Graft Incompatibility in Fruit Crops

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The inability or failure of rootstock and scion grafted together to produce a successful graft union is called as graft incompatibility. In contrast, if the graft union is successful, it is called as graft compatibility. The distinction between a compatible and an incompatible graft union is not clear cut. The ability of two plants to unite successfully into a graft is due to their natural relationship. For example, stock and scion of closely related species unite readily and grow as a composite plant and that of unrelated plants do not. Even sometimes stock and scion of unrelated species unites initially and develops symptoms of incompatibility later and die eventually. Many graft combinations lie between these two extremes in that they unit initially but gradually develops sign of incompatibility in form of abnormal growth pattern. Thus, plants differ widely in their ability to produce a successful graft union. For example some pear cultivars are successfully grafted on quince rootstock, whereas, the others may die soon. However, the reverse combination i.e. the quince on pear rootstock is always a failure. Further, plum grows well on peach rootstock but peach graftage on plum is always a failure. The incompatibility symptoms may appear soon after grafting or may be delayed for several years.

Symptoms of incompatibility

Graft incompatibility symptoms are variable in nature and it depends on genotype of components of graft used. The following symptoms are known to be associated with graft incompatibility:

- Complete failure to form a successful graft or bud union by some species, varieties or clones.
- Very low percentage of graft success.
- Union takes place and initial growth also occurs but the tree dies pre maturely either in the nursery or in the field.
- Degeneration of the tissues at graft union, decline in vegetative growth and premature defoliation.
- Marked differences in the growth or vigour of the stock and the scion (figure 33).
- Appearance of deficiency symptoms or nutritional disorders.
- The plants may have stunted growth.
- There may be yellowing of foliage in later part of the season.
- Appearance of outgrowth at, above and below the graft union.
- Excessive swelling at the graft joint and
- Graft components break off cleanly at the graft union.

However, one or combinations of these symptoms does not mean that the combination is incompatible because the above symptoms may be a resultant of nutritional deficiency, insect-pest and disease incidence or poor budding or grafting technique. Similarly, swelling or outgrowth at, below or above the graft union is not sometimes considered to be associated with incompatibility because some compatible forms also develop such symptoms. For example, Kinnow mandarin budded on Troyer citrange usually develop an outgrowth above the bud union. Similarly, Allahabad Safeda scion of guava also develops such swellings above graft union if grafted on dwarfing Aneuploid No.82 rootstock. Thus, the symptoms of outgrowth at or above the graft union are not a reliable indication of incompatibility reaction. However, incompatibility is clearly indicated if the plant breaks off clearly at joint after a few months or years of satisfactory growth and the break is smooth and clean.

Types of graft incompatibility

Graft incompatibility is of two types 1) localized incompatibility and 2). Translocated incompatibility.

a)Localized incompatibility: This type of incompatibility reactions apparently depend upon the actual contact between the stock and scion and localized in nature. This type of incompatibility can be overcome by insertion of mutually compatible interstock between the stock and scion, which separates the incompatible components of graft. In this incompatible combination, the union structure is often weak resulting in discontinuity in cambium and vascular tissues of stock and scion. It may result in poor translocation of the metabolites across the graft union. The external symptoms appear slowly depending upon the degree of anatomical differences at the graft union. Usually masses of undifferentiated parenchymatous tissues are commonly found at the graft union this type of incompatibility or even inclusion of bark tissue may develop, which may disrupt the normal vascular connection between the stock and scion. Localized incompatibility reactions are quite common in apple when grafted on pear and plum on cherry. An example of this category of incompatible reaction is that of Bartlett pear grafted on quince rootstock. With the insertion of compatible interstock "Old Home" pear, the combination becomes compatible and satisfactory tree growth takes place.

***b). Translocated incompatibility**:* Sometimes the incompatibility reaction is due to some labile influence, which can move across the graft union. Such type of incompatibility reaction can be corrected by insertion of a mutually compatible interstock. In this type, usually phloem degeneration takes place resulting in formation of brown line and necrotic area in the bark. It imposes restriction on the movement of carbohydrates through the graft union, with the accumulation above and reduction below. Most important example of this category of incompatibility is that of Hale's Early peach grafted on Myrobalan B plum rootstock. This forms a weak union in which distortion of tissues takes place with the accumulation of starch at the base of peach. If a mutually compatible interstock, Brompton plum is inserted between these two, the incompatibility still exists, with the accumulation of starch at the base of Brompton interstock. But if the same combinations are tried at cotyledonary stage, these are highly compatible indicating that some factors responsible for incompatibility reactions are not present at juvenile or nursery stage of the plants. Similarly, the combination of Non Pareil almond on Mariana 2624 plum shows complete phloem breakdown, although the xylem tissues are normal. However, the Texas, another almond is highly compatible on Mariana 2624. If a piece of Texas almond is inserted as an interstock between Non Pareil and Mariana 2624, bark disintegration occurs, resulting in incompatible graft union.

A third type of virus induced incompatibility cases apparent and widespread and more are continually being found. The failure of successful graft union can be due to pathogens. For example, sweet orange budded on sour orange in certain parts of the world showed incompatibility while in other regions, it was successful. After thorough studies, it was found that incompatibility was mainly due to viruses. The compatibility reactions change with the time also. For example, the pear cultivar Bristol Cross when grafted on Quince in 1932 made good growth but required interstock Beurre Hardy 30 years later to form a acceptable union. Such changes in plants may result from mutations or from latent viruses. In certain cases delayed incompatibility symptoms were observed where in initial stage graft union was successful but later they showed incompatibility and usually clean breakage at union point was observed. For example, Black line in walnut.

Causes of graft incompatibility

Although, grafting is totally a physical phenomenon but compatibility and incompatibility reaction is the result of genetic differences between the stock and scion. However, the mechanism by which a particular case is expressed is not fully known. Many proposals or attempts have been made to explain the causes of incompatibility but the evidence supporting them are inadequate and conflicting. However, of the possible causes, structural, physiological, biochemical, incidence of diseases, insects or combination of all these factors may be responsible for incompatible reactions.

***Structural or anatomical reasons**:* In histological studies, it has been found that stock and scion may not differ structurally but abnormalities may be found due to the presence or development of parenchymatous cells at the graft union, preventing the formation of vascular continuity between the stock and scion. Sometimes a bark layer develops at the joint may result in graft failure. Distortion of vascular tissues between stock and scion also takes place due to the development of some whorls or loops, which restrict the movement of essential nutrients and water across the graft union, resulting in poor growth or failure of a graft union. Similarly, from microspectrographic examination of the cell walls of incompatible graft union, it was found that the cell wall adjoining cells are lacking in lignin, whereas the cells in the compatible forms were lignified. Thus any reaction inhibiting the formation of lignin and development of middle lamella between the stock and scion results in week union. The incompatibility reactions in plum, pear and peach are primarily due to structural abnormalities. Usually, development of undifferentiated tissues at the graft union causes mechanical weakness, resulting in phloem disintegration and uneven or poor growth of the graftage.

Physiological and biochemical reasons*:* Sometimes, there is insufficient supply of the necessary components either by stock or scion. Usually, in incompatible unions, the water supply is impeded. It may be due to failure of phloem or xylem at the union resulting in root starvation and subsequent wilting and death of the scion. In compatible unions, translocation of sugars from scion to stock is normal. In many cases, there is accumulation of assimilates in the scions of incompatible combinations. For example, when certain pear cultivars are grafted on to quince, a cyanogenic compound (prunasin) found in quince (not in pear) is translocated to pear phloem. The pear tissues breakdown prunasin with hydrocyanic acid as one of the products. This acid accumulates near graft union resulting in tissue breakdown and lack of cambial activity and pronounced anatomical disturbances in the phloem and xylem of the union. As a result of which conduction of water and other materials is seriously hampered. Thus, presence of toxic chemical may inhibit the growth of other or kill it altogether. It is a world known fact that dwarfing effects of rootstock on the scion cultivar are mainly due to the restricted supply of water and nutrients to the scion cultivar. It is a common observation that there is development of an outgrowth at or above the graft union if budded or grafted on to a dwarfing rootstock. This out growth is considered to restrict the supply of nutrients and water to plant top, resulting in dwarf structure.

Nutritional deficiency*:* Deficiency of certain nutrients may also result in incompatible unions. It has been found that when Jonathan apple is grafted on to EM-IX rootstock, the scion develops molybdenum deficiency. It may be due to the inability of EM-IX rootstock to absorb Mo in sufficient quantity to supply to the scion cultivar. However, Jonathan on other rootstocks does not show such deficiency symptoms. Similarly, deficiency of P, K and Mg in peach has been reported if grafted on to Myrobalan B plum rootstock, resulting in incompatibility symptoms.

Presence of viruses*:* Presence of latent viruses and mycoplasma like pathogens may result in failure of graft unions. Pear decline disease on Bartlett trees grafted on *Pyrus pyrifolia* rootstock is quite common due to the presence of viruses at the graft union. However, it never appears if *Pyrus communis* is used as rootstock. Further, the incompatibility reactions in citrus are primarily due to infection by viral diseases like tristeza, psorosis and xyloporosis etc. The failure of rough lemon rootstock for many sweet orange varieties in Punjab has been due to occurrence of bud union crease -- a viral disease. Similarly, black line of walnuts, a delayed incompatibility reaction is believed to be due to a virus and not due to a rootstock failure.

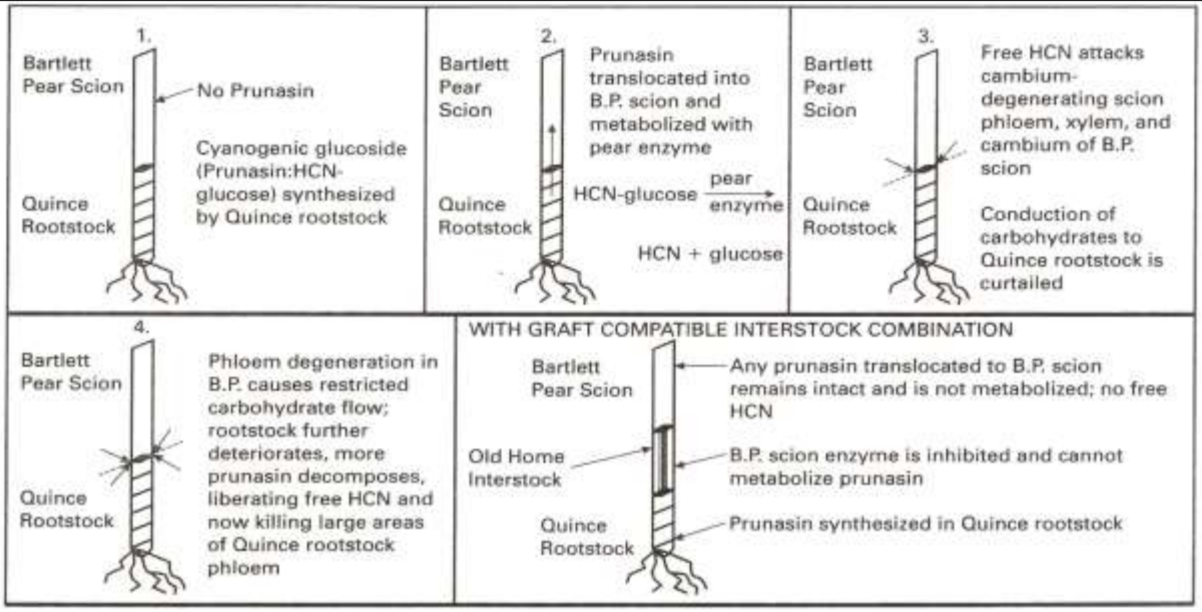

Fig. 1. Graft incompatibility in pear cv. Bartlett grafted on quince rootstock *(Source: Hartmann & Kester, 2002 Plant Propagation : Principles and Practices)*.

Table 1. Important rootstocks and their influences on scion cultivars.

Sl. No.	Fruit crop	Rootstock	Distinct influence on scion
1.	Mango	Totapuri Red Small	Dwarfing
		Vellai Kollumban	Dwarfing
		Rumani, Olour	Dwarfing
		Kurukkan	Salt tolerance
		Creeping	Dwarfing
2.	Grape	Dogridge	Resistance to *Phylloxera*, nematodes and salts.
		Salt creek	Resistance to salt and nematodes
		St. George	Resistance to *Phylloxera* root louse
		Temple	Resistant against pierce's disease anthracnose and downy mildew
3.	Ber	*Zizyphus nummularia*	Dwarfing effect
4.	Guava	Pusa Srijan	Dwarfing effect on Allahabad Safeda scion cultivar
		Psidium pumilum	Used for the induction of dwarfing
5.	Citrus	Flying Dragon	Most dwarfing, highly suitable for high density planting
		Trifoliate orange	Deciduous, cold hardy, dwarfing, resistant to nematodes, resistant to most viral diseases
		Cleopetra mandarin	Most salt tolerant citrus rootstock
		Sweet orange	Resistant to tristeza, and exocortis
		Rangpur lime	Hardy rootstock, adaptable to various soil conditions and salt tolerant
		Rough lemon	Relatively tolerant to saline and calcareous soils

		Sour orange	Cold hardy, resistant to phytophthora root rot but highly susceptible to tristeza
		Citrus unshiu	Freeze tolerant
6.	Apple	M_9	Dwarfing effect and highly suitable for high density planting
		M_{27}	Ultra-dwarfing, suitable for high density planting
		Malus sikkimensis	Induces precocity in bearing
		M_{26}	Better anchorage to scion cultivar
		M_7	Semi-dwarfing, stronger and deeper root system
		MM_{111} & MM_{106}	Suitable for light sandy soils
		Northen Spy	Wooly aphid resistant
		EMLA series	Free from viruses
7.	Peach	Nemaguard	Resistant to nematode and crown gall
		GF-557	Nematode resistant
		GF-677	Drought tolerant, and high pH tolerant
8.	Pear	Quince C	Semi vigorous
9.	Plum	Pixie and St. Julien	Dwarfing rootstocks
		Marian 2624	Resistant to nematodes, crown gall, cold hardy and tolerant to high soil moisture
		Myrobalan B	Resistant to bacterial gummosis
10.	Almond	GF-557 and GF-677	Tolerant to high soil pH
		Alnem 1	Resistant to nematode

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