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Role of grafting on tomato production: Review

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ABSTRACT

Tomato an important vegetable crop is a rich source of red pigment carotenoid, lycopene, vitamins and minerals. Its world production is reached to 182,256,458 tons in 2018 with productivity of 38.269 t ha^{-1}. The contribution of Ethiopia for World market in case of tomato is insignificant due to its low production of about 43,816 tons in 2018 with area coverage and productivity of 7089 ha and 6.18 t ha^{-1} respectively. The low production and productivity of tomato may be associated with abiotic and biotic factors. Grafting positively affects the life of plants in different ways. As it is indicated by various findings, grafted tomato plant was well performed both in growth and eventually in yield related parameters without significant quality reduction in most cases. To boost the production of tomato crop in the areas where there are different biotic and abiotic factors, using grafting technology with disease resistant and abiotic factors tolerant rootstock is the noble solution. Especially in Ethiopia, grafting which is almost new technology for the country can improve tomato production and productivity. To adopt such important technology in Ethiopia, it is necessary to conduct researches regarding tomato grafting. Furthermore, the rootstocks with desired characteristics should be identified within the species through researches.

Keywords: Grafting, Growth, Yield

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1. INTRODUCTION

Back ground and Justification

Tomato (*Lycopercicon esculentum* Mill.) is belongs to the *Solanaceae* family and it is the most important vegetable crops produced throughout the world for its nutritional and economic importance. Central and South America are believed to be center of origin and diversity of the crop (Nelson, 2008). It distributed to Europe and Asia in the early and mid-1960s (Asfew Zeleke and Eshetu Derso, 2015).

Tomato varies in shape, size, and color depending on the varieties. It varies from small cherry like, fresh market and processing types. It is served raw, baked, stewed, fried, and processed to pickles, sauce, juice and concentrated pastes (Zeleke and Derso, 2015).

A very valuable constituent of tomato is the red pigment carotenoid and lycopene, which are important anti-oxidants (Nasir *et al*., 2015). Tomato seeds contain high-quality plant proteins that can be supplemented into various food products. Studies have revealed that it is economical to utilize protein isolated from tomato seeds, as a substitute for wheat flour used in bakery products since it contains most essential amino acids at higher content (Organization for Economic Co-operation and Development (OECD), 2010). It is an excellent source of vitamin C, biotin, molybdenum, vitamin K, vitamin A (in the form of beta-carotene), vitamin B, vitamin E, foliate, and niacin. It is also a good source of protein, chromium, pantothenic acid, molybdenum, choline, zinc, and iron (Zeleke and Derso, 2015). Besides the use of tomatoes and tomato products for direct human consumption, tomatoes and its by-products serve as raw materials for several secondary products (Sogi *et al*., 2005).

In addition to the mentioned importance, tomatoes have also economic importance for smallholder farmers in Ethiopia as they are high value crops. The high yielding potential coupled with its high price, tomato is an important income source for small scale farmers in the country (Melese, 2017).

Moreover, commercial farms of tomato are also recently established in the central rift valley areas, which create job opportunity for young people in the area (Tefera *et al*., 2013). Therefore, if the commercial scopes of tomato production are appropriately used it can reduce unemployment and increase the daily income of the produces and employees.

The world tomato production is reached to 182,256,458 tons in 2018 with productivity of 38.269 t ha^{-1}. Ethiopia recorded low production of 43,816 tons in the same year, with the area coverage and productivity of 7089 ha and 6.18 t ha^{-1} respectively (FAOSTAT, 2019). As a result, the contribution of Ethiopia for world market is very low. The low production and productivity of tomato is associated with abiotic and biotic factors that hamper the production of tomato ((Estan *et al*., 2004; Castillo *et al*., 2007). From the biotic factors, soil borne diseases like root knot, fusarium, wilt and bacterial wilts and

insect pest like mite, aphids, leaf borers, armyworms, weevils, wireworms and etc. are very important (Capinera, 2001).

The most known abiotic factors that reduce the production of vegetables including tomatoes are problems associated with salinity and high temperatures (Castillo *et al*., 2007). These problems are especially serious, as tomato is mostly produced by irrigation in lowland areas with high temperatures and evaporations that results deposition of salts and thus salinity (Baye, 2017).

In this regard, various research results demonstrated that grafting of tomato on resistant variety of eggplant reduce the growth and yield reduction associated with salinity and other biotic and abiotic problems (Colla *et al*., 2014; Semİz *et al*., 2015; Kariada and Aribaw, 2017). Therefore the objective of this paper is to review on role of grafting on tomato production.

2. Role of Grafting Technology on Tomato Production

2.1. Description of the Tomato Plant

Tomato is a flowering vegetable plant of the nightshade family (Solanaceae) and cultivated widely for its edible fruits (Petruzzello, 2019). Tomato plants are branched, spreading and 60– 180 cm in height. The plant is somewhat trailing when fruiting, while a few forms are compact and upright. Leaves has hairy characteristics with strong odorous and also it is pinnately compound, and up to 45 cm (18 inches) long. The flowers are five-petaled yellow with 2 cm (0.8 inches) across and clustered nature. The fruit berries are varying in diameter from 1.5 to 7.5 cm (0.6 to 3 inches) or more. They are typically different in color such as red, light red or yellow, green and purple varieties are the common. They vary in shape from almost spherical to oval and elongate to pear-shaped. Each fruit contains at least two cells of small seeds surrounded by jellylike pulp (Petruzzello, 2019).

Tomatoes have two types of growth patterns, determinate and indeterminate (Dessalegn, 2002). The main differences between two categories are that determinate tomatoes establish the flowers and fruit at the tip of the branches. Thus plants of this group of tomatoes are usually smaller in size and the growth is terminated with the flower production. The fruits of such group ripen earlier and usually uniformly.

On the other hand, indeterminate tomatoes give flowers and fruit at the location where two branches meet each other. Unlike the determinants, the branches keep growing and as a result, they are usually larger in height and form vines. Some tomato varieties share the habits between the two forms (Rashid and Singh, 2000).

2.2. Ecological Requirement of Tomato Plant

Tomato is usually grown as an annual for both fruits as well as seed purpose. It is warm-season crop and requires relatively warm weather and much sunlight. In cooler climate the crop is therefore grown in hot houses. The temperature requirements of tomato vary with its developmental stage like germination, vegetative growth, flower and fruit set stages. An optimum temperature for seed germination is close to 29 ºC. Tomato growth best at the temperature ranges of 21-24 ºC. Temperatures below 10 ºC and above 38 ºC are not suitable for growth and development of tomatoes as they slow down physiological activities (Krishna dubey, 2012).

Tomato plant doesn't withstand frost and high humidity and thus they require low to medium rainfall (Bighaat, 2020). In addition, bright sunlight, especially at the time of fruit set, is required for the development of attractive dark red colored fruits (Newenhouse, 2010). Tomato requires well-drained loamy soils which are rich in organic matter content. The pH of the growing media/soil should be at the range of 6.5-7.5 (Ramasamy, 2004).

The plants are susceptible to several pests and diseases, including bacterial wilt, early blight, mosaic virus, Fusarium wilt, nematodes, and tomato hornworms (Capinera, 2001). Many of these problems can be controlled with crop rotation, the use of fungicides and pesticides, and the planting of resistant varieties. The tiny currant tomato (*S. pimpinellifolium*) is a closely related species and has been used by breeders to hybridize several pests- and disease-resistant tomato varieties (Petruzzello, 2019).

2.4. Vegetable Grafting

Grafting is a process by which a piece of scion is attached to a rootstock in such a way that the cambiums of both scion and rootstock come in firm contact, so that the new secondary tissue resulting from cambial cell division in the scion and rootstock is closely knitted (Kumar, 2011; Malik, 2000). When the two genotypes are compatible, the vascular bundles reconnect at the graft union and the wounded surfaces of the scion and rootstock meet without presenting a barrier for water and nutrient translocation.

Vegetable grafting is an important component of sustainable horticulture as it increases the vigor of the crops and resistance against diseases, tolerance to temperature, salinity, flooding and drought, and increase nutrient uptake (Colla *et al*., 2014). Commercial grafting of vegetable plants began in Korea and Japan in the late 1920s when watermelon plants were grafted onto squash rootstocks for Fusarium wilt resistance (Grieneisen *et al.,* 2018).

Since then, research on vegetable grafting has substantially increased. Vegetable grafting is mainly applied to *Solanaceae* and *cucurbitaceous* crops, primarily tomato, eggplant, pepper, watermelon, cucumber, and melon (Goreta *et al.,* 2008). Currently, in many countries in Latin America, Europe, and Asia, grafted plants represent a large percentage of the tomato industry (Leonardi and Romano, 2004; Grieneisen *et al.,* 2018). However, information is still needed to answer the questions like how to graft vegetables, which one is compatible to which, how to develop and exploit the vegetable grafting techniques and understand the potential contribution of vegetable grafting for sustainable vegetable production (Giuseppe and Cardaralli, 2014).

2.5. Effects of Grafting on Growth, Yield and Fruit Quality of Tomatoes

2.5.1. Grafting methods used for tomato

Grafting of tomato plants involves the joining of two seedlings of different plants, with one serving as the rootstock and the other as the scion (Grieneisen *et al.,* 2018). It can be either with other crops of similar species like *Solanaceae* families or self-grafting (Poudel and Lee, 2009; Kumar, 2011).

Different types of grafting techniques including whip grafting, tongue, and cleft grafting can be used for tomato grafting. According to Koirala (2018) whip/Clip grafting technique is the simplest method to join a stock and scion and suitable for

herbaceous plants. For successful grafting, the stock and scion should be less than 1 inch in diameter and of equal thickness (Kumar, 2011).

In the case of whip grafting long, diagonal cuts of equal lengths are made on root stock and scion so as to exactly fit the cut surfaces. The two pieces of stock and scion should be hold together with plastic tape or other tying materials. When the diameter of stock and scion are not equal, the scion should be placed to one side of the stock to ensure cambial contact on at least one side (Grieneisen *et al*., 2018). According to Kumar (2011), greenhouse tomatoes, eggplants, cucurbits such as zucchini, pumpkin, and squash are some examples of vegetable crops that can be grafted by whip or splice grafting.

2.5.2. Effects of grafting on growth of tomatoes

Grafting influences most of the growth performance of vegetable crops including tomatoes (Kumar *et al.,* 2011). Based on the rootstock species and variety, grafting can improves the growth and development of tomato plants which associated with higher concentration of chlorophyll fluorescence and photosynthetic pigments in leaves due to better nutrient translocation and availability (Rivero *et al.,* 2004; Leonardi and Giuffrida, 2006; Kumar *et al.,* 2011; Draie, 2017). Therefore, grafted tomato plants generally produces more vigorous, higher branch number, longer stem and highest aboveground dry weight of the vegetative organs compared to non-grafted plants (Khah *et al.,* 2006 and Yaris, 2011; Draie 2017; Ulas *et al.,* 2019). In addition to growth it also influences days to physiological maturity and days to first harvest of tomatoes (Pogony *et al*., 2005; Nkansah *et al.*, 2013).

2.5.3. Effects of grafting on yield and quality of tomatoes

Yield and quality of tomatoes is influenced through various agronomic practices including grafting. Pogony *et al.* (2005) investigated the effects of grafting on yield and quality of greenhouse tomato. According to the results of the authors, fruit yield was significantly higher on grafted tomato plants than on Non-grafted one. Nkansah *et al.* (2013) also reported that grafted tomatoes on *solanum* rootstocks performed better in terms of growth, yield, disease incidence and flood tolerance. Colla *et al.* (2008) concluded from researches they conducted in soilless media that higher marketable fruit yield was harvested from grafted tomato.

Pék *et al*. (2007) reported the production of significantly more number of fruits on grafted tomato plants in five consecutive harvests than Non-grafted plants. Therefore, grafting improves the yield and yield components of tomatoes including flowers number per cluster, marketable and unmarketable fruit yield (Khah, *et al.,* 2006; Nkansah *et al.,* 2013) that can be partly through the increased fruit number and partly by increase in fruit weight (Pogony *et al.,* 2005).

Furthermore, although higher total costs in grafted tomatoes, particularly labor costs; the difference in revenue was large enough to make grafted tomato significantly more profitable (Wang and Chen, 2012; Milenković *et al.*, 2018).

Not only the quantity but also the quality of tomato can be influenced by grafting of on different root stocks whereby fruit quality is described by size, firmness, pH content, total soluble solid content and other physical and chemical properties. In this regard,

Pogony *et al.* (2005) reported that soluble solids (Brix°), carbohydrate and organic acids concentrations and the ratio of carbohydrate and acid content of fruits harvested from grafted tomatoes were lower than those from Non-grafted ones. According to Nkansah *et al.* (2013) fruit TSS didn't have significant differences on grafted and non-grafted fruits. According to Poudel & Lee (2009) the fruit size of tomato grafted on eggplant rootstock was significantly smaller than non-grafted and self-grafted.

Both horizontal and vertical diameter of the fruits of non-grafted and self-grafted possessed significantly higher values than tomato grafted on eggplant rootstock. Therefore, although fruit quality values were lower in grafted plants, these values were still satisfactory and lied within the adequate ranges (Khah *et al.,* 2006 and Milenković *et al.*, 2018).

2.5.4. Effect of grafting on salt tolerance of tomato plants

Salinity is among abiotic factors that affect the overall life of plant through imposing both osmotic and specific ion stresses (Castillo *et al.,* 2007). Tomato growth is sensitive to salt concentration above 2.5dS/m, which causes yield reduction (Dessalegn 2002; Ezin *et al.*, 2012; Zhai *et al.,* 2015; Umar *et al.,* 2018). Furthermore, the increment of salinity cases blossom end rot that can result fruit quality loss (Zhai *et al.,* 2015 and Adams *et al.*, 2008).

Grafted plants deploy numerous and diverse physiological and biochemical mechanisms to cope with salt stress (Korrekturen, 2012). It is also reported that grafting tomato on salt tolerance root stock is considered as the best solution (Fernandez-Garcia *et al.,* 2004). In this regard, Mahmoud (2014) observed significantly better vegetative growth, yield and water use efficiency of tomato plants which were grafted on salt-tolerant varieties compared to those none grafted plants.

Generally, the grafted plant on salt tolerant root stock still produced higher yield while the yield of non-grafted plants was reduced with the increment of salt level (Mahmoud, 2014; Korrekturen, 2012; Semİz *et al*., 2015). Similarly, tomato plants grafted on salt-tolerant rootstock withstand the salt stress and gave better yield than Non-Grafted one where the ability of the plant to withstand the stress depends on the type of rootstock (Bahadur *et al.,* 2015).

2.5.5. Role of grafting tomato in organic farm

The accumulation of harmful chemicals that results from pesticide application throughout the world is increasing from time to time. Despite, converting crop production from conventional to organic farming could reduce the persistent and harmful pesticides from entering the environment (Chait, 2019).

The technology of vegetable grafting is the best way of reducing pesticide contamination of crops and environment since it can be considered as non-chemical pest control methods (Aktar *et al.,* 2009; Martin, 2009). Therefore, it is effective integrated pest management (IPM) tool for the management of soil-borne diseases (Louws *et al.,* 2010; Guan *et al.,* 2012; Kyriacou, 2017). Various researches also recommended the technology as one of the best methods to be included in organic farming practices (Aktar *et al.,* 2009; Martin, 2009; Pogony *et al.,* 2005; Kyriacou, 2017).

Despite the relatively high cost of grafted transplants, due to increased labor and input for their production, grafting has evolved into a unique cultural practice that helps to reduce pesticide use, enhances yield and production efficiency, and improves economic viability in sustainable vegetable production under both open field and protected culture systems (Kubota *et al*., 2008).

2.6. Vegetable Grafting in Ethiopia

In Ethiopia there are abundant production lands which have different agroecology. The country has quality groundwater potential of the country is about 2.6 billion cubic meters (Agency, 2012)

The elevation ranges from -47 up to 3000 m.a.s.l. allows the productions various tropical subtropical and temperate crop such as onion, tomato, garlic, shallot, capsicum, , cole crops, Ethiopian kale, head cabbages, muskmelon, watermelon, pumpkin, beetroot, carrot, snap bean, sweetpotato, Irish potato, anchote, colocosia, yam, taro, moringa etc. throughout the country. Although grafting is known technology in Ethiopia its applicability to vegetables is not yet adopted (Yassin & Hussen, 2015).

3. CONCLUSION

Grafting positively affects the life of plants in different ways. As various researches indicate grafted tomato plant was well performed both in growth and eventually in yield related parameters without quality reduction in most cases. To boost the production of tomato crop in the areas where there are different biotic and abiotic factors it is necessary to use grafting technology with rootstock which is resistant to disease and tolerant to abiotic factors that challenging the crop production in the world. Especially in Ethiopia the yield reduction due to different factors can get solution by using grafting which is almost new technology for the country.

4. Future Prospect

In Ethiopia the culture of grafting vegetable is not yet adopted. Even though, some researchers and MSc. Students are trying to conduct the research on grafting. To adopt such important technology, it is necessary to conduct researches regarding tomato grafting. Furthermore, the rootstocks with desired characteristics should be identified within the species through resarches.

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