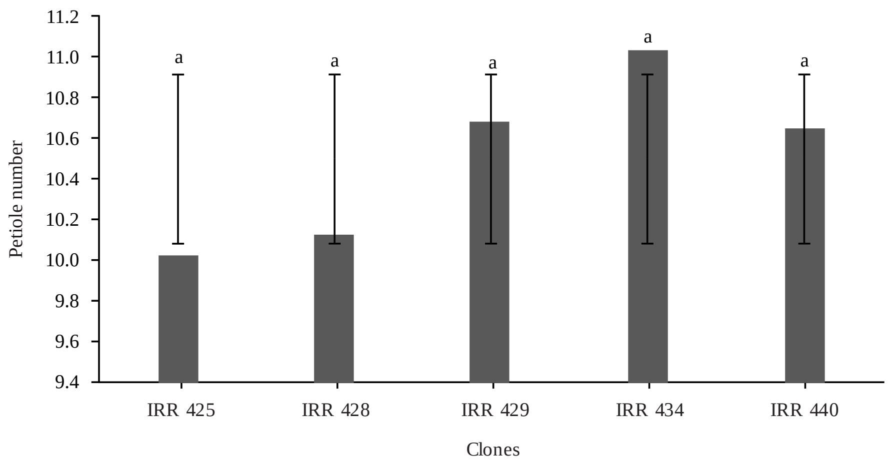

Fig. 4: Pattern of petiole number of IRR 400 series clones budded with GT1 seedlings
Data are represented as Mean±SD. [a]Same letter is not significantly different for each other ($p<0.05$) using the Tukey test

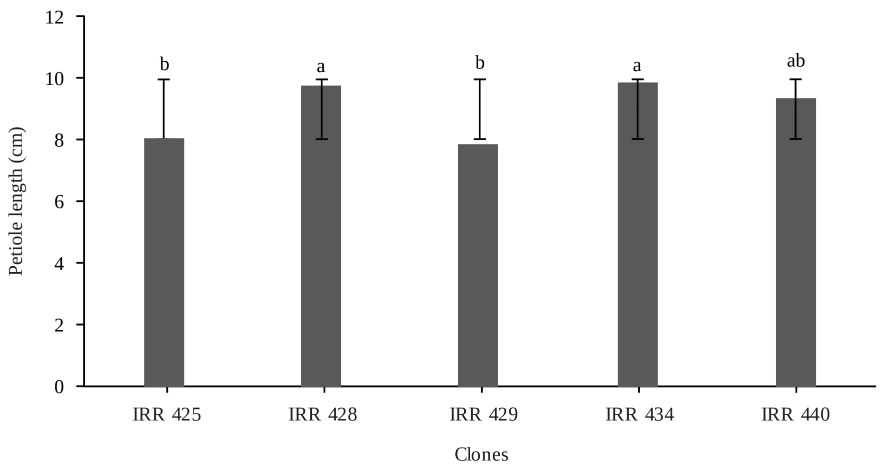

Fig. 5: Pattern of petiole length (cm) of IRR 400 series clones budded with GT1 seedlings
Data are represented as Mean±SD. [ab]Same letter is not significantly different for each other ($p<0.05$) using the Tukey test

and IRR 429 (7.9 cm). It is suspected that the observed differences between clones can be used to determine whether a scion clone can be budded with the rootstock of the rubber plant. The pattern of petiole length (cm) of the IRR 400 series clones can be seen in Fig. 5.

Whorl distance (cm): The mean whorl distance of the IRR 400 series clones was 22.2 cm, with the shortest distance being 13.0 cm and the longest 28.8 cm. The whorl distance of the clones showed a large coefficient of variation (19.6%); each clone showed a big difference. Further, the results of the whorl distance analysis revealed significant differences among the IRR 400 series clones that were budded. The longest distance between the whorls was 25.5 cm in IRR 429, followed by 23.9 cm in IRR 434, 23.9 cm in IRR 440, 21.4 cm in IRR 428 and 16.1 cm in IRR 425. This characteristic can, therefore, be used as a determinant of whether a scion clone is compatible with the rootstock via the budding technique. The whorl distance pattern for the IRR 400 series clones can be seen in Fig. 6.

P-total (mg L^{-1}): The mean P-total of the IRR 400 series clones was 0.21 mg L^{-1}. The lowest P-total was 0.19 mg L^{-1} and the highest was 0.23 mg L^{-1}. The variation in the total P-total of the clones was homogeneous and the coefficient of variation was 5.8%. The results of the P-total analysis showed no significant differences among the IRR 400 series clones that were budded. The IRR 428 clone (0.217 mg L^{-1}) had the highest P-total, followed by IRR 429 (0.215 mg L^{-1}), IRR 425 (0.205 mg L^{-1}), IRR 440 (0.204 mg L^{-1}) and IRR 434 (0.196 mg L^{-1}). The pattern of P-total content (mg L^{-1}) of the IRR 400 series clones can be seen in Fig. 7.

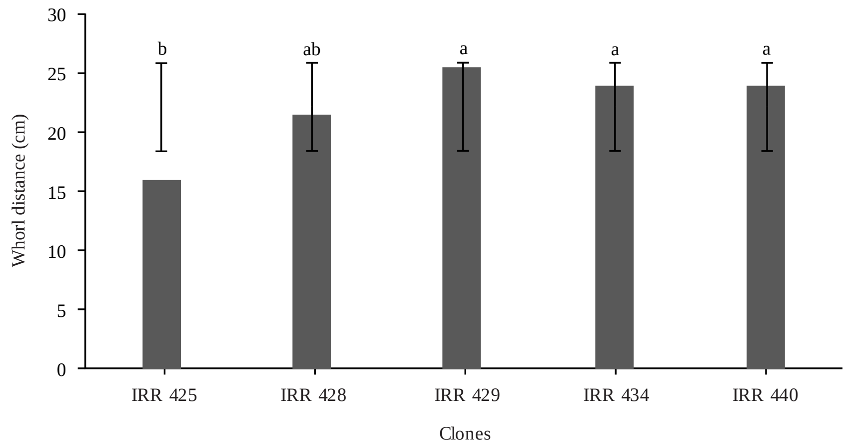

Fig. 6: Pattern of whorl distance (cm) of IRR 400 series clones budded with GT1 seedlings
Data are represented as Mean±SD. [ab]Same letter is not significantly different for each other ($p<0.05$) using the Tukey test

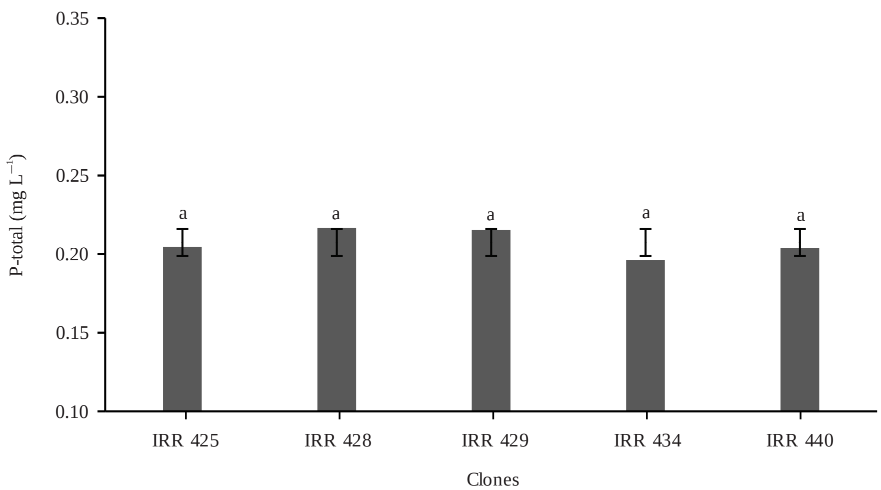

Fig. 7: Pattern of P-total (mg L^{-1}) of IRR 400 series clones budded with GT1 seedlings
Data are represented as Mean±SD. [a]Same letter is not significantly different for each other ($p<0.05$) using the Tukey test

Correlation among characters: Based on the correlation analysis of several characteristics, it was found that several had a close relationship with the value of r >0.5, namely the shoot height and shoot angle (r = 0.83), shoot height and petiole number (r = 0.91), shoot height and whorl distance (r = 082), diameter shoot and petiole number (r = 0.62), diameter shoot and whorl distance (r = 0.73), shoot angle and petiole number (r = 0.58), shoot angle and whorl distance (r = 0.62) and petiole number and whorl distance (r = 0.80). These characteristics exhibited a relationship that fulfilled the requirements for a correlation, thereby ensuring that they can be used as a differentiator between one scion and another. The correlation between the several characteristics observed from the budding values of the IRR 400 series clones and GT1 seedlings can be seen in Table 2. The interactions of compatibility between rootstock and scion are important. There is rootstock/scion compatibility when a given combination can form a solid and durable bud union. Compatibility is complicated to predict, but there is a general approval that a degree of taxonomic linkage should exist for a special stock/scion combination to be compatible. The greater is the taxonomic distance between scion and stock, the lower the opportunity of forming a successful bud union. This means that the theoretical success of bud-particular union combinations are intraclonal>interclonal>intraspecific >interspecific>intrageneric>intergeneric>intrafamilial, in that order[23]. The compatibility is specific, wherein a particular rootstock is generally not compatible with all commercial varieties of species. Compatibility can be considered a confession system in which molecules, regardless of the

Table 2: Correlation between of some characteristics observed of the IRR 400 series clones by budded with GT1 seedlings

Characters	Shoot height	Diameter shoot	Shoot angle	Petiole number	Petiole length	Whorl distance	P-total
Shoot height (cm)	1						
Diameter shoot (mm)	0.41	1.00					
Shoot angle (°)	-0.83	-0.01	1.00				
Petiole number	0.91	0.48	-0.58	1.00			
Petiole length (cm)	0.37	0.62	-0.04	0.28	1.00		
Whorl distance (cm)	0.82	0.73	-0.62	0.80	0.25	1.00	
P-total (mg L^{-1})	-0.26	0.01	-0.15	-0.49	-0.30	0.08	1.00

plasmalemma, merge to form a complex via catalytic activities, which then initiates a developmental continuity resulting in successful budding. Incompatibility studies conducted between scion and rootstock have sometimes shown needy vascular connection, vascular interdiction and phloem devolution, which can be identified early on or weeks after bud formation[24,25]. That is because; the water and nutrient unbalance prevents sign development of cell at the bud region, resulting in incompatibility[26]. The differentiation is interrupted due to a lack of vascular connections and incompatibility is observed a year after the budding is performed, producing differences in growth and requiring the solving of the connectivity of the host and point of bud[26]. In specific conditions, incompatibility may be early detected, as was the matter in apricot budding, in which the hoarding of phenolic compounds was indicatory of incompatibility through the first week after budding[27].

The physiological potential in CRINTc1 and CRINTc2. For patch budding, the two hybrids showed very high compatibility efficiency with eight weeks old F3 Amazon rootstock. Generation of clones from these elite genetic materials (hybrids) (i.e., CRIN Tc1, CRIN Tc2 and CRIN Tc3) may be challenging due to the different proportion of success. Improved cloning through top grafting can be enhanced by choosing a specific rootstock clone with the best compatible support; for instance, T101/15 mostly supported the regeneration of CRIN Tc3. Therefore, for top budding, specific stock and scion genotypes with high compatibility efficiency must be identified[28]. Dadzie *et al.*[29] and Waite *et al.*[19] asserted this through their Kola (*Cola nitida*) and Cacao vegetative propagations, respectively. Some authors[30,31] have attributed stock-scion interaction, compatibility and phytohormone roles to the success of budding. Rootstock heterogeneity in the grafting system of *Hevea brasiliensis* can cause interactions between rootstock and scion, giving rise to different levels of diversity responses between individual scions of the same clone. Based on cluster fingerprint and UPGMA of merging SDS-PAGE analysis data for protein and isoenzymes, the scions of the clone are indicative of the same, which are grafted on various stems under different, generally within the same subgroup. However, the level of genetic similarities varies, indicating a difference in the influence of rootstock against the same scion[32]. The scion union should intimately unify and prepare an active system for the uptake and translocation of minerals, water, assimilates and hormones throughout the entire lifespan of the plant[31,33,34]. In contrast, graft incompatibility leads to unhygienic trees, grafting breakage, premature death or failure of the graft combination as well as incapability to form a strong and lengthy functional union[35]. Two types of incompatibility that have been identified are the so-called translocated and localised graft incompatibilities[36,37]. Graft incompatibility is a problem in *Hevea*, plum, cherry, apricot, almond and peach. In general, cultivars are closely related and species lean to be compatible, but taxonomically distant plants often reel from incompatibility[23]. The selection of species is vital in plant budding because of budding failure due to incompatibility between the rootstock and the scion, absence of development of normal tissue in the bud and not completely lignified vascular vessels. This interferes with the vascular and cambial continuity with physical effect problems at the concourse.

Heritability values: The heritability values obtained in this study can help determine the influence of genetic or environmental factors. If genetic factors have a dominant influence, the observed characteristics can be used to determine whether a scion clone can be budded to the rootstock. If environmental factors are more dominant in influencing the observed characteristic, then it cannot be used as a marker for the level of compatibility because it will change depending on the environmental conditions. Based on this heritability value, there are three characteristics that are important ($h^2>0.5$): shoot height ($h^2 = 0.72$), petiole length ($h^2 = 0.51$) and whorl distance ($h^2 = 0.58$). High heritability provides the prospect of high selection progress while breeding for improved budding[38]. Vegetative reproduction is commonly associated with the perennial life form, longevity and in habitats where sexual recruitment is often restricted. The many vantages of vegetative propagation are increasingly becoming recognised, one of which is that clonal growth can also affect sexual reproduction in ways that may be detrimental to fitness. Three particular influences that have

Table 3: Heritability value of some characters of IRR 400 series clone by budded with GT1 seedling

	Variance components			
Characters	Genotype variance (δ^2g)	Environment variance (δ^2e)	Phenotype variance (δ^2p)	Heritability (h^2)
Shoot height (cm)	79.28	31.00	110.28	0.72
Diameter shoot (mm)	0.07	0.30	0.36	0.19
Shoot angle (°)	14.80	15.30	30.10	0.49
Petiole number	0.07	0.50	0.57	0.13
Petiole length (cm)	0.77	0.74	1.50	0.51
Whorl distance (cm)	12.07	8.79	20.86	0.58
P-total (mg L^{-1})	0.000018	0.00013	0.00015	0.12

been identified[39] are as follows: First, the rapid expansion of clones may limit allocation to flowering and seed production if there are strong trade-offs between investment in vegetative and sexual reproduction[40]. Second, vegetative reproduction has the potential to disturb pollination and hybridisation, resulting in subtraction of the quantity and quality of heredity. This can happen when clonal dispersal disturbs the sexual systems' functioning, leading to the absence of group mating for outcrossing, or where clones experience cost of fitness (inbreeding depression and pollen discounting) connected to geitonogamy (between flower) and self-pollination, because of large floral displays[39,41,42]. Finally, in highly clonal populations in which sexual reproduction is limited, there is growing proof that the collection of somatic mutations may result in subtraction infertility, potentially leading to the loss of sex[43]. The heritability value of each characteristic observed is outlined in Table 3.

CONCLUSION

The compatibility level of IRR 400 series rubber clones from the observed agronomic characteristics showed three distinguishing characteristics that can be used as early indicators in vegetative propagation by budding: shoot height, petiole length and whorl distance. The assessment of these characteristics was reinforced by a correlation value of >0.8 and a heritability value of >0.5.

SIGNIFICANCE STATEMENT

This study found that there were growth characters that can be assessed early to find out any incompatibilities in IRR 400 rubber clones which could be useful for rubber plant researchers. This finding is expected to help researchers to uncover the critical areas of incompatibility between the scion and rootstock of rubber plants propagated by budding techniques. Thus the new theory of incompatibility can help early assess the character of growth, namely shoot height, petiole length and whorl distance.

ACKNOWLEDGMENT

This study was supported by the Penelitian Disertasi Doktor project No. 11/AMD/E1/KP.PTNB/2021, from the Directorate General of Research and Community Service, the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia.

REFERENCES

1. Cardinal, Á.B.B., P. de Souza Gonçalves and A.L.M. Martins, 2007. Stock-scion interactions on growth and rubber yield of *Hevea brasiliensis*. Sci. Agri., 64: 235-240.
2. Gireesh, T., Y.A. Varghese, K.E. Woeste, V.C. Mercykutty and J.G. Marattukalam, 2012. Effect of monoclonal and assorted seedling rootstocks on long term growth and yield of Hevea clones. Silvae Genet., 61: 52-57.
3. Krishan, B., 2015. Growth assesement of popular clones of natural rubber (*Hevea brasiliensis*) under warm dry climatic conditions of Chattisgarh state, central India. J. Exp. Biol. Agric. Sci., 3: 157-161.
4. Cahyo, A.N., R. Ardika, J. Saputra and T. Wijaya, 2014. Acceleration on the growth of rubber planting materials by using foliar application of humic acid. Agrivita J. Agric. Sci., 36: 112-119.
5. Novalina, N. and A.D. Sagala, 2013. Construction of *Hevea brasiliensis* genetic linkage map and identification of quantitative trait loci using RAPD markers. Int. J. Adv. Sci., 3: 71-75.
6. Naik, K.E. and C.S.R. Kumar, 2018. Effect of different age of rootstock on grafting of jackfroit (*Artocarpus heterophyylus* L.) var.palur-1. Int. J. Curr. Microbiol. Appl. Sci., 7: 3994-3998.
7. Recena, R., I. Díaz and A. Delgado, 2017. Estimation of total plant available phosphorus in representative soils from Mediterranean areas. Geoderma, 297: 10-18.
8. Gunter, B., 2012. Design and analysis of experiments. Technometrics, 27: 313-315.
9. Priyadarshan, P.M., P.S. Gonçalves and K.O. Omokhafe, 2009. Breeding Hevea Rubber. In: Breeding Plantation Tree Crops: Tropical Species, Jain, S.M. and P.M. Priyadarshan (Eds.)., Springer, New York, pp: 469-522.

10. Junior, E.E.E., C.R. Gusua, T.D. Tchapda and O.N.P. Andre, 2017. Vegetative propagation of selected clones of cocoa (*Theobroma cacao* L.) by stem cuttings. J. Hortic. For., 9: 80-90.
11. Nguyen, V.H. and C.R. Yen, 2018. Rootstock age and grafting season affect graft success and plant growth of papaya (*Carica papaya* L.) in greenhouse. Chil. J. Agric. Res., 78: 59-67.
12. Daymond, A.J., P. Hadley, R.C.R. Machado and E. Ng, 2002. Genetic variability in partitioning to the yield component of cacao (*Theobroma cacao* L.). Hortic. Sci., 37: 799-801.
13. Traore, A., S.N. Maximova and M.J. Guiltinan, 2003. Micropropagation of *Theobroma cacao* L. using somatic embryo-derived plants. *In Vitro* Cell. Dev. Biol. Plant, 39: 332-337.
14. Adebisi, M.A., F.S. Okelola, C.O. Alake, M.A. Ayo-Vaughan and M.O. Ajala, 2010. Interrelationship between seed vigour traits and field performance in new rice for Africa (NERICA) genotypes (*Oryza sativa* L.). J. Agric. Sci. Environ., 10: 15-24.
15. Ambika, S., V. Manonmani and G. Somasundaram, 2014. Review on effect of seed size on seedling vigour and seed yield. Res. J. Seed Sci., 7: 31-38.
16. Xianhong, C., C. Qing, W. Jun and L. Weifu, 2020. Effects of reverse bud-grafting on growth and nutrient uptake of rubber mini-seedling buddings. Int. J. Environ. Agric. Biotech., 5: 838-841.
17. Carr, M.K.V., 2012. The water relations of rubber (*Hevea brasiliensis*): A review. Exp. Agric., 48: 176-193.
18. Sodré, G.A. and A.R.S. Gomes, 2019. Cocoa propagation, technologies for production of seedlings. Rev. Bras. Frutic., Vol. 41, No. 2. 10.1590/0100-29452019782.
19. Waite, H., M. Whitelaw-Weckert and P. Torley, 2015. Grapevine propagation: Principles and methods for the production of high-quality grapevine planting material. N. Z. J. Crop Hortic. Sci., 43: 144-161.
20. Xianhong, C., W. Jun, L. Weifu and C. Qing, 2015. Affinity of five scions budded on clonal rootstocks reyan7-33-97. Chinese J. Trop. Agric., Vol. 35, No. 7. 10.12008/j.issn.1009-2196.2015.7.001.
21. Udayakumara, E.P.N. and P. Seneviratne, 2006. Position of the bud on the bud stick on success of bud graft and growth *Hevea brasiliensis* (Muel Arg). J. Agric. Sci., 1: 31-40.
22. Baron, D., A. Cristin, E. Amaro, A. Pina and G. Ferreira, 2019. An overview of grafting re-establishment in woody fruit species. Sci. Hortic., 243: 84-91.
23. Gainza, F., I. Opazo and C. Muñoz, 2015. Graft incompatibility in plants: Metabolic changes during formation and establishment of the rootstock/scion union with emphasis on *Prunus* species. Chil. J. Agric. Res., 75: 28-34.
24. Pina, A. and P. Errea, 2005. A review of new advances in mechanism of graft compatibility-Incompatibility. Sci. Hortic., 106: 1-11.
25. Pina, A., P. Errea, A. Schulz and H.J. Martens, 2009. Cell-to-cell transport through plasmodesmata in tree callus cultures. Tree Physiol., 29: 809-818.
26. Cassol, D.A., K. Pirola, M. Dotto, I. Citadin, S.M. Mazaro and A.W. Júnior, 2017. Grafting technique and rootstock species for the propagation of *Plinia cauliflora*. Cienc. Rural, Vol. 47, No. 2. 10.1590/0103-8478cr20140452.
27. Errea, P., L. Garay and J.A. Marin, 2001. Early detection of graft incompatibility in apricots (*Prunus amerniaca*) using *in vitro* techniques. Physiol. Plant, 112: 135-141.
28. Daouda, K.K., N.Z. Jean-Claude, K. Jane, D. Lucien, K. Jean-Luc, B. Kauadio and K. Christophe, 2018. Comparison of grafting techniques and their effects on some growth parameters of ten elite cocoa clones (*Theobroma cacao* L.). Afr. J. Agric. Res., 13: 2249-2255.
29. Dadzie, A.M., A. Akpertey, J. Yeboah, S.Y. Opoku and A. Ofori *et al*., 2014. Genotypic effect of rootstock and scion on grafting success and growth of kola (*Cola nitida*) seedlings. Am. J. Plant Sci., 5: 3873-3879.
30. van Hooijdonk, B., D. Woolley, I. Warrington and S. Tustin, 2011. Rootstocks modify scion architecture, endogenous hormones and root growth of newly grafted `royal gala` apple trees. J. Am. Soc. Hortic. Sci., 136: 93-102.
31. Koepke, T. and A. Dhingra, 2013. Rootstock scion somatogenetic interactions in perennial composite plants. Plant Cell Rep., 32: 1321-1337.
32. Khotcharat, N., S. Sdoodee and U. Meesawat, 2016. Growth performance of clonal rubber rootstocks and combining ability test with the scion of clone RRIM 600. Agric. Nat. Resour., 50: 98-103.
33. Martinez-Ballesta, M.C., C. Alcaraz-Lopez, B. Muries, C. Mota-Cadenas and M. Carvajal, 2010. Physiological aspects of rootstock-scion interactions. Sci. Hortic., 127: 112-118.
34. Gregory, P.J., C.J. Atkinson, A.G. Bengough, M.A. Else, F. Fernández-Fernández, R.J. Harrison and S. Schmidt, 2013. Contributions of roots and rootstocks to sustainable, intensified crop production. J. Exp. Bot., 64: 1209-1222.
35. Zarrouk, O., Y. Gogorcena, M.A. Moreno and J. Pinochet, 2006. Graft compatibility between peach cultivars and *Prunus* rootstocks. HortScience, 41: 1389-1394.
36. Xu, Q., S.R. Guo, H. Li, N.S. Du, S. Shu and J. Sun, 2015. Physiological aspects of compatibility and incompatibility in grafted cucumber seedlings. J. Am. Soc. Hortic. Sci., 140: 299-307.
37. Dogra, K., K. Kour, R. Kumar, P. Bakshi and V. Kumar, 2018. Graft-incompatibility in horticultural crops. Int. J. Curr. Microbiol. Appl. Sci., 7: 1805-1820.
38. Venkatachalam, P., N. Geetha, P. Sangeetha and A. Thulaseedharan, 2013. Natural rubber producing plant: An overview. Afr. J. Biotechnol., 12: 1297-1310.

39. Loupit, G. and S.J. Cookson, 2020. Identifying molecular markers of successful graft union formation and compatibility. Front. Plant Sci., Vol. 11. 10.3389/fpls.2020.610352.
40. Rasool, A., S. Mansoor, K.M. Bhat, G.I. Hassan and T.R. Baba *et al*., 2020. Mechanisms underlying graft union formation and rootstock scion interaction in horticultural plants. Front. Plant Sci., Vol. 11. 10.3389/fpls.2020.590847.
41. Flaishman, M.A., K. Loginovsky, S. Golobowich and S. Lev-Yadun, 2008. *Arabidopsis thaliana* as a model system for graft union development in homografts and heterografts. J. Plant Growth Regul., 27: 231-239.
42. Cookson, S.J., M.J.C. Moreno, C. Hevin, L.Z.N. Mendome, S. Delrot, C. Trossat-Magnin and N. Ollat, 2013. Graft union formation in grapevine induces transcriptional changes related to cell wall modification, wounding, hormone signalling and secondary metabolism. J. Exp. Bot., 64: 2997-3008.
43. Barrett, S.C.H., 2015. Influences of clonality on plant sexual reproduction. Proc. Nat. Acad. Sci. USA, 112: 8859-8866.