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REVIEW **(Open Access)**

Dynamics of graft formation in fruit trees: a review

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Abstract

This review paper comprehensively discussed the dynamics of graft union formation in fruit trees. Histological studies confirmed graft union is a continuous process and reliable indicators of graft-compatibility are not visible. Although initiation of scion bud development is signs of graft formation processes but early callus formation determines subsequent survival of scion prior to cambial and vascular connectivity. Process of graft union formation is similar in most plants with few variations in days to completion. Factors attributed to graft-incompatibility or otherwise have been mentioned whiles research should also target specific tropical plants.

Key words: Graft incompatibility, Graft union formation, Callus formation, Cambium, Vascular connectivity

1. Introduction

Grafting is defined as the natural or deliberate fusion of plant parts so that vascular continuity is established and functions as a single plant [22]. However, to achieve the beneficial effects of grafting, the plant has to undergo external and internal processes to establish communication between rootstock and scion [25]. Graft success or failure determination may be difficult at one time because graft-failure could increase gradually with ageing of grafted plants. Therefore, in-depth information on graft-union behavior supports better handling of plants and plant environment for success. This paper comprehensively discussed the dynamics of graft union formation in fruit trees which take rather a longer time to examine and also influenced by abiotic conditions. The paper also highlights some areas of future research advances. In this presentation the following terms will be used interchangeably; graft-success or compatibility and graft-failure or incompatibility.

2. Graft union formation

Graft union formation is a process that establishes the connection between rootstock and scion that may eventually determine their graft-compatibility or incompatibility [12]. Complete union formation is the final and most reliable determinant of graft-compatibility particularly in tree crop that are difficult to 'take'. With respect to this presumption, there is high degree of similarity in the pattern of the union process in different fruit tree species including *Mangifera indica* [1, 7, 4, 24] and *Malus domestica* [28]. The stages of union formation include the death of layers of cells at the graft interface, cohesion of scion and rootstock, generation of callus cells, differentiation of callus and establishment of vascular continuity [1]. Copes [5] also indicated the order of union formation; contact or isolation layer formation, cell enlargement, callus formation, phellogen formation and vascular cambium formation. Soule [27] categorized these stages into four namely pre-callus, callus, cambial bridge and the healed union, whilst [17] suggested three stages of compatible graft union as cohesion of the rootstock and scion, proliferation of callus and vascular connection across the interface. Essentially, entire union process is the same for all species [7] but interaction between the various stages of the process and subsequent time to completion is plant specific. However, this paper discussed below, three main stages of graft formation; callus formation, cambial formation and vascular connectivity to practically enhance understanding of the entire process.

3. Callus formation

Callus is a mass of soft parenchymatous tissue that is quickly formed on or below the injured surface and the closing of the wound by the formation of a

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callus is the first stage in the healing after the operation [7]. Celik [3] suggests that the degree of callus formation at the graft union shortly after grafting operation is the main determinant of graft-compatibility. Mendel [13] also indicated that the onset of cell division marks the beginning of callus formation but the exact time of the first division depends on the activity of the tree and on external factors including temperature. According to [11] contact between the cambial regions of the rootstock and scion is capable of producing parenchymatic cells and callus tissues cement the two graft components. Other authors also indicated that the high degree of compatible grafts is due to the high rate of callus proliferation [31]; abundant root development [21]; cohesion of the stock and scion [18]; and vascular connection across the graft union [17]. According to [9] the basis of callus formation depends on protein released from the plasmalemma forming a complex with catalytic activity resulting in the formation of a successful graft.

Observations by [18] noted the presence of callus on the third day in Sedum whilst [30] indicated satisfactory callus by 28 days in Nectarine/Almond. Turkoglu [33] also reported adequate callus production in 14 days samples of *Rosa canina* / *R. centifolia* combination and [2] observed an increased callus production early as three weeks after grafting in nut graft combinations. Unal and Ozcagiran [34] notified large and stable callus formation in 30 days samples of *Pyrus communis* / *Eriobotrya japonica* combination. However, [7] reported satisfactory but delayed callus production in 45 days. The presence of the callus initiates rootstock-scion interaction that create bridge or conducting tissues for water and nutrients transport to the scion [1, 14] ; a short fall of moisture in the scion leads to delay or failure of cambial formation [37]. In view of this, early callus formation is vital but influenced by plant type, physiological condition, environmental (temperature and relative humidity) and craftsmanship [11].

4. Cambial formation and vascular connectivity

According to [7] cambial continuity was observed 60 days after grafting with newly formed cambium producing vascular tissues (xylem and phloem). Tekintas and Dolgun [30] confirmed cambial continuity and vascular transformation between 45 and 60 days in nectarin/almond combination. Tekintas [32] also observed cambial continuity in Citrus grafts in 45 days after grafting but 40 days earlier after grafting in loquat/quince-c combination [23]. Copes [5] indicated that initiation of shoot growth by the scion is a good indication that cambium is present and tracheids had differentiated in the union. Cambium maintains vascular connection in the callus bridge and for that reason proper matching of graft partners is important [11]. On the contrary, poorly aligned graft components result in slow cambial formation [5] but severe misalignment may result in complete failure of cambia union [1].

Vascular tissue formation is considered the last stage of the successful grafting beginning after the establishment of cambial continuity and a strong connection may occur in a short time in compatible grafts [35]. Failure to achieve vascular continuity in the union within a period of 4-8 weeks might result in desiccation of the scion and graft failure [36]. Singh [26] gave 2-3 months for complete union formation whilst, [4] suggested healing of the graft joint by 4 months after grafting. The entire anatomical changes discussed above are entirely a continuous process with no definite time limit to the completion of each stage [16]

5. Graft Compatibility and Incompatibility in union formation

Graft-success is defined as the ability of some plant components to form a sufficient graft union that could also be described as “graft-take” or “graft-compatibility”. Whiles graft-take could also mean the sprouting of scion few days after grafting operation, and graft-compatibility perhaps is the long-term assessment of grafts into a complete single plant beyond the initial sprouting of scion [11]. There are several external symptoms to detect graft-incompatibility; graft union uniformity, lack of lignification, yellowing of foliage, decline in vegetative growth and vigor and anatomical ab-normalities [11]. Whiles the appearance of these symptoms could take several years [10]; graft-incompatibility is one of the greatest obstacles in breeding rootstocks of fruit trees [6].

Factors affecting graft-incompatibility are multiple but categorized into adverse physiological response between scion and rootstock and/or anatomical abnormalities of vascular system with the later being the major cause [20]. According to [8] graft-compatibility is achieved between homogenetic rather than heterogenetic combination. Güçlü and Koyuncu [10] found these two compatible but lignifications finished in homogenetic combination earlier than achieved between heterogenetic combinations. This means that heterogenetic combination is often not absolutely incompatible; hence the causes of this graft-incompatibility remain uncertain. Errea [8] and Mosse [19] suggested that biochemical causes, rather than anatomical ones, are responsible for the graft-incompatibility by altering the cambial continuity. Moore [17] also attributed biochemical causes to toxins but could not ascertain the specific toxins. Rather, [29] identified high indoles content to facilitate callus formation whiles least phenols content decreased cell division and suppressed graft-compatibility. Mng'omba [15] also confirmed the important role of phenol compounds in plants especially in scion–rootstock associations. Güçlü and Koyuncu [10] also confirmed peroxidase activity to predicting graft-incompatibility in sweet cherries. This prediction is considered relevant to detect combinations of graft components that might show delayed incompatibility, especially before grafting.

6. Conclusion

In conclusion, an in-depth knowledge of graft union process helps to evaluate performance of graft success or failure. Studies on graft-incompatibility effect in tropical woody plants still limited. Biochemical and molecular mechanisms in incompatibility of tropical fruit trees in particular are lacking. Again, methods for graft-incompatibility prediction are inadequate. Finally, research should explain the statement the fact that diseases' attacking the scion of grafted plant is not strictly graft-incompatibility unless the graft union is affected.

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