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Role of Grafting and Budding on Yield and Quality of Selected Horticultural Crops: Review

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Abstract: **Grafting and budding are horticultural techniques applied in horticultural crop production to tackle biotic and abiotic stresses. As per the review, fruit vegetables mainly grafted by tongue, cleft and splice method of grafting and their success is varied among the crops being grafted. Investigations conducted on tomato, cucumber, watermelon and eggplant revealed that grafting had a pronounced positive effect on yield, quality, on tackling soil borne diseases, stress due to water and salinity, heavy chemical and drins. In spite of the role of grafting in fruit vegetables there are challenges related to the incomplete resistance of grafted seedlings, presence of high number of scion/rootstock combinations, the need for skilled workers, cost of grafted seedlings and limited research works obstruct the diffusion of this technology. Though application of grafting has aforementioned problems, breeding programs for production of multipurpose rootstocks, developing efficient grafting machines and improved grafting techniques will undoubtedly encourage use of grafted seedlings all over the world. In addition introduction of new rootstocks with desirable traits compatible with locally selected scions can boost the status of grafting technology. Therefore, application of grafting in fruit vegetables has bright prospects in the world. As a result of its benefits and value, demand for high-quality grafted seedlings by growers and is expected to rapidly increase in Ethiopia due to the expansion of private farms those intended to sell the produces to local and export market.**

Keywords: **Budding, Fruit vegetable, Grafting, Stress, Quality, Yield.**

1. INTRODUCTION

Agriculture is the deliberate cultivation of crops and animals for use by humans which involves plant breeding, plant propagation, crop production and food technology (Hartmann *et al*., 2002). The progressive domestication of food crops has been intimately related to a series of innovations in plant propagation (Mudge *et al*., 2009). Among plant propagation techniques, Grafting and budding are horticultural techniques used to join parts from two or more plants so that they appear to grow as a single plant. In grafting, the upper part (scion) of one plant grows on the root system (rootstock) of another plant. In the budding process, a bud is taken from one plant and grown on another (Lewis and Alexande, 2008). Grafting is the common and practiced long time ago in horticultural industry. Grafting can be defined as the natural or deliberate fusion of plant parts so that vascular continuity is established between them (Pina and Errea, 2005) and the resulting genetically composite organism functions as a single plant (Mudge *et al*., 2009).

Since the beginning of civilization, fruit and nut trees have been grafted because of the difficulty in propagating by cuttings, and the superiority and high value of the grafted crop. Leonardi and Romano (2004) reported that, grafting used for a long time ago to increase uniformity, vigour and resistance to biotic and abiotic stresses of vegetatively propagated plants. Especially grafting has been used in the horticultural industry for woody species, such as apples and grapes, for centuries (Rivard and Louws, 2006). Not only woody species, grafting of herbaceous seedlings is a unique horticultural technology practiced for many years in East Asia to overcome issues associated with intensive cultivation using limited arable land for vegetable production (Kubota and Michae, 2008).

Budding is the form of grafting in which the scion is reduced in size and usually contains one bud (Maynard and. Bassuk, 1990). The horticulture and forestry industries have sought to develop clonal propagation systems that avoid labor intensive graftage. Yet, traditional and highly efficient grafting and budding are essential for the propagation of many woody plants. New markets continue to require grafted and budded plants for improved plant quality, fruit yield, superior forms, and better adaptation to greater ecological ranges. In the southeastern United States, where high temperatures and periodic flooding of soils (low soil oxygen) are the norm, cultivars of birch, fir, oak, and other species are grafted onto adapted rootstock. The propagator benefits via new markets, while the consumer gains a greater variety of better adapted landscape plants. The acid-loving blueberry can be produced in more basic pH soils when grafted to pH-tolerant rootstock (Howard, 1993).

Grafting and budding can be performed only at very specific times when weather conditions and the physiological stage of plant growth are both optimum. The timing depends on the species and the technique used. For example, conditions are usually satisfactory in June for budding peaches, but August and early September are the best months to bud dogwoods. Conversely, flowering pears can be grafted while they are dormant (in December and January) or budded during July and August (Lewis and Alexander, 2008). Even though Vegetable production with grafted seedlings was originated in Japan and Korea to avoid the serious crop loss caused by infection of soil-borne diseases aggravated by successive cropping, this practice is now rapidly spreading and expanding over the world. Vegetable grafting has been safely adapted for the production of organic as well as environmentally friendly produce and minimizes uptake of undesirable agrochemical residues (Lee *et al*., 2010).

It has been reported that sugar, acids, and juice pH can be affected by grafting vegetables and the type of rootstocks used (Davis *et al*., 2008). Changes in grafted vegetable fruit quality in particular the flavor compounds appear to be not only scion but also rootstock dependent. There are many reasons why rootstocks affect scion fruit quality. The most obvious is rootstock/scion incompatibility, which induces undergrowth or overgrowth of the scion, leading to decreased water and nutrient flow through the grafted union, causing wilting. Incompatibility can be affected by tissue and structure difference, physiological and biochemical characteristics, growing stage of rootstock and scion, phytohormones, and the environment (Lee and Oda, 2003). Most reports on grafting suggest that changes in the scion are controlled by the rootstock through controlled uptake, synthesis, and translocation of water, minerals, and plant hormones (Lee and Oda, 2003). Therefore, the aim of this paper is to review the role of grafting and budding on the yield and quality of selected horticultural crops.

2. OVERVIEW OF GRAFTING AND BUDDING METHODS

Most plants multiply from seeds whereas certain plants are preferentially multiplied from their parts such as stem, roots, or leaves. Multiplication of plants using parts other than seeds is known as vegetative (asexual) propagation and the resultant plants are referred to as clones. For various reasons, some plants are multiplied by combining vegetative plant parts (stem or vegetative buds) from two separate plants into one. Grafting and budding are techniques used to combine one plant part with another to encourage growth as a unified plant (Kumar, 2011).

Since grafting and budding are asexual or vegetative methods of propagation, the new plant that grows from the scion or bud will be exactly like the plant it came from. These methods of plant reproduction are usually chosen because cuttings from the desired plant root poorly (or not at all). Also, these methods give the plant a certain characteristic of the rootstock - for example, hardiness, drought tolerance, or disease resistance. Since both methods require extensive knowledge of nursery crop species and their compatibility, grafting and budding are two techniques that are usually practiced only by more experienced nursery operators (Lewis and Alexander, 2008).

2.1. Grafting Methods

Grafting methods vary considerably with the type of crops being grafted, and the sowing time for scion and stock seeds vary with grafting method and crop. However, the most common methods for grafting fruit vegetables are the splice or tube, tongue and cleft grafting method. Splice grafting also known as top grafting, tube grafting, and slant-cut (45°) grafting. This is the most widely used grafting technique for tomatoes and also works well for eggplants (Johnson *et al*., 2011).

Various grafting methods have been developed and growers must choose their favorite methods based on experiences and preferences. Grafting cucurbitaceous crops is commonly done when scion and rootstock seedlings are young, i.e., before the outgrowth of the first true leaf between the cotyledons. Some of the most widely practiced grafting methods are shown in. Grafting methods vary considerably with the type of crops being grafted, and the sowing time for scion and stock seeds vary with grafting method and crop. For example, "hole insertion grafting" would be convenient for watermelons because of their small seedling size compared to the size of stock seedlings, such as gourd and squash. In cucumbers, however, "tongue approach grafting" has been used widely, mainly because of their large seedling size, including hypocotyl length and diameter, and grafting ease (Kurata, 1994).

Leonardi and Romano (2004) reported that, grafting used for a long time ago to increase uniformity, vigour and resistance to biotic and abiotic stresses of vegetatively propagated plants (i.e. fruit and ornamental trees and shrubs). Especially grafting has been used in the horticultural industry for woody species, such as apples and grapes, for centuries (Rivard and Louws, 2006). Not only woody species, grafting of herbaceous seedlings is a unique horticultural technology practiced for many years in East Asia to overcome issues associated with intensive cultivation using limited arable land for vegetable production (Kubota *et al*., 2008). The technique becoming a common practice in Japan, Korea, the Mediterranean basin and several European countries with several objectives including increasing plant tolerance to environmental stresses like low soil temperatures, salinity, heavy metal toxicity and unsuitable soil conditions (Lee and Oda, 2003; Chang *et al*., 2008).

2.2. Budding Methods

Budding different cultivars onto a common rootstock produces a multi-variety tree that yields more than one type of fruit. Budding techniques help you designate specific varieties for propagation that will produce stronger and disease-resistant fruit trees. Fruit trees that take to T-budding include apricot, avocado, cherry, citrus, kiwi, mulberry, nectarine, peach, pear, plum, quince and persimmon. Apple trees do well with T-budding or chip budding, while grapes and hackberries do best with chip budding only (Rajan, 2007).

Chip budding works well in regions with shorter growing seasons (e.g., Northern Unites States, England). Chip budding has gradually replaced T-budding as the primary budding method for many woody ornamental trees, shrubs, and fruit trees in many parts of the world (Osborne,1987). Commercial nurseries have switched to chip budding because of better takes and straighter, more uniform tree growth. Chip budding in late summer gives excellent results in budding grape cultivars on phylloxera or nematode-resistant rootstocks (Patrick, 1992).

T-budding is known by both names—the T-bud" designation arises from the T-like appearance of the cut in the rootstock, whereas the "shield bud" is derived from the shield-like appearance of the bud piece when it is ready for insertion in the rootstock. T-budding is widely used by nurserymen in propagating nursery stock of many fruit trees, shade trees, roses, and some ornamental shrubs. If extreme weather conditions are likely to occur during the critical graft union period following budding, the bud is placed on the side of the rootstock in order to give as much protection from prevailing winds as possible. Some believe that placing the bud on the windward side gives less chance for the young shoot to break off. Otherwise, it probably makes little difference where the bud is inserted, and the convenience of the operator and the location of the smoothest bark are controlling factors (Patrick, 1992).

Citrus plants are almost universally propagated by T-budding, either inverted or normal. Because citrus is an important commercial crop, a wide range of different rootstock types has been selected to suit various situations, such as tolerance of wet soils, root rot fungi, and citrus nematodes (citranges and *Poncirus trifoliata*); sandy soils (sweet orange); and salty or alkaline soils (Cleopatra mandarin) (Lewis and Alexande, 2008).

The distinguishing feature of patch budding and related methods is that a rectangular patch of bark is completely removed from the rootstock and replaced with a patch of bark of the same size containing a bud of the cultivar to be propagated .Patch budding is somewhat slower and more difficult to perform than T-budding. It is widely and successfully used on thick-barked species, such as walnuts and pecans, in which T-budding sometimes gives poor results, presumably owing to the poor fit around the margins of the bud—particularly the top and bottom. Patch budding, or one of its modifications, is also extensively used in propagating tropical species, such as the rubber tree (*Hevea brasiliensis*). Patch budding requires that the bark of both the rootstock and budstick be slipping easily. In propagating nursery stock, the diameter of the rootstock and the budstick should preferably be about the same (Taylor, 1972).

2.3. Vegetables and Rootstocks

Grafting's early purpose was to avoid or reduce the soilborne disease caused by *F. oxysporum*, but the reasons for grafting, as well as the kinds of vegetables grafted, have increased dramatically. Watermelons, other melons *(Cucumis* spp.), Oriental melons, cucumbers, tomatoes *(Lycopersicon esculentum* Mill.), and eggplants *(Solanum melongena* L.) are commonly grafted to various rootstock, especially for cultivation in greenhouses or plastic houses. Numerous rootstocks also have been developed. Watermelons are commonly grafted to gourd *[Lagernaria siceraria* (Mol.) Standl.] or to interspecific hybrids *[C. maxima* Duch. × *C. moschata* (Duch.) Duch. ex Poir.]. Cucumbers are most frequently grafted to figleaf gourd *(C. ficifolia* Bouché) or interspecific hybrids *(C. maxima* × *C. moschata).*

However, many rootstock having distinctive characteristics are available today (Yamakawa, 1983), and growers select the rootstock they think are the most suitable for their growing season, cultivation methods (field or greenhouses), soil environments, and the type of crops and cultivars (Jeong, 1986; Kato and Lou, 1989; Pisarczyk, 1983). For example, cucumbers grown in greenhouses during the cool season should be grafted onto figleaf gourd; however, those grown during the hot summer season are sually grafted onto Sintozwa rootstock (interspecific hybrids) or others (Lee, 1989; Yoon, 1986). Several new rootstocks are being developed. For example, bur cucumber *(Sicyos angulatus* L.) collected near Andong, Korea, showed good compatibility with cucumbers and watermelons for early summer growth and good resistance to nematodes (Choi *et al*, 1992; Kang *et al*., 1992).

Rootstock and interstock effects on the vigor of growth, flowering, fruit set, yield efficiency, and fruit quality of deciduous fruit tree scions are many, complex, and poorly understood. A better understanding of the mechanisms underlying these effects would aid future rootstock breeding and selection. Further research is required, particularly on the possible involvement of endogenous hormones in rootstock effects on scion growth and cropping. Comparisons of rootstocks budded with scions and growing in the orchard often yield quite different conclusions when conducted on different sites or with different scion cultivars. A better understanding of these interactions, between rootstocks and scions, soil, or climatic factors would aid more efficient selection and use of rootstocks in the future (Webster, 1995).

Understanding the role of rootstocks in fruit quality is not a straight-forward task. It is unclear how rootstocks exert their influence on fruit quality but water relations, nutrition, and plant growth regulators are undoubtedly among the most important factors involved. Certain effects on fruit physical characteristics and chemical composition are well-documented for some crops but whether they are direct or indirect is generally unknown and unstudied (Crane & Iwakiri 1986; Autio 1991). One reason for this short-coming is the interactive nature of the more obvious, quantifiable rootstock effects like yield(fruit size is often negatively correlated with crop load), vigor or growth (canopy shading interferes with soluble solids accumulation and external colour), and fruit size (which is negatively related to juice soluble solids concentration in citrus). Cleverly designed experiments and sophisticated statistical techniques such as principal component analysis have a place in rootstock-fruit quality research in efforts to identify sources of variation and their contributions (Castle *et al.*, 1993).

3. ROLE OF GRAFTING AND BUDDING ON YIELD AND QUALITY OF SELECTED HORTICULTURAL CROPS

Grafting and budding in horticultural crops like for fruit vegetables play a great role in increasing yield and quality and helps to provide resistance/tolerance to biotic and/or abiotic stress. The major vegetable crops being grafted are: tomato, cucumber, eggplant, melon, pepper and watermelon (Nichols, 2007). And commonly grafted with splice or tube, tongue and cleft method (Khankahdani *et al*., 2012).

3.1. Role of Grafting on Yield and Quality of Tomato

Tomato is one of the most important horticultural crops in the world and grafting has become an important cultural practice for this fruit vegetable. Continuous cropping is inevitable in vegetable production especially in indoor areas, and this reduces the yield and quality of the produce (Marsic and Osvald, 2004). Accumulated fruit yield of tomato was significantly higher on grafted plants than on un-grafted ones (the difference is 62%). This change was caused partly by the increased fruit number (14%) and partly by the fruit weight (45%) (Pogonyi *et al*., 2005).

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Concerning fruit quality traits and how grafting affects them, there are some contradictory results. Traka-Mavrona *et al* (2000) cited in Nicoletto *et al*. (2012) reported that the solutes associated with fruit quality are translocated in the scion through the xylem, whereas quality traits, e.g. fruit shape, skin colour, skin or rind smoothness, flesh texture and colour and soluble solids concentration are influenced by the rootstock (Nicoletto *et al*., 2012). Presumably, fruit quality affected due to the rootstock–scion interaction. This could induce overgrowth and undergrowth of the scion, leading to important changes in water and nutrient flow uptake. In contrast to this result, Vrcek *et al*. (2011) reported,nutritional properties of grafted tomatoes indicated satisfactory quality.

The primary purpose of grafting vegetables worldwide has been to provide resistance to soil borne diseases (King *et al*., 2008). Soil borne diseases (corky root, fusarium wilt, verticillum wilt, bacterial wilt) and nematodes, are some of the biotic stress causedamages in vegetable production and especially in continuous cropping in greenhouses (Lee and Oda, 2003; Pogonyi et al., 2005). The most common disease controlled by grafting appears to be fusarium wilt on tomato crops caused by various pathovars of Fusarium oxvsporum Schltdl (King et al., 2008).

Most greenhouse tomato growers are using grafting techniques to decrease susceptibility to root disease and to increase fruit production through increased plant vigour (Vrcek *et al*., 2011). Investigation revealed that, disease pressure is severe (96-100%) of the non- and self-grafted 'celebrity' controls were killed by southern blight. Furthermore, two weeks after first harvest >80% of the non- and self-grafted celebrity had been infected. However, the examined rootstock-specific hybrids (celebrity grafted on to RST- 04-105-T) had lower southern blight incidence (54-64%) than the non- and self-grafted controls (O'Connell, 2009).

3.2. Role of Grafting on Yield and Quality of Watermelon

Grafting is widely used for the production of fruit bearing vegetables in Japan, Korea and some other Asian and European countries where intensive and continuous cropping is performed. And currently, Watermelon is one of the vegetables in which grafting is performed intensively in the world (Bekhradi *et al*., 2011). The fruit yield was significantly higher in grafted plants than non grafted plants (Alexopoulos *et al*., 2007).

The greatest fruit number was observed in grafted watermelons on bottle gourd rootstock by splice grafting (2.6 fruits) and the least in direct seeded watermelon (1.0 fruit). Fruit yield is greatest in grafted watermelons on 'Bottle gourd' rootstock by splice grafting technique (13.60 kg/plant) and the least recorded in seedy watermelons (4.37kg/plant) (Khankahdani *et al*., 2012). With regard to watermelon fruit quality, grafting on to different rootstocks has been known to increase fruit firmness and thus increase shelf life (Ali, 2012). In support of this study, irrespective of cultivars of watermelon cultivars, grafting treatment alone affected firmness which was greater from plants grafted to rootstock '451' and '1330' . Fruit soluble solid content (SSC) and lycpopene also varied with the cultivar and rootstock (Davis and Perkins-Veazic, 2005).

The role of grafting in giving resistant to diseases provides boosting production. Research proved the resistant gourd rootstocks to disease has been led to double production of watermelon in south eastern of United State of America (Khankahdani *et al*., 2012). In line with this, grafting of watermelon onto other cucurbitaceae rootstocks to provide soil-borne disease resistance has been highly successful (Ali, 2012). Furthermore, researches proved that, grafted watermelon plants onto wild watermelon rootstocks (C. Lanatus var. citroides) were resistant or moderately resistant to the southern root knot nematode, M. incognita. (Thies and Levi, 2007). Grafted watermelon has potential to survive under abiotic stress. Research showed that, grafted mini-watermelons onto a commercial rootstock (PS 1313: Cucurbita maxima Duchesne X Cucurbita moschata Duchesne) revealed a more than 60% higher marketable yield when grown under conditions of deficit irrigation compared with ungrafted melons. The higher marketable yield recorded with grafting was mainly due to an improvement in water and nutrient uptake (Schwarz *et al*., 2010). In consistent to this result, grafting watermelons with saline-tolerant rootstocks showed yield increases up to 81% under greenhouse production in the Mediterranean (Colla *et al*., 2010).

3.3. Role of Grafting on Yield and Quality of Cucumber

Cucumber is one of the most cultivated crops in the world both in open field and greenhouse condition and application of grafting help to counterattack soil borne pathogens especially in controlled environment (Marsic and Jakse, 2010). Investigation on growth and yield of grafted cucumber on different soilless substrates showed that, grafted plants formed a significantly larger stems and longer root systems which led to 24% increased yield (Marsic and Jakse, 2010). Yield increment due to grafting and budding of cucumber also proved by Reid and Klotzbach in 2011.

Grafting also has a significant effect on cucumber frit quality. As Davis *et al*. (2008) reviewed, different rootstocks affect grafted cucumber quality characteristics such as fruit shape, skin and flesh color and texture, skin smoothness, firmness, rind thickness, and soluble solids content. Grafted cucumber better survives and gave acceptable yield and quality that un-grafted one under abiotic stress. Research conducted to evaluate grafting effect on cucumber under stress caused due to NaCl showed that, grafted cucumber showed comparable flavor, taste and nutrient contents to those of nongrafted plants and the least impact registered on grafted cucumber (Zhou *et al*., 2010).

3.4. Role of Grafting on Yield and Quality of Eggplant

Eggplant (Solanum melongena L.) is widely cultivated in tropical and temperate regions around the world and is amenable to grafting (King *et al*., 2008). Eggplant is susceptible to numerous diseases and parasites, in particular to Ralstonia solanacearum, Fusarium and Verticillum wilts, nematodes and insects (Collonnier *et al*., 2001).

Horticultural crop quality is a broad term and includes physical properties, flavor, and health-related compounds (Rouphael *et a*l., 2010). Although there are many conflicting reports on changes in fruit quality resulting from grafting in vegetables (Daviset al., 2008a), Oxalic acid content of eggplant fruit differed significantly depending on grafting and cultivar (Table). The average oxalic acid content of Faselis was 18% lower than that of Pala. Grafting resulted in a significant reduction (9%) in average oxalic acid content in both cultivars (Çuruk *et al*., 2009).

Treatment	Oxalic acid (%)
Grafted	0.098[b]
Un-grafted	0.108[a]

(Source: Çuruk *et al*., 2009).

In contrast grafting of eggplant on Solunum torvum and Solunum Sisymbriifolium negatively affected vitamin C content, firmness and some sensory attributes but overall impression was not influenced (Arvanitoyannis *et al*., 2005). The differences in reported results may be due in part to different production environments, type of rootstock used, interactions between specific rootstocks and scions, and harvest date. There are many reasons why rootstocks affect scion fruit quality. The most obvious is rootstock/scion incompatibility, which induces undergrowth and/or overgrowth of the scion, leading to decreased water and nutrient flow through the grafted union, ultimately causing wilting (Davis et al., 2008). Nevertheless, to get positive effect of grafting on vegetable quality, rootstock/scion combinations should be carefully selected for specific climatic and geographic conditions (Davis *et a*l., 2008).

Non-nutrient heavy metals such as cadmium, arsenic, lead, and mercury, which are harmful for both plants and humans, are introduced to agricultural ecosystems from various sources, including industry, reclaimed wastewater, and soil amendments originating from various sources (Diacono and Montemurro, 2010). Even though, problem of heavy metal contamination in fruit vegetables is currently not widespread, some recent reports are worrying (Savvas *et al*., 2010). Survey conducted in Japan showed that, approximately 7% of eggplant fruit contain cadmium at concentrations exceeding the internationally acceptable limit for fruiting vegetables (Arao *et al*., 2008). Hence, grafting fruit vegetables onto appropriate rootstocks, may limit the heavy metals accumulation in the aerial parts, thereby mitigating their adverse effects on crop performance and human health (Savvas *et al*., 2010). According to Arao *et al*. (2008), grafting reduce cadmium concentrations in eggplant fruit by grafting onto Solanum torvum. In particular, grafting Solanum melongena plants onto Solunum torvum reduced the leaf and stems cadmium concentrations by 67–73% in comparison to self-grafting or grafting onto Solanum integrifolium, in both cadmium polluted and unpolluted soils.

3.5. Role of Budding on Yield and Quality of Citrus

orange (Citrus aurantium) is used as the rootstock, fruits of sweet orange, tangerine, and grapefruit are smooth, thin-skinned, and juicy, with excellent quality, and they store well without deterioration . Sweet orange (C. sinensis) rootstocks also result in thin skinned, juicy, high-quality fruits. The larger fruit size of ‘Valencia’ oranges is associated with the dwarfing trifoliate orange rootstock, whereas sweet orange rootstocks produce smaller fruits (Hussein and Slack, 1994).

Budding uses a bud cut from the parent tree (scion) that is grafted onto a seedling rootstock. Once the bud is in place, the foliage of the rootstock above it is cut off or tied down to "force" the bud growth. There are several horticultural advantages to budding. A major advantage is the known success in reproducing the characteristics of the parent tree (Williamson and Jackson, 1994). Producing trees through budding allows the selection of rootstocks that can impart disease tolerance and allow production in soils not suited for the scion

3. 6. Role of Budding on Yield and Quality of Guava

Guava is propagated both sexually and asexually. In sexual propagation seeds are sown immediately because they are sensitive to dry conditions and lose viability (Mitra and Bose, 1990). Since Guava is generally propagated from seeds, each plant symbolizes variation in genetic makeup and each individual plant thus has variation in quality, maturity and other vegetative and reproductive growth habits. Sexual propagation, no doubt, is the major source of genetic variation essential for the development of crops. Improvements achieved, however, must be maintained for economic benefits of farming community. Asexual propagation ensures conservation of an improved crop variety. In Horticultural crops, therefore, it is a generally accepted method of propagation. Lack of standardized method of Guava production has reflected in low quality of fruit, haphazard maturity and lower yields than the potential and its further exploitation for processing industry. Guava seedlings budded through T-budding showed good results in terms of yield and quality as compared to chip budding (Zamir *et al*., 2009).

4. SUMMARY AND CONCLUSION

Grafting and budding are horticultural techniques used to join parts from two or more plants so that they appear to grow as a single plant. Due to problems related to biotic and abiotic stress in horticultural crops production, the use of grafting and budding as alternative means becoming the known techniques in different parts of the world. There are different grafting methods however the most common methods for grafting vegetables are the splice or tube, tongue and cleft method. Primarily, grafting solves problems related to infections by soil-borne pathogens and to enhance the tolerance against abiotic stresses. The grafting technique could help in the solution of many problems. Therefore, the advantages of grafted plants which offer high yield and consequently higher profit, to be of value for farmers. In addition, the use of grafting is a simple step for more developed cultivation forms. Grafting of horticultural crops represents an effective tool not only for overcoming the salinity problem but also for enhancing fruit quality. Moreover, it may reduce or eliminate the use of certain pesticides (especially soil fumigants) because the rootstocks will provide tolerance to many soil insect and disease pests

Grafting and budding are not associated with the input of agrochemicals to the crops and is therefore considered to be an environment-friendly operation of substantial and sustainable relevance to integrated and organic crop management systems. It is a promising tool to enhance plant performance under growth conditions in which plants (roots) have to deal with suboptimal and/or super optimal temperatures, water stress and organic pollutants. Overall, it can conclude that grafting and budding are effective agricultural approaches to improve fruit quality under both adequate growth conditions and salinity, and results indicated that, the fruit quality of the shoot, at least partially, depends on the root system. The fact that the positive effect of the rootstock on fruit quality may be dependent on both, the shoot and root genotypes, as well as the growth conditions, with or without stress, makes the selection of optimum rootstocks a difficult task. Yet, selection of the best combination of rootstock and scion is necessary to get best result

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