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ROOTSTOCK-SCION RELATIONSHIPS IN BUDGRAFTED PLANTS WITH SPECIAL REFERENCE TO *HEVEA BRASILIENSIS*

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Although known to man for several centuries, the art of grafting has been first used in modern agriculture to perpetuate desirable phenotypic traits in fruit crops in Europe during the fifteenth century. Since the beginning it has been known that while the scion characteristics could be maintained, the rootstocks also played a major role in the growth and development of the scion. One of the most pronounced effects of rootstock has been in reducing the scion tree size and altering its shape, and this has been commercially exploited in crops like apple by the use of dwarfing rootstocks.

Bud grafting is the most popular means of propagation in *Hevea brasiliensis*, the natural rubber tree. There are no rootstock options available in rubber cultivation unlike in several fruit crops. The rootstocks of *H. brasiliensis* are grown from highly cross-pollinated seeds that have different genetic lineages. Rootstock heterogeneity has been known to be a source of intra-clonal variability in growth and yield in *H. brasiliensis*. It is suspected that the differences in the genetic make up between the rootstock and scion leads to subtle interactions, or "genetic conflict" between them. Such conflicts may gradually reflect at all levels of tissue organization- from the molecular to the phenotype levels of the scion.

Though generally considered to be an adverse factor, the rootstock effects could also be positive in terms of growth and development of the scion or endurance to environmental stress. But no attention has been made so far to exploit such positive rootstock-scion interaction in *H. brasiliensis*. A clear understanding of the stock-scion relationships can help us to identify the right combination of stock and scion for the best agronomic performance of the tree. This study reviews stock-scion interactions and discusses the need to focus on exploiting ideal stock-scion combinations in rubber cultivation.

INTRODUCTION

Grafting is a popular method of vegetative propagation in several horticultural species. By this technique two plants with different genetic make-up are joined together to form and function as a new single plant. The upper portion or top of the plant (shoot) is known as scion and the lower portion (root) is called stock or rootstock. Due to the asexual nature of this technique, the traits of the scion are perpetuated without any change. The Chinese had been practicing this technique since 1000 BC and the Greeks were familiar with it since the times of Aristotle (Rom 1987). It became a popular mode of propagation during the fifteenth century in Europe primarily to multiply scions of fruit crops with desirable pomological characteristics and the most important consideration for selecting a rootstock has

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been its compatibility with the scion.

Various anatomical, physiological and genetic factors determine the success of the graft union and its eventual establishment as a healthy plant. For instance, a proper vascular tissue with continuous cambium that is metabolically active is an essential prerequisite for the establishment of a bud union (Andrews and Marquez, 1993). Thus grafting is more successful in dicots than in monocots (Hartman *et al.*, 1990). If the stock and scion are genetically different as in the case of two different species or genera, they may be biochemically and physiologically too incompatible to establish a successful bud union. Grafting compatibility is genetically controlled by multiple genes (Copes, 1970; 1978; Salesses and Alkai, 1985). The chance of grafting success and hence establishment of a healthy grafted plant is more when the genetic, physiological and anatomical differences between the stock and scion are less.

Due to the different genetic make up of the stock and scion, a bud grafted plant is often considered as a multiple genetic system. Although the graft functions as a single metabolic entity, subtle differences may still persist between the rootstock and scion. The physiology of the rootstock can interfere with that of the scion and *vice versa*. The performance of a scion could be different when grown with its own root system or grafted to a rootstock with another genetic makeup, and the difference depends on the extent of the genetic distance between the stock and scion (Hartman and Kester, 1976; Errea, 1998). In some graft combinations, the stock may have greater effects on the scion, and in others it could be *vice versa*.

In every plant there exists a dynamic system of metabolic communication between the root and shoot systems. In grafts, this may be more complex given the differences in the genetic make up between the rootstock and the scion. Rootstock-scion communication could result in simple and direct effects of one on the other, or a more complex effect quite different from their individual physiology. In the former case we would call it as simple rootstock-scion effect and in the latter, rootstock-scion interaction. It appears that such effects must have been known since ancient times. St. Paul in his epistle to the Romans (Romans 11: 17-24) talks about grafting branches of a wild olive tree onto a good olive tree, and the former producing good fruits, thanks to the effect of the rootstock. Of course, the apostle was referring to one's innate spiritual goodness that produces good fruits, but, the fact that he used the parable of grafting suggests that the common man of his time was aware of the art of grafting and the importance of rootstock to the performance of the scion. Today, we have several rootstock-scion options available in various crops for different situations. This became possible because of the emphasis placed on breeding and selecting both desirable scions and rootstocks.

During the brief history of domestication of natural rubber, which confines to a little more than a century, there is a tenfold increase in its productivity (Sethuraj, 1996). One of the important attributes for this spectacular increase in yield has been the development of high yielding elite clones, and their subsequent multiplication through bud-grafting. This procedure ensured that the genetic constitution and hence the yield potential of the selected high yielding clones remained the same when they were multiplied into millions of bud-grafted plants. Dependence on bud-grafting has been inevitable since reproductive multiplication of a selected clone would not ensure genetic homogeneity, given the highly heterogeneous nature of this cross-pollinated tree species (Hartman and Kester, 1976).

Although the genetic constitution of the scion could be maintained constant in a large *Hevea* population through bud-grafting, it may be noted that the rootstocks are always grown from heterogeneous rubber seeds that have different genetic constitutions. Hence, rootstock is a potential source of functional variability among the individual trees of the same clone despite their genetic homogeneity (Dijkman, 1951). Such variations exist not only in rubber, but in almost all other bud-grafted species also. A brief summary of the effects observed in rubber are presented in Table 1.

A clear understanding of the stock-scion relationships can help us in identifying their right combination for the best agronomic performance. It gives an opportunity to combine desired traits of the stock and scion into a single plant for which multiplication of "true-to-type" rootstocks is a prerequisite. Rootstock options are presently not available in *H. brasiliensis* as there has never been any rootstock improvement program. Also there is no viable protocol for large-scale vegetative multiplication of a particular *H. brasiliensis* rootstock. In several other crop species, particularly fruit crops such as apple, plum and grapes in which specific rootstocks are commercially available, rootstock-scion interaction has been successfully exploited (Hartman and Kester, 1976). Breeding for suitable rootstocks is a priority in several of these crops. Specific adaptive characteristics of the rootstock in terms of their tolerance to biotic and abiotic stresses are beneficially utilized in several fruit tree species by bud-grafting (Southwick and Weis, 1999).

The effects of rootstock-scion interactions could be observed at all levels of tissue

Table 1. **A summary of various growth and physiological parameters affected by rootstock-scion interactions in *H. brasiliensis***

Parameter	References
Growth vigour and yield	Dijkman, 1951; Templeton, 1960; Buttery, 1961; Senanayake, 1975; Combe and Gener, 1977; Ng *et al.*, 1981; Ghosh and Ghosh, 1989; Tiong, 1989; Castro *et al.*, 1990; Goncalves *et al.*, 1994; Seneviratne and Samarakoon, 1995; Yeang *et al.*, 1995; Sagy and Omokhafe, 1996; Seneviratne *et al.*, 1996; Sobhana, 1998.
Root growth and root: shoot ratio	Sobhana *et al.*, 1980; Sobhana, 1998.
Photosynthesis, stomatal conductance	Sobhana *et al.*, 2000 b.
Stomatal responses and drought adaptation	Bastiah, 1999.
Mineral nutrition and cation exchange capacity	Teng and Pushparajah, 1974; Sobhana *et al.*, 1980; Sobhana, 1998.
Biochemical components and	Krishnakumar *et al.*, 1992;
Isozyme polymorphism	Sobhana, 1998; Sobhana *et al.*, 2000.

organization ranging from various phenotypic features such as size and shape of the canopy to subtle physiological processes like mineral and water uptake, photosynthesis and hormone metabolism (Rom, 1987; Hartman and Kester, 1976). Molecular and genetic level effects in scions of bud grafted plants are also reported for several species (Degani *et al.*, 1990; Yagishita *et al.*, 1986 and 1990; Fachinello *et al.*, 1999). Such effects have also been reported in *Hevea* (Krishnakumar *et al.*, 1992; Sobhana, 1998). The stock-scion interactions at different levels of tissue organization in various plant species with special reference to *H. brasiliensis* is reviewed here.

PHENOTYPIC LEVEL

Growth and productivity

Rootstock has a profound effect on the vigour of the scion and the size and shape of its canopy in various species. The intraclonal (tree-to-tree) variability in several growth parameters and latex yield has been attributed to the differences in the genetic make up of the heterogeneous rootstocks of *H. brasiliensis* (Thomas *et al.*, 2000). In spite of large tree-to-tree variations in latex yield in a particular clone of *H. brasiliensis*, the mean yield of a population is always higher in a high yielding than in a low yielding clone. For instance, the coefficient of variation in latex yield was 42.6% in a 13 year old plantation of high yielding clone RRII 105. The mean yield of RRII 105 (54.2g/tree/tap) remained higher than that of a poor yielding clone, PR 107, which had a mean yield of 22.7g/tree/tap (Annamalainathan *et al.*, 1998). This suggests that despite the large intraclonal variability induced by the heterogeneous rootstocks, the yield potential of the scion has an overwhelming impact. It has been suggested that in *H. brasiliensis* girthing of scion is more influenced by the rootstocks than its yield (Templeton, 1960; Seneviratne *et al.*, 1996). Several studies have shown that the vigour of the rootstock and the scion are tightly correlated in *H. brasiliensis* (Djikman, 1951; Templeton, 1960; Tiong, 1989; See also Table 2).

As far as yield and trunk girth of *H. brasiliensis* are considered, scion has a more pronounced influence than the rootstocks (Buttery, 1961) suggesting that a high yielding or a high biomass clone will continue to be so when budgrafted on seedlings raised

Table 2. **Relationship between different growth and physiological parameters before budgrafting (18 months old polyclonal seedling rootstock) and after budgrafting (18 months old scion) in five clones of *H. brasiliensis***

Parameter	Correlation between before (rootstocks) and after budgrafting (scion)
Growth	
Height	r = 0.71 ($p<0.001$)
Girth	r = 0.35 ($p<0.05$)
Total number of leaves	NS
Total leaf area	r = 0.28 ($p<0.05$)
Shoot biomass	r = 0.53 ($p<0.001$)
Physiological	
Photosynthesis	r = 0.74 ($p<0.001$)
Stomatal conductance	NS

from heterogeneous seeds. Thus the yield and girthing of a *H. brasiliensis* clone remain preserved even when multiplied through budgrafting. But tree–to–tree variations in yield and growth still exist to a considerable extent in the field.

There is a general tendency among breeders, physiologists and agronomists to view rootstock-scion interactions in *H. brasiliensis* as an adverse factor affecting its growth and productivity. This notion is not justifiable because there is always an equal chance that rootstock–scion interactions may influence the performance either way. Thus, while rootstock–scion interaction is a source of variability in growth and productivity, there is always a possibility of identifying and exploiting the best rootstock–scion combinations which improve the performance of the scion. For instance, monoclonal seedlings of PB 5/51 (RRIM, 1982) and IAN 873 (Goncalves *et al.*, 1994 a; 1994 b) gave the best performance as rootstocks in terms of better growth and yield in the scion and this positive effect persisted in the long term. The highest yield even after 12 years of tapping continued to be from plantations grown with monoclonal seedlings of PB 5/51 as rootstocks (RRIM, 1982). Although reports of a few desired rootstocks are available, it has also been reported that polyclonal seedlings were better rootstock materials than monoclonal seedlings (Yeang *et al.*, 1995). Several studies have shown that rootstocks can influence the yield of scion which could be to the extent of 23 per cent or even more (Tiong, 1989; Yeang *et al.*, 1995).

Rootstock influenced girth, height and leaf area of the scion in *H. brasiliensis* (Sobhana, 1998). The influence of rootstock on scion need not always be simple and direct. In fruit crops, the rootstock effects varied with the variety of the scion used (Singh, 1980). Rootstock-scion interaction has been commercially exploited in a large number of fruit crops and one of the most significant applications has been in altering the canopy size and architecture using appropriate dwarfing rootstocks. This increases the number of fruiting points per tree and also has obvious management advantages during harvesting and plant protection operations (Rom, 1987).

Root system

Just as the influence of rootstock on growth of scion, scion also exerts influence on the growth of the rootstock in *H. brasiliensis*, but relatively less information is available on this. When monoclonal seedlings of the clone Tjir 1 were used as rootstocks for budgrafting with four different scion clones, the fresh and dry weights of both the main and lateral roots were significantly different for different scions (Sobhana *et al.*, 1980; Sobhana, 1998).

PHYSIOLOGICAL LEVEL

Photosynthesis

The relation between the photosynthesis of rootstock and scion in different species is not clearly understood. Several studies have shown the influence of rootstocks on the photosynthetic rate of scion leaves in species such as apple (Brown *et al.*, 1985; Baugher *et al.*, 1994)) and lemon (Sharma and Singh, 1989).

A clear influence of rootstock on the photosynthetic rate of the scion leaves has been observed in *H. brasiliensis* (Sobhana, 1998). The greater the photosynthetic rate of the rootstock seedlings (before bud-grafting), the greater is the photosynthetic rate of the scion leaves (after budding). But there was no correlation between the stomatal conductance of the rootstock and the scion. (Table2).

Biotic and abiotic stresses

The rooting behaviour of the rootstocks has obvious effects on the water relations of the scion leaves in *H. brasiliensis.* A scion grafted to monoclonal seedlings of GT1 and RRIM 623 was better adapted to drought than those grafted to the monoclonal seedlings of RRIM 600 (Bastiah, 1999). This could be due to better rooting of the seedlings of GT1 and RRIM 623 than of RRIM 600.

Although root stocks have been found to influence the response of the scion cultivars to pests and diseases in various crop species (Rom, 1987) no such information is available for *H. brasiliensis.* However, rootstock appears to have a role on incidence of tapping panel dryness (TPD) of rubber trees which result in complete shut down of latex production (Sobhana *et al.*, 1999). Unlike fungal diseases like *Phytophthora* infection that affects almost every tree in rubber plantations occurrence ofTPD is at random which could be explained by the genetic heterogeneity of the rootstocks. If we can identify some trees that have never become TPD affected after several years of observations spanning twenty or twenty five years there are chances that their rootstocks may be imparting TPD tolerance in the scion. If that be true, multiplication of "TPD resistant rootstocks" may assume importance. Without evolving a viable protocol for large scale vegetative multiplication of rootstocks we will not be able to agronomically exploit any useful trait of the rootstock.

There has been no serious efforts for developing a rootstock for best performance of the scion of *H. brasiliensis.* Always the emphasis has been scion-focused, whether it is high yield or tolerance to environmental stresses. For instance, the drought tolerant plants which have been identified (Sreelatha *et al.*, 2003) are being multiplied as drought tolerant clones (scions). But from a physiological point of view, it is more likely that these selected clones would perform as better rootstocks than scions *vis-à-vis* drought tolerance. The lack of a protocol for large-scale vegetative multiplication of rootstocks prevents such attempts. It is perhaps now appropriate to make an attempt in this direction, so that there are better chances of combining ideal rootstocks and scions for better growth, yield and stress tolerance.

Mineral nutrition

Root stocks have been known to influence the cation exchange capacity (CEC) of the roots which influences the mineral uptake. It has been observed that CEC of lateral roots was significantly influenced by the scion clone in *H. brasiliensis* (Sobhana *et al.*, 1980). Similarly the NPK contents in the scion leaf also were determined by the scion itself and rootstock had no effect. There has been a positive correlation between magnesium and manganese contents in the leaves of the rootstock and scion in some clones, but not in others (Sobhana, 1998).

BIOCHEMICAL LEVEL

Tissue composition

Several reports are available on the effects of the rootstock on the biochemical composition of the scion in various species (Brown *et al.*, 1985). In *H. brasiliensis* root stocks have profound influence on the biochemical composition of the leaves such as enzymes, reducing sugars, phenols and amino acids (Sobhana, 1998).

Isozymes

Several enzymes such as aspartate aminotranferase, leucine aminopeptidase, acid phosphatase, alkaline phosphatase, and phosphoglucoisomerase showed polymorphism in the scion tissues collected from rubber trees grafted to different *H. brasiliensis* rootstocks (Krishnakumar *et al.*, 1992). Rootstocks have been found to influence isozyme patterns of peroxidase, esterase and catalase in the bud grafted plants of five *H. brasiliensis* clones (Sobhana *et al.*, 2000). It may be noted that samples collected from the same tree always showed identical isozyme pattern, suggesting that intraclonal (tree to tree) isozyme polymorphism could be attributed to differences in the rootstock. Isozyme polymorphism has also been reported in other bud-grafted species namely pear (Fachinello, 1999) and mango (Degani *et al.*, 1990)

INFLUENCE OF INTERSTOCK

Although not practiced on a commercial level, it is possible to graft a third individual in between a stock and scion. This technique is also called crown budding. This additional section is usually called interstock or intermediate stock. Such three part plants have several advantages in *H. brasiliensis*. Through this technique we can combine disease resistance in the crown or leaf (shoot scion) and high yield in the trunk (interstock scion) (Yoon 1972). It has been reported that in *H. brasiliensis* the interstock has an effect on the growth of the shoot scion (Leong and Yoon, 1978). Vigour, yield, disease and latex characteristics were modified by the crown clones (Lam and Hai, 1993; Hoang, 1985).

PERFORMANCE OF OWN-ROOTED PLANTS

Own-rooted (self-rooted) plants of tree crops, especially fruit trees are gaining much importance now-a-days as they are devoid of any influence of rootstocks. Uniform growth and yield, by reducing the heterogeneity induced by the rootstock, is expected from these plants. But the performance of these own-rooted plants has to be evaluated before planting them commercially. Own-rooted plants of *H. brasiliensis* raised from stem cuttings were not successful for commercial plantings (Yoon and Leong, 1975; Leong and Yoon, 1984). However, growth of these plants has been found to be less variable than buddings (RRIM, 1962). Though tap root system is lacking in own-rooted plants of *H. brasiliensis*, one or two strong roots with profuse lateral root growth were observed and these main roots grew deep in to the soil (Sobhana *et al.*, 1995; Sobhana, 1998). With improvements in techniques to produce and train adventitious roots of stem cuttings or air layers, it might be possible to use self-rooted scions for field planting or to use such techniques for multiplying specific rootstocks.

Studies with own-rooted plants of apple indicated that these trees in the first year or two grew more slowly than their counter parts grafted to different rootstocks. But, these own-rooted trees seemed to grow quite rapidly after the slow start in the early phase (Rom, 1987). Micropropagated trees on their own roots were equal in vigour to budded trees in apple (Zimmerman and Miller, 1991). As they were growing on their own roots the trees (14 years old) did not show any intraclonal variations in vegetative vigour, photosynthesis and stomatal conductance (Zimmerman and Steffens, 1996).

MECHANISM OF STOCK-SCION INTERACTION

Obviously stock-scion interaction is a complex phenomenon. Different theories to explain the mechanisms involved in stock-scion relationship have been documented (Hartman and Kester, 1976; Singh, 1980). The effects of the rootstock on the scion could be mediated by the characteristics of the root system that determine their nutrient uptake, transport of nutrients and water from the roots to the scion and alterations in the endogenous hormone levels.

It has been suggested that if the scion is bud-grafted onto the rootstock in such a way that a portion of the stem of the rootstock is maintained, then the rootstock will have a more predominant influence on the scion. This suggests that the more the amount of the rootstock tissue, the more its effect on the scion. Therefore, it has been suggested that grafting at a point as low as possible (*ie.* closer to the rootsystem) may be a better option to reduce rootstock effects on scion. However, according to Vyvyan (1930) and Hartman and Kester (1976) the root system itself has a predominant effect on the scion. In either case, the role of various physiological factors controlling the stock-scion relationship cannot be underestimated (Chandler, 1925; Hartman and Kester, 1976)). For instance, any change in the vigour of the scion has influence on the rootstock, which in turn will influence scion.

It has been suggested that the physiology of rootstock-scion relationship is mediated through the movement of endogenous growth factors and other biochemical components between rootstock and scion. Exchange of such factors between stock and scion can have profound effects. For example, juvenile characters in ivy (*Hedera helix)* could be induced in the adult form by grafting the scion onto juvenile plants: Hormones play a crucial role in such induction of juvenile characters (Hartman and Kester, 1976). The dwarfing mechanism in apple was related to the influence of auxins translocated down the phloem to the roots and cytokinins synthesized and translocated to the shoot (Lockard and Schneider, 1981).

The influence of rootstock on growth and productivity of scion has been suggested to be due to the impedance in the flow of water, nutrients, photosynthates and growth regulators at the graft union (Layne *et al.,* 1977). Recent studies by Kamboj and Quinlan (1998) in apple indicated that the most vigorous rootstocks showed a higher uptake and greater polar transport of endogenous hormones than did the more dwarfing rootstocks. There was a higher concentration of cytokinins in root exudates from roots of vigorous stocks than those from dwarfing stocks. Abscisic acid (ABA) levels were consistently higher in the bark of dwarfing stocks sampled throughout the growing season. The possible influence of roots on growth of shoots *via* cytokinin supplies in the xylem sap was reported (Kamboj *et al.,* 1999) in apple trees. Cytokinins (zeatin and zeatine riboside) in root exudates and shoot xylem sap increased vigour of the rootstock.

Cytokinin content of shoot sap differed with rootstock, the most invigorating had the greater amount of cytokinins than others. Noda *et al.* (2000) suggested that the regulation of scion vigour in citrus scion-rootstock combinations may be related to IAA and ABA levels. Dieleman *et al.* (1998) suggested that if rootstocks would mediate scion growth *via* their cytokinin production, it might be possible to improve the performance of a bud-grafted plant by exogenous application of cytokinins.

Rootstock – scion interaction: A case of genetic conflict?

Wider genetic differences between rootstocks and scion could lead to incompatibility symptoms in bud-grafted plants (Hartman and Kester, 1976; Andrews and Marquez, 1993). Graft incompatibility need not always result in a failure of graft establishment or poor growth of bud-grafted plants. "Delayed" incompatibility may appear after a period of several years of successful growth and affect the metabolic activities of the bud-grafted plants (Andrews and Marquez, 1993; Errea, 1998). The metabolic activities of the bud-grafted plants could be entirely different when compared with the two graft partners. The variations observed in the bud-grafted plants of a particular cultivar may be due to the genetic differences in the rootstocks and the scion, especially when the rootstocks are raised from heterogeneous seeds. It is possible that when the genetic distance between the rootstock and the scion is wider the chances of incompatibility will be higher (Hartman and Kester, 1976). In other words, a subtle "genetic conflict" may be existing between the genetically divergent rootstock and scion. Incompatibility symptoms or wide variations observed among the bud-grafted plants may be a manifestation of this "genetic conflict". The large tree to tree variations noticed in the growth and yield of bud-grafted *H. brasiliensis* are likely to be due to the effect of the genetically heterogeneous rootstocks (Dijkman, 1951).

The 'genetic conflict' resulting from the genetic differences between the rootstock and the scion may lead to variations in the metabolic activities of the bud-grafted plants as evident from the isozyme polymorphism (Sobhana *et al.*, 2001) in the scion leaves and RAPD profiles of the rootstock and the scion in *H. brasiliensis* (Sobhana *et al.*, 2000 a). Reports of such studies on the genetic conflict between rootstock and the scion are scanty in literature especially for *H. brasiliensis*. RAPD analysis of the rootstock and scion of *H. brasiliensis* revealed that as expected the DNA profiles of the scion tissues of each cultivar were identical and the genetic distance between them was zero indicating the genetic homogeneity of the scion. But the DNA profiles of the rootstocks were different indicating their genetic heterogeneity, because the rootstocks were raised from polyclonal/assorted seeds. Preliminary studies on TPD affected trees indicated that the genetic distance between the rootstocks and the scion was higher than that of the normal healthy trees. The results led to the assumption that when the genetic distance between the rootstock and the scion is large, there is a possibility of "genetic conflict" resulting in metabolic disorders in the budgrafted plants (Sobhana *et al.*, 1999).

It has been reported that cytokinin: ABA imbalances of a budgrafted plant result from rootstock-scion interaction

(Kamboj *et al.*, 1999). Such hormonal imbalances could be a subtle, but highly effective means of signalling a "genetic conflict" between the rootstock and the scion which have different genetic lineage. In this context, it may be observed that the parent–offspring conflicts observed in multi-ovulated fruits of species such as *Dalbergia sissoo*, are effected through imbalances in the hormones and this results in differential allocation of resources to the seeds of different paternal lineage (Ganeshaiah and Umashaanker, 1988, 1992; Umashaanker and Ganeshaiah, 1988; Umashaanker *et al.*, 1988). The existence of such genetic conflicts in plants in general, and between a rootstock and scion in particular will not be as easily noticeable as in animals. Because in the case of animals, the conflicting participants will express their conflicts through visible and audible interactions (Trivers, 1974) which plants are not capable of doing. But plants have other more subtle ways and means of expressing a conflict, and hormones are a good and effective means of signaling a conflict (Ganeshaiah and Umashaanker, 1993; Ravishankar *et al.*, 1995). Thus, rootstock-scion interactions could also be an expression of certain subtle "genetic conflict" between the genetically different rootstock and the scion.

There has been a recent report on long-distance movement of mRNA from the stock to the scion in tomato grafts (Kim *et al.*, 2001). The translocated mRNA caused morphological changes in the scion leaves similar to the morphology of the stock leaves, suggesting that the translocated mRNA was functional. Although cell to cell migration of RNAs and their role in signal transmitting has been known for a while, the graft transmissibility of mRNA assumes great relevance. Given the differences in the genetic composition between the rootstock and scion in *H. brasiliensis*, their RNA population also could be naturally expected to be different, and this could be a source of expression of genetic conflicts between the stock and the scion. It would be interesting to examine if these RNAs from rootstock could migrate and become functional in the scion tissues as observed in the grafted tomatoes. In this context it is interesting to note that at least one effect of the rootstock reported in the literature has been genetically stable and heritable. A low capsicin variety of red pepper grafted on to a high capsicin rootstock gradually produced red peppers that were very hot and this was inherited into the next generation as in the case of genetic transformation (Ohta and Chuong, 1975 a & b; Hirata *et al.*, 1986). Thus, it can be concluded that there exists a genetic basis for stock scion interactions.

CONCLUSION

Grafting has been known to man as a means of perpetuating desirable scion traits and the effects of the rootstocks in modifying the performance of the scion also has been known. The rootstock influences the scion at all levels of organizations, namely from phenotypic to genetic. The most profound effects can be noticed in growth characteristics of the scion. At the physiological level, photosynthesis, water relations, mineral uptake and responses to biotic and abiotic stresses are influenced by the rootstocks. At the biochemical level, changes in the hormonal ratios and polymorphism in the isozyme pattern have been observed in different plant species. Even genetically controlled traits like capsicin biosynthesis in scion has been reported to be influenced by the rootstocks.

Therefore, it is evident that the rootstock has a significant role in the overall growth and performance of the scion. In a seedling or own-rooted plant (grown through cuttings, air-layering or micropropagation) the aboveground portion and the root system have the same genetic constitution, but this is different in bud-grafted plants. This genetic difference between the two partners of the bud-grafted plants may lead to subtle 'genetic conflicts' between them and eventually reflect in the metabolic activities of the scion that could be entirely different from those of the two graft partners. In some cases, these differences in the metabolic activities of the bud-grafted plants can be advantageous resulting in a better performance of the scion. In such cases, the influence of the rootstock on scion can be exploited for better growth, yield and other desirable characteristics like adaptation to stress conditions or disease resistance. This calls for crop improvement efforts in rootstocks and their large scale multiplication in *H. brasiliensis* as is the case with most of the major fruit crops of the world.

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