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Highlights

Analysis of Tea Production

Benefits of Inventions in China

UV-C in Washing Treatment

Participatory Agronomic Performance

Discovering Thoughts, Inventing Future

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Reiview on Role of Grafting on Yield and Quality of Selected Fruit Vegetables

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Abstract- Grafting can be defined as the natural or deliberate fusion of plant parts so that vascular continuity is established between them and the resulting genetically composite organism functions as a single plant. 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). The technique also applied in vegetable production to tackle biotic and abiotic stresses. Grafting of vegetables is a common practice in different parts of the world, but not in Ethiopia. However, there is no review attempt made so far pertinent to the issues of vegetable grafting in Ethiopia. Therefore, this paper aimed to review the importance of grafting on selected fruit vegetables yield, quality, disease resistant and stress tolerant.

Keywords: grafting, fruit vegetable, yield, quality, stress.

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REIVIEWONROLEOFGRAFTINGONYIELDANDQUALITYOFSELECTEDFRUITVEGETABLES

Strictly as per the compliance and regulations of :

Reiview on Role of Grafting on Yield and Quality of Selected Fruit Vegetables

Hassen Yassin [α] & Seid Hussen [σ]

Abstract- Grafting can be defined as the natural or deliberate fusion of plant parts so that vascular continuity is established between them and the resulting genetically composite organism functions as a single plant. 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). The technique also applied in vegetable production to tackle biotic and abiotic stresses. Grafting of vegetables is a common practice in different parts of the world, but not in Ethiopia. However, there is no review attempt made so far pertinent to the issues of vegetable grafting in Ethiopia. Therefore, this paper aimed to review the importance of grafting on selected fruit vegetables yield, quality, disease resistant and stress tolerant. 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 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. And producers currently faced problems due to biotic and abiotic stresses in fruit vegetable production that push them to apply grafting techniques as alternative means.

Keywords: *grafting, fruit vegetable, yield, quality, stress.*

I. Introduction

Agriculture began some 10,000 years ago when ancient peoples, who lived by hunting and gathering, began to cultivate plants and domesticate animals. It 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).

Since the origins of agriculture, 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 is the common and practiced long time ago in fruit 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). In grafting, the upper part (scion) of one plant grows on the root system (rootstock) of another plant. Unlike budding, which can be performed before or during the growing season, most grafting is done during winter and early spring while both scion and rootstock are still dormant.

As Hartmann *et al.* (2002) described the sequence events of the grafted herbaceous plants. First, new parenchymatous cells proliferate from both stock and scion produces the callus tissues that fill up the spaces between the two components connecting the scion and the stock. Following, the new cambial cells differentiate from the newly formed callus, forming a continuous cambial connection between the stock and scion. Furthermore, prior to the binding of vascular cambium across the callus bridge, initial xylem and phloem may be differentiated. The wound repair xylem is generally the first differentiated tissue to bridge the graft union, followed by wound-repair phloem. Finally, the newly formed cambial layer in the callus bridge begins typical cambial activity forming new vascular tissues. Production of new xylem and phloem thus permits the vascular connection between the scion and rootstock.

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 and Michae,

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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).

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). Recorded data revealed that, grafting of watermelon onto bottle gourd to increase its tolerance to soil-borne diseases (Heidari *et al.*, 2010) and to diminish fusarium wilt (Rivard and Louws, 2006). 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).

Ethiopia has favorable conditions for the production of a number of vegetable crops. The wide range of altitude from below sea level to over 3000 m.a.s.l., gives it wide range of agro-ecological diversity ranging from humid tropics to alpine climates, where most types of vegetable crops can be successfully grown. Further, the abundant labor, vast land and water resources give her an opportunity and facilitation for the production of different types of vegetable crops (Fekadu and Dendena, 2006). Currently there are commercial farms that engaged in exporting vegetables like potato, beans, shallot, cucurbits, tomato, etc.

However, lack of high-yielding, multiple pest and disease resistant cultivars, proper agronomic practices, appropriate pest and disease control techniques and lack of sufficient quantity of seed supply are some of the constraints in vegetable production in Ethiopia (Fekadu and Dendena, 2006). Abiotic and biotic stresses preclude crop varieties from displaying their full genetic potential and fuel the development of new, improved varieties bur development of new is time-consuming, expensive, technically-demanding, and marked by compromise since gains in one attribute can be offset by declines in another. Grafting is a proven technique for enhancing crop genetic potential but it is under-utilized in vegetable production (Kleinhenz *et al.,* 2009).

Continuous cropping is inevitable in greenhouses, but this reduces the yield and quality of produce. Soil borne diseases and nematodes has become a problem in Ethiopia for vegetable producers in green house and in particular Jittu Farm has these problems. Since soil sterilization can never be complete, grafting has become an essential technique for the production of repeated crops of vegetables grown in both greenhouse and open field condition. Hence, the aim of this paper is to review the recent literatures on the responses of grafted plants to some biotic and abiotic stress so as to increase yield and quality of selected fruit vegetables.

II. Overview of Fruit Vegetable Grafting

Grafting is one of the techniques used to combine one plants part with another to encourage a unified plant using different methods so as to minimize or avoid biotic and abiotic stresses. Even though, there are some challenges in application of the technique, but producers used as alternative solution for production problems.

a) Grafting

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).

According to Besri, (2008) grafting is a method of asexual plant propagation that joins plant parts for them to live together. So they will grow as one plant. Grafting is accomplished by inserting a piece of stem containing three to four vegetative buds onto the stem of the plant that will serve as the root system for the unified plant (Kumar, 2011). There are points should be considered during grafting and these are: incompatibility, plant species and type of graft, environmental conditions during and following grafting, growth activity of rootstock and craftsmanship of grafting (Hartmann *et al.,* 2002).

Furthermore, for a successful graft union to form, the cambium of the rootstock and scion must be well aligned and in contact with one another. The scion and rootstock plants must therefore have similar stem diameters at the time of grafting. However, the scion and rootstock may not germinate or grow at the same rate. Conducting a preliminary trial to determine the growth rates of rootstock and scion plants in the growing environment is vital (Johnson *et al.,* 2011).

Normally the method has been largely applied to propagate trees that will not root well as cuttings or whose own root systems are not strong enough or resistant to several soil-borne pathogens. But now the method is used for other crops, as vegetables, such as solanaceous plants (tomato, eggplant and pepper) and cucurbits (melon, cucumber and watermelon) (Besri, 2008).

b) *Methods of Grafting for Fruit Vegetables*

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 (Appendix Figure 1). This is the most widely used grafting technique for tomatoes and also works well for eggplants (Johnson *et al.,* 2011).

Tongue-approach grafting also known as side-by-side grafting which is one of the grafting techniques in which the rootstock and scion while are on itself roots is grafted together (Appendix Figure 2). After confidence of graft place union, scion and rootstock are cut below and above of graft place, respectively (Khankahdani *et al.,* 2012).

Cleft grafting also known as apical grafting and wedge grafting (Appendix Figure 3). According to Johnson *et al.,* (2011) it can accomplish through making horizontal cut to remove the top of the plant. Then a 0.5cm long vertical incision made in to the centre of the rootstalk and scion has to be cut a 0.5cm long wedge so as to insert it into the vertical incision in the rootstalk. Finally, a scion roots from the grafted plants such that the two are completely separated within three days.

Hole insertion grafting is also one of the other grafting technique in vegetables which in this technique rootstock is cut from above of cotyledons and is made a hole in cutting place and the scion (consist cotyledons and hypocotyl axis) is placed into hole (Khankahdani *et al.,* 2012).

The methods used for different vegetables depend on different factors and research proved this fact. Hole-insertion grafting was highly effective in watermelon and cucumber (Salehi *et al.,* 2008). While one may choose "one cotyledon graft" is also known as "splice", "slant" or "tube" graft due to its simplicity and less labour intensive than the approach graft (Hassell and Memmott, 2008) cited in Ali (2012). Table 1 depicted the fact that, irrespective of rootstalk used, grafting techniques alone affect the graft union percent efficiency for watermelon (Khankahdani *et al.,* 2012).

Table 1 : Comparison the effect of grafting techniques, rootstocks and interaction between them on graft union percent on watermelon at Iran

	Grafting Technique			
Rootstock	Hole insertion	Splice	Tongue-approach	Mean
Bottle gourd	6.8[c]	75.4[a]	25.8[bc]	36.0[A]
Shintoza	5.4[c]	41.5[b]	15.7[bc]	20.9[B]
Pumkin	0.0[c]	12.8[bc]	6.4[c]	6.4[C]
Mean	4.1[C]	43.2[A]	16.0b[B]	

Means with small letters, followed by similar letters are not significantly different at the 1% level according to Tukey's test (HSD). In below row or right column, means with capital, followed by similar letters are not significantly different at the 1% level according to Tukey's test (HSD). Source: (Khankahdani et al., 2012).

In general, grafting methods varied based on different factors. And research has to be done to evaluate the efficiency of grafting methods for specific crop. Tomato and eggplants are mainly grafted by conventional splice and cleft grafting. The survival ratio of grafted *Cucurbitaceae* plants is higher if a tongue approach grafting is used, especially for cucumber. This is because the root of the scion remains until the formation of the graft union. Splice grafting is easy to do and has recently become popular for watermelon and melon (Marsic and Osvald, 2004).

c) *Reasons for Grafting of Fruit Vegetables*

The rationale behind grafting of plants may be to get benefits from rootstocks, aimed to changing the cultivars of established plants, hastening plant growth rate and earlier fruit production and or to study and elimination of virus diseases (Hartman *et al.,* 2002). In addition, grafting is used to reduce infections by soil-borne pathogens and to enhance the tolerance against abiotic stresses (Krumbein and Schwarz, 2011).

Investigation done on tomato showed that, tomatoes grafted on rootstocks BHN 1054, Cheong Gang, BHN 998, and RST 106 had lower bacterial wilt incidence and higher yields than the un-grafted and self grafted controls (Mc Avoy *et al.,* 2011). Vegetable grafting is nowadays extremely popular in some countries and is mainly used to improve plant tolerance to biotic stresses occurring particularly in intensive agro-systems. This technique has also been proposed as a way to enhance vegetable tolerance to abiotic stresses (Leonardi and Colla, 2011). In addition to avoid soil-borne diseases, watermelon grafting onto cucurbit rootstocks is another agronomic interest for plant vigour and production (Ali, 2012).

Environmental stresses represent the most limiting conditions for horticultural productivity and plant exploitation worldwide. Important factors among those are temperature, nutrition, light, oxygen availability, metal ion concentration etc. One direction out of these problems is to develop crops that are more tolerant to such stresses. This is carried out with tremendous efforts particularly at breeding companies; however, due to a lack of practical selection tools like genetic markers, it is a slow and inefficient process so far. As one effect, each year a high number of new cultivars are released which can be used by the growers. A special method of adapting plants to counteract environmental stresses is by grafting elite, commercial cultivars onto selected vigorous rootstocks (Lee and Oda, 2003).

In line with this, one of the possible applications of grafting in commercial vegetable production is the mitigation of stress caused by adverse chemical soil conditions in the root environment (Schwarz *et al.,* 2010). Studies revealed that, grafting fruit vegetables onto appropriate rootstocks may be used to mitigate or even eliminate yield restrictions owing to nutrient and heavy metal toxicities and minimize intake of heavy metals by consumers (Savvas *et al.,* 2010).

The other stress in vegetable production is water which quickly becoming an economically scarce resource in many areas of the world, especially in arid and semiarid regions. Ethiopia has also arid and semiarid regions those showed shortage for water. The increased competition for water among agricultural, industrial, and urban consumers creates the need for continuous improvement of irrigation practices in commercial vegetable production. One way to reduce losses in production and to improve water use efficiency under drought conditions in high-yielding genotypes would be grafting them onto rootstocks capable of reducing the effect of water stress on the shoot as observed in tree crops (Garcia *et al.,* 2007).

Furthermore, growers go for grafting to alleviate problems related to organic pollutants. Drins (aldrin (oxidized to dieldrin) and endrin) have been categorized as a group of persistent organic pollutants because of their high toxicity, high bioaccumulation and persistency in the environment. Since 1995, aldrin was permitted for import to Congo, Ethiopia, Malaysia, Nepal, SriLanka, Sudan, Tanzania, Thailand, Trinidad and Tobago, and Venezuela. Fortunately, grafting can reduce the uptake of these pollutants to the plant tissue. Investigation on cucumber revealed that, it is possible to reduce aldrin pollution in cucumber by about 50% using a low-uptake rootstock like 'Yuyuikki-black' (Schwarz *et al.,* 2010). For better result, selecting of low-uptake rootstock varieties is a promising practical technique to reduce dieldrin concentration in cucumber fruits grown in contaminated fields.

d) World Status of Fruit Vegetable Grafting

Intensive labour input and resulting high costs of grafted seedling production have been issues preventing this technology from being widely adopted outside of Asia. However, along with the development of efficient commercial production techniques for grafted seedlings and the introduction of new rootstocks with desirable traits compatible with locally selected scions, grafting technology was introduced to European countries in the early 1990s (Oda, 2002) mainly through marketing efforts of international seed companies and through information exchanges among research communities. As a result, many countries in Europe, the Middle East, Northern Africa, Central America, and other parts of Asia (other than Japan and Korea) adopted the technology and the areas introducing grafted plants increased rapidly during the past two decades (Kubota *et al.,* 2008).

Furthermore, with the rapid development of intensive protected cultivation technologies using high tunnels and greenhouses, which presumably prevented farmers from continuing traditional crop rotation, vegetable grafting became a crucial tool to overcome soil borne diseases and other pests. In the 1990s, nearly 60% of open fields and greenhouses in Japan producing muskmelon, watermelon, cucumber, tomato, and eggplant were reportedly planted with grafted seedlings (National Research Institute of Vegetables, 2001) and 81 % in Korea. Over 500million grafted seedlings are produced annually in Japan (Kobayashi, 2005). Surveys conducted in North America in 2002 and 2006 showed that the total number of grafted seed-lings used in North America was over 40million with the majority of these used in hydroponic tomato greenhouses (Kubota et al., 2008).

In Greece, grafting is highly popular, especially in southern areas, where the ratio of the production area using grafted plants to the total production area, amounts to 90-100% for early cropping of watermelon and 40-50% for melons under low tunnels, 2-3% for tomato and egg plants, and 5-10% for cucumbers (Khah *et al.,* 2006). Report of status of grafting in countries is presented in Table 2.

Table 2 : Use of grafted vegetables in the world (2007)

Country	Watermelon	Cucumber	Melon	Tomato	Eggplant	Pepper
Israel	70%	*	5%	15%	5%	*
Japan	93%	72%	30%	48%	65%	5%
Korea	98%	95%	95%	15%	2%	25%

Greece	100%	5 -10%	40-50%	2-3%	*	*
Spain	98%	*	3%	4500ha	*	*
Morocco	*	*	*	75%	*	*
Cypres	80%	*	*	170ha	*	*
Italy	30%	*	5-6million	1200ha	*	*
France	*	3%	1000ha	2800ha	*	*
Netherlands	*	5%	*	50%	*	*
Turkey	30%	5%	*	25%	10%	*

**= No data available. (Source: Hishtil South Africa (PTY), 2007).*

With respect to Ethiopia, at present, different vegetable crops are produced in many home gardens and also commercially in different parts of our country. These include onion, garlic, shallot, capsicum, tomato, cole crops, Ethiopian kale, head cabbages, watermelon, muskmelon, pumpkin, beetroot, carrot, snap bean, sweetpotato, Irish potato, anchote, colocosia, yam, taro, moringa etc. Most of them are produced by individual growers and others by private investors as well as state enterprises (Fekadu and Dendena, 2006).

Nevertheless, application of grafting on fruit vegetables in Ethiopia is not well known and not used by individual growers and private sectors too, except grafting trials of cucurbits, pepper and tomato to combat soil borne diseases at Jittu farm (Bishoftu site).

III. Role of Grafting on Selected Fruit Vegetables

Grafting in fruit vegetables play a great role in increasing yield and quality and helps to provide resistance/tolerance to biotic and/or abiotic stress.

a) Role of Grafting on Tomato

Tomato (*Lycopersicon esculentum* Mill.) is a crop of high importance in many countries (Marsic and Osvald, 2004). It is also popular and widely grown vegetable crop in Ethiopia ranking 8th in terms of annual national production (Ambecha *et al.,* 2012). However, there are production problems like weeds, insect pests and diseases including late blight and Fusarium wilt reducing the yield (Ambecha *et al.,* 2012). Among other mechanisms, grafting is one of the techniques to solve some of the aforementioned problems existed in tomato (Pogonyi *et al.,* 2005).

i. *Effect 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).

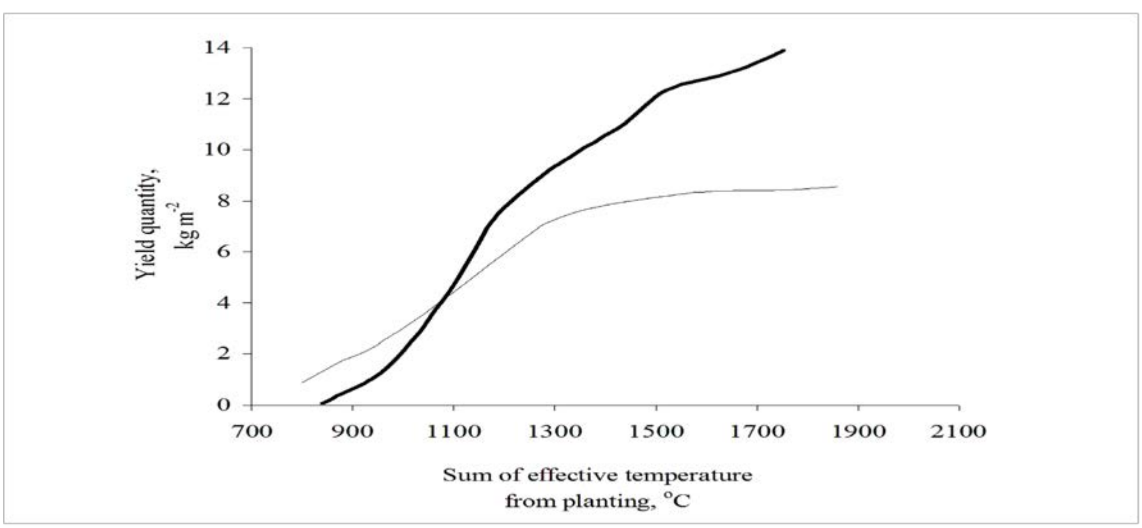

Figure 1 : Accumulated yield quantity of tomato fruits from grafted (solid line) and un-grafted (light line) plants at Hungary. Source: (Pogonyi *et al.,* 2005)

A perusal of Figure 1 showed that, 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).

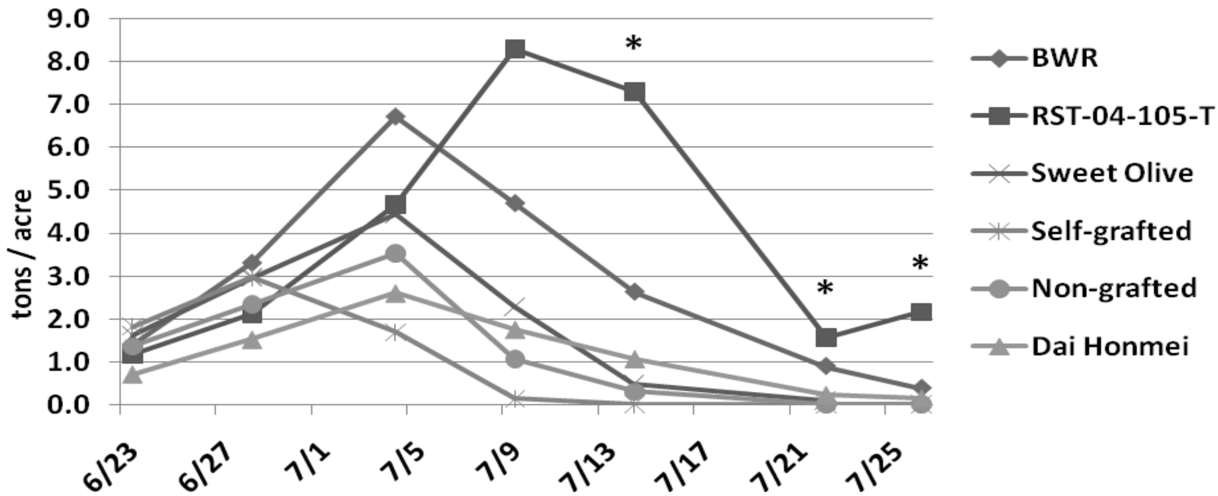

Figure 2 : Total weekly fruit yield for grafted and non-grafted 'Celebrity' tomatoes over time at North Carolina

Source: (O'Connell, 2009).

In parallel research conducted at Black River Organic Farm in North Carolina also confirmed that, fruit yield of tomato significantly affected through grafting techniques (Figure 2). Fruit yield collected on weekly based showed that, on the corresponding sample date the 'Celebrity-RST-04-105-T' grafts had significantly greater values compared to the 'Celebrity-Sweet Olive' grafts, non-grafted, and self-grafted treatments (O'Connell, 2009). Similarly, increase in yield of tomato due to grafting also reported (Marsic and Osvald, 2004; Pogonyi *et al.,* 2005; Khah *et al.,* 2006; Kleinhenz *et al.,* 2009; Garden News, 2011).

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.

ii. *Grafting of tomato in resistance/tolerance to biotic and abiotic stress*

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 cause damages 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). The list of diseases that are shown to be reduced by grafting listed in Appendix Table1.

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 (Figure 3). 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).

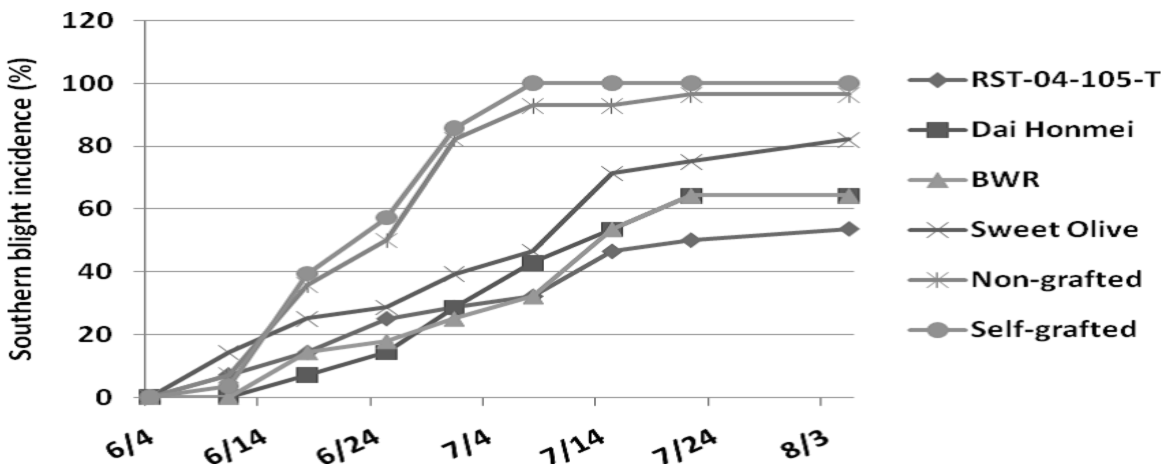

Figure 3 : Southern blight disease progress curve grafted and non-grafted 'Celebrity' tomatoes over time at North Carolina

Source: (O'Connell, 2009).

In the same fashion grafting on tomato contributed in combating root not nematode in which the susceptible tomato cultivar grafted on beaufort dramatically reduced root galling due to root-knot nematodes, and this was the best treatment among all other treatments (Kaskavalci, *et al.,* 2009).

Abiotic stress significantly affects tomato production both in open field and greenhouse condition. These include, too cold, wet or dry, hypoxia, salinity, heavy metal contaminations, excessive and insufficient nutrient availability, and soil pH stress. These conditions cause various physiological and pathological disorders leading to severe crop loss (Savvas *et al.,* 2010). Nevertheless, grafting can provide resistance and or tolerance to tomato for such conditions. Salinity in soil or water is one of the major abiotic stresses that reduce plant growth and crop productivity worldwide (Arzani, 2008). Grafting tomato plants for increased salinity tolerance is a promising practice to improve the crop performances in saline soil conditions (Colla et al., 2010).

b) *Role of Grafting on 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).

i. *Effect of grafting on yield and quality of cucumber*

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). Based on result Table 3, irrespective of substrate, grafting treatment alone increased the yield of cucumber.

Table 3 : Main effects of substrate and grafting on marketable yield of cucumber fruits

Treatment	Marketable yield Kg/plant	Number of fruits/plant
Substrate		
Perilite	7.90[a]	24.00[a]
Clay pellets	6.10[b]	18.30[b]
Grafting		
Grafted on	7.72[a]	23.60[a]
Un-grafted	6.22[b]	18.80[b]

Means followed by different letters are significantly different at $P < 0.05$ using Duncan's Multiple Range Test Source: (Marsic and Jakse, 2010).

Yield increment due to grafting of cucumber also proved by Reid and Klotzbach in 2011. A perusal use of Figure 4 depicted that, grafted plants of both varieties Manar and Diva out yielded their un-grafted counterparts.

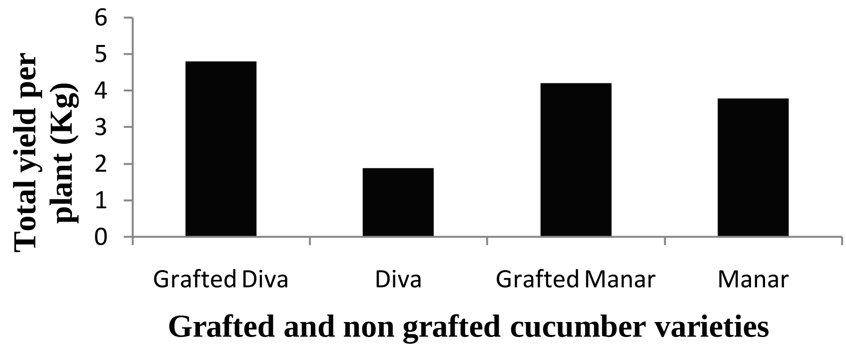

Figure 4 : Cucumber fruit yield per plant of grafted and non grafted varieties

Source: (Reid and Klotzbach, 2011).

Grafting has also a pronounced effect on cucumber fruit 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.

ii. *Grafting of cucumber in resistance/tolerance to biotic and abiotic stress*

Greenhouse experiment conducted to evaluate the effect of different cucurbit rootstock on growth and yield of cucumber under the impact of root-knot nematode revealed that, rootstock type affected the fruit yield where Strongtosa and Shintosa produced higher marketable yield ranging from 260% to 280% of that un-grafted plants (Al-Debei *et al.*, 2011).

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 non-grafted plants and the least impact registered on grafted cucumber (Zhou *et al.*, 2010).

c) Role of Grafting on 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).

i. *Effect of grafting on yield and quality of watermelon*

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). According to Table 4, 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 (4.37 kg/plant) (Khankahdani *et al.*, 2012).

Table 4 : Comparison of different types of watermelon plant based on evaluated characters

Plant type	Fruit yield (kg/plant)
Seedy	4.37^{e}
Transplant	5.63^{d}
Shintoza rootstock Splice grafting	11.97^{b}
Bottle gourd rootstock Splice grafting	13.60^{a}
Shintoza rootstock Tongue-approach grafting	10.67^{c}
Bottle gourd rootstock Tongue-approach grafting	12.17^{b}

Means in each column, followed by similar letters are not significantly different at the 5% level according to Tukey's test (HSD). Source: (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' (Table 5). Fruit soluble solid content (SSC) and lycpopene also varied with the cultivar and rootstock (Davis and Perkins-Veazic, 2005).

Table 5 : Comparison of fruit quality from grafted and non-grafted watermelons

Cultivar	Rootstock	Type	SSC	Firmness (Pa)	Lycopene (ug/g)
SF800	None	Control	12.20[a]	7.90[b]	63.7[b]
	1330	Squash	10.90[b]	10.50[a]	65.8[a]
	451	Gourd	10.70[b]	11.80[a]	60.1[b]
SS5244	None	Control	11.70[ab]	7.50b	56.00[b]
	1330	Squash	10.70[b]	10.20[a]	61.10[a]
	1332	Gourd	11.60[ab]	6.30[b]	64.20[a]
	451	Gourd	12.20[a]	10.50[a]	65.40[a]

Means followed by the same letter are not significantly different by the Bonferoni method at the 5% level of probability. Source: (Davis and Perkins-Veazic, 2005).

ii. *Grafting of watermelon in resistance/tolerance to biotic and abiotic stress*

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 un-grafted 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.*, 2009).

d) Role of Grafting on Eggplant

Eggplant (*Solanum melongena* L.) is widely cultivated in tropical and temperate regions around the world and is amenable to grafting (King *et al.*, 2010). Eggplant is susceptible to numerous diseases and parasites, in particular to *Ralstonia solanacearum*, *Fusarium* and *Verticillum* wilts, nematodes and insects (Collonnier *et al.*, 2001).

i. *Effect of grafting on yield and quality of eggplant*

Like the mentioned crops grafting in eggplant play role in increasing yield (Figure 5). However, the economic feasibility has to be studied before application of the techniques (Reid, 2012).

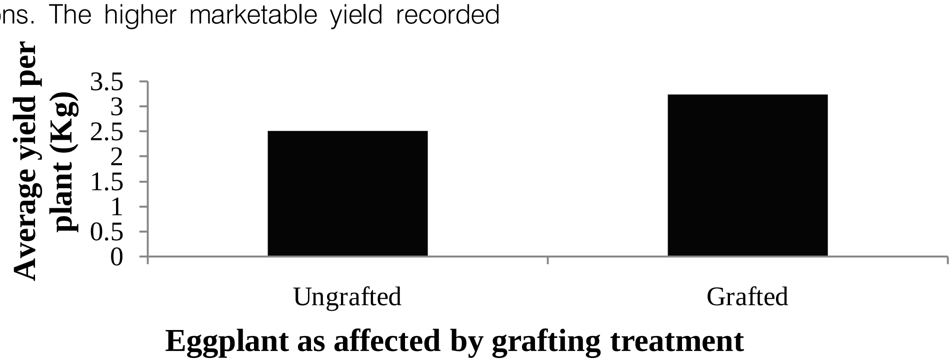

Figure 5 : Average yields per plant of grafted and un-grafted eggplant. Source: (Reid, 2012)

In horticultural industry, the focus has traditionally been on yield. However, in recent years consumer interested in the quality of vegetable products has increased worldwide. Vegetable quality is a broad term and includes physical properties, flavor, and health-related compounds (Rouphael *et al.*, 2010). Although there are many conflicting reports on changes in fruit quality resulting from grafting in vegetables (Davis *et al.*, 2008a), Oxalic acid content of eggplant fruit differed significantly depending on grafting and cultivar (Table 6). 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).

Table 6 : Mean values of oxalic acid of eggplant cultivars grown with or without rootstock

Treatment	Oxalic acid (%)
Cultivar	
Pala	0.113[a]
Faselis	0.093[b]
Grafting	
Un-grafted	0.108[a]
Grafted	0.098[b]

Means in each column, followed by similar letters are not significantly different in Duncan's multiple range tests at 5% probability. (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.*, 2008b). 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 al.*, 2008a).

ii. *Grafting of eggplant in resistance/tolerance to biotic and abiotic stress*

Grafting of eggplant on to appropriate rootstalk is environmentally friendly solution to counter biotic stress. Investigation proved that, grafted eggplant which was planted on infected soil with wilt disease produced better yield over the non-grafted plants (Bletsos *et al.*, 2003).

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.

IV. Challenge and Prospects of Grafting on Fruit Vegetables

a) *Challenges*

Though grafting play significant role in fruit vegetable production, it has challenges that might attributed for low diffusion of the technology. Among those, the presence of different rootstocks for each species that are proposed by seed companies as being resistant or tolerant to soil born diseases and nematodes. Besides, lack of detailed information on the degree of this resistance/tolerance poses problems for an appropriate choice of rootstock. It is interesting to observe that commercial rootstocks, considered tolerant to some diseases, react differently to inoculation under controlled conditions (Trionfetti *et al.*, 2002). On the other hand, lack of information is also related to the high number of available rootstocks (i.e. commercial cultivars or relative species used as rootstocks). And also regarding to the problems related to diffusion of grafting are the incomplete resistance and high number of scion/rootstock combinations (Leonardi and Romano, 2004).

Grafting of nursery plants can be performed manually, but it requires precise techniques and is becoming increasingly difficult due to the need for advanced age of skilled workers (Rouphael *et al.*, 2010). On the other hand the cost of a grafted seedling is surely one of the main concerns of growers, especially since grafted seedling costs from three to five times more than non-grafted seedling (Leonardi and Romano, 2004). However, investigation proved that, on-farm grafted tomato transplant production can be successful and the results of the economic analysis indicate that grafting tomatoes onto hybrid grafting rootstocks can increase on-farm net returns by approximately $50,000 when soil borne disease pressure is high (O'Connell, 2009).

One of the tough works in producing grafted seedlings of fruit vegetable is healing the graft junctions. After the grafts are clipped back together they need to be placed in a high humidity environment known as a healing chamber. A healing chamber can be constructed in various ways using wooden or metal frames and a plastic covering. The goal is to create a closed environment in which the humidity can increase and the temperature can be controlled (Wilson *et al.*, 2012).

Besides, limited researches on vegetable grafting obstruct from exploiting the importance of grafting and further investigation on it. Generally, the incomplete resistance of grafted seedlings, high number of scion/rootstock combinations, the need for skilled workers, cost of grafted seedlings and limited research works are some of the challenges observed in fruit vegetable grafting.

b) Prospects

Grafting techniques in fruit vegetables will be further known and used in the world because it has at least two distinct functions. First, resistant rootstock can be deployed to limit risk of crop losses from soil borne pathogens. Second, rootstock hybrid lines could be identified for increased plant vigor and crop yield, even in the absence of disease pressure. In addition the technique is an effective integrated pest management tool for growers that face heavy disease pressure from soil borne pathogens (Rivard and Louws, 2008).

The proved positive effect of grafting on yield and quality of tomato, cucumber, watermelon and eggplant results in the increment of the status of using grafting for fruit vegetables (Pogonyi *et al.*, 2005). Though grafting is extremely laborious and time-consuming, and growers are trying to reduce the labour input required and currently robots are invented and make it possible for eight plugs of tomato, eggplant, or pepper to be grafted simultaneously. Robotic grafting is about ten times faster than conventional hand grafting (Bekhradi *et al.*, 2011).

Until recently, grafted seedling production and its use were not common in Ethiopia. The exception is the trial practice in Jittu Farm. But it has encouraging prospects due to the expansion of private farms those intended to sell the produces to local and export market. Yet the continuous cropping in greenhouse and open field condition results in nutrient depletion and development of soil borne diseases that lower the productivity of the crops ultimately, producers forced to use chemicals which are expensive and persistent pollutants. Hence, grafting can be used as alternative way to tackle the biotic and abiotic stress. Furthermore, grafting is an environmentally friendly technique that can be used in organic farming. Even though the process is costly partly due to the high input for labor, but this is not as such a problem in our country. So that the cost of making grafted seedlings might be lowered that boost using of this technique.

Overall, vegetable grafting can be considered a powerful technique. Nonetheless, different "actors" have to be involved in order to allow grafting to become further widespread (Leonardi and Romano, 2004). Though, application of grafting has mentioned 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.

V. Summary and Conclusion

Due to problems related to biotic and abiotic stress in vegetable production, the use of grafting as alternative means becoming the known technique 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 increased 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 fruit vegetables 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 is 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 is an effective agricultural approach 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.

As a result of its benefits and value, demand for high-quality grafted seedlings by growers and is expected to rapidly increase. Researchers, extension specialists, and industries need to work together to integrate this modernized technology as an effective tool for sustainable horticultural production in Ethiopia.

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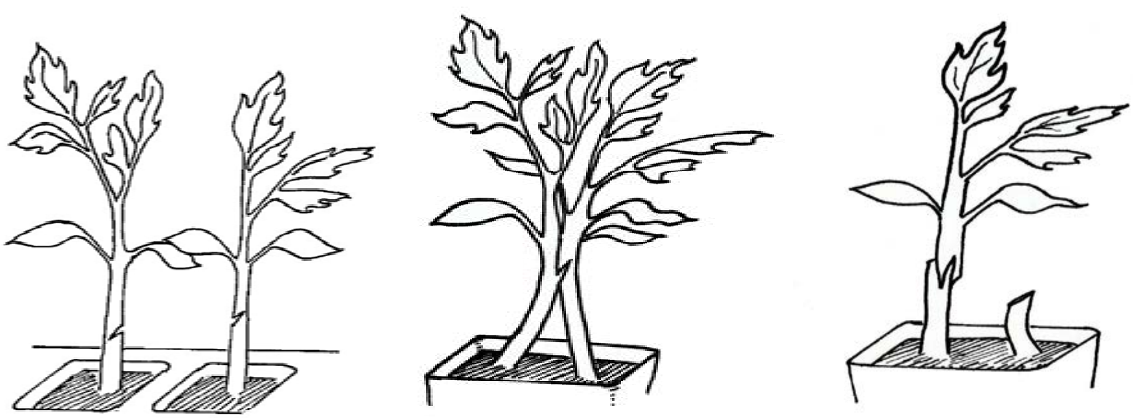
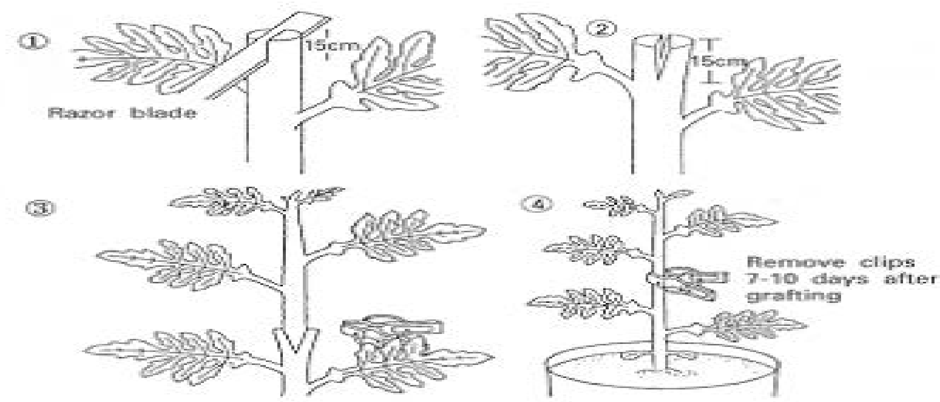
VI. Appendices

Appendix A

Appendix Figure 1 Splice grafting of tomato plants. Cutting tomato stem at a 45^o angle (A) and using a clip to secure the scion to the rootstock (B). Source: (Johnson *et al*., 2011).



Appendix Figure 2 Tongue-approach grafting. Source: (Johnson *et al*., 2011).



Appendix Figure 3 Cleft grafting. Source: Johnson *et al.*, 2011).

Appendix B

Appendix Table 1 Lists of crops and diseases reported to be controlled by grafting

Crop	Disease	Organism
Cucumber	Fusarium wilt	*Fusarium oxysporum*
	Phytopthora blight	*Phytopthora capsici*
	Root-not nematodes	*Meloidogyne spp.*
	Verticillium wilt	*Verticillium dahlia*
	Target leaf spot	*Corynespora cassicola*
	Black root rot	*Phomopsis sclerotiodes*
Melon	Fusarium wilt	*Fusarium oxysporum*
	Vine decline	*Monosporascus cannonballus*
	Root-not nematodes	*Meloidogyne spp.*
	Gummy stem blight	*Didymela bryoniae*
	Verticillium wilt	*Verticillium dahlia*
	Black root rot	*Phomopsis sclerotiodes*
Cucurbita sp. Watermelon	Spider mites	*Tetranychus cinnabarinus*
	Fusarium wilt	*Fusarium oxysporum*
	Root-not nematodes	*Meloidogyne spp.*
	Verticillium wilt	*Verticillium dahlia*
	Virus complexes	CMV, ZYMV, PRSV,WMV-II
Eggplant	Verticillium wilt	*Verticillium dahlia*
	Corky root	*pyrenochaeta lycopersici*
	Root-not nematodes	*Meloidogyne spp.*
Tomato	Bacterial wilt	*Ralstonia solanacearum*
	Fusarium wilt	*Fusarium oxysporum*
	Corky root	*pyrenochaeta lycopersici*
	Root-not nematodes	*Meloidogyne spp.*
	Verticillium wilt	*Verticillium dahlia*
	Tomato yellow leaf curl	ToYLCV

CMV, Cucumber Mosaic Virus; ZYMV, Zucchini Yellows Mosaic Virus: PRSV, Papaya Ring spot Virus; WMV-II, Watermelon Mosaic Virus II. Source: (King et al., 2008).

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UV-C in Washing Treatment for Preserving Quality and Functional Content of Minimally Processed Fragaria Vesca Strawberry

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Abstract- The effect of UV-C radiation as sanitizer in washing treatment on the quality of minimally processed Fragaria vesca strawberry is presented. Processed strawberries were packaged in thermally sealed polypropylene trays using passive modified atmosphere packaging. During a storage period of 10 days at 4 °C, quality parameters, functional content, sensory attributes and microbial counts analysis were performed. It was concluded that the use of UV-C radiation in the washing water was effective in reducing the microbial counts, maintaining the antioxidant compounds and the sensorial quality of the product throughout the storage period.

Keywords: industrial practices, uv-c radiation, quality attributes, functional content.

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A. M. Fernández-León [α], D. Bohoyo-Gil [σ], S. Nogales-Delgado [ρ], J. Delgado-Adámez [ω] & M. F. Fernández-León[¥]

Abstract- The effect of UV-C radiation as sanitizer in washing treatment on the quality of minimally processed Fragaria vesca strawberry is presented. Processed strawberries were packaged in thermally sealed polypropylene trays using passive modified atmosphere packaging. During a storage period of 10 days at 4 ºC, quality parameters, functional content, sensory attributes and microbial counts analysis were performed. It was concluded that the use of UV-C radiation in the washing water was effective in reducing the microbial counts, maintaining the antioxidant compounds and the sensorial quality of the product throughout the storage period.

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I. Introduction

Minimally processed products are quite popular among consumers, who are demanding ready-to-eat fruits and vegetables, presumably due, in part, to their characteristics of freshness, low caloric content, commodity to be used and an active promotion of fruits and vegetables as basic components of a healthy diet *(5)*. Nevertheless, it is well known that minimal processing alters the integrity of the fruit and induces surface damages increasing lightly the tissue respiration and leading biochemical deteriorations such as browning, off-flavour development and texture breakdown decreasing the fresh-cut fruit quality *(14, 16)*.

Strawberries that are one of the most popular fruits worldwide, are rich in nutrients but also highly perishable, being susceptible to mechanical injury, desiccation, decay and physiological disorders during storage. Among fruits, they have one of the highest antioxidant activities *(6)*. The shelf life of fresh strawberries at cold temperature is usually less than 5 days. This storage time is reduced when the product is minimally processed. Improvements in shelf-life can be achieved by using good quality raw products, special care during processing and along the trade chain, control of temperature and relative humidity, and use of modified atmosphere packaging *(19)*.

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In order to decrease microbial contamination, fresh-cut industry commonly uses sodium hypochlorite as disinfection agent but by-products such as trihalometanes and chloramines are potentially harmful for healthy human and the production of high amounts of wastewater producing environmental risk making necessary the search of alternative disinfectant agents.

Organic acids, mainly citric, lactic and acetic acid, which are in GRAS (Generally Recognized As Safe) status, have been investigated because of their bactericidal activity *(21, 24)*. Physical methods including ultraviolet radiation (UV) have been shown to be capable of killing or inhibiting bacterial growth *(27)*. Its application to a re-circulating water stream maintains the water at a reasonable bacteriological quality, but has no effect at all on surfaces either of the process machinery or on the product itself *(8)*. As pathogens can survive for relatively long times in water, they can subsequently contaminate the product that passes through it before microbial inactivation with UV occurs. The maintenance of the quality of the process water is very important as it might serve as a source of cross-contamination. In fact, the main effect of sanitizing treatments for washing fresh-cut produce is to reduce the microbial load and keep process water free from contamination rather than having a preservative effect *(9)*.

In the present study, samples were directly processed in a fresh-cut processing line and cleaning room. The main purpose of this work was to evaluate if the use of UV radiation in the washing water affects the microbial growth, sensory and functional quality of fresh processed *Fragaria vesca* strawberry.

II. Materials and Methods

a) Materials

Strawberries (*Fragaria vesca* L.) were provided by Asociación para el Desarrollo del Sistema Productivo Vinculado a la Agricultura Onubense (ADESVA) (Huelva, Spain).

b) Sample preparation

The temperature in the processing clean room was maintained at 8 ºC. The steps of processing were: *(a) reception*: strawberries were carefully selected for uniform size and colour as well as the absence of damage and defects; *(b) cutting*: the calyx was cut off using special knives designed for fruit; *(c) washing*: strawberries were washed during 90 seconds using one patented industrial washing equipment, model CAMEL (Turatti, Italy) coupled with a ultraviolet system of six lamps (Montagna, Italy). The following treatment were applied: water and UV-C radiation (30 mW cm^{-2}); *(d) draining*: strawberries were drained using an industrial drying tunnel system by hot/cold air, Mod. "Domino Junior Laboratorio" (Turatti, Italy); *(e) packaging*: 150.0 g of strawberries were placed in a polypropylene (PP) tray and thermally sealed with a PP film (permeability to O_2 was 114 $cm^3 m^{-2}$ 24h at 25 ºC) in order to generate a passive modified atmosphere (MAP). An industrial packaging, Mod. "Verpakungs-Systeme" (Western, Germany) was used; *(f) storage*: packaged samples were stored at 4 ºC in refrigeration for up to 10 days.

c) Total soluble solids, titratable acidity and pH

Total soluble solids (TSS), titratable acidity (TA) and pH were measured for each independent homogenate. TSS were measured by refractometry using a RE40 refractometer (Mettler Toledo, S.A.E., Coslada, Spain); results are expressed as ºBrix. TA and pH were determined using a DL50 Graphix automatic titrator (Mettler Toledo, S.A.E., Coslada, Spain). Results were expressed as g malic acid 100 g^{-1} fresh weight (fw).

d) Colour

Flesh colour was measured using a CR-200 tristimulus colorimeter (Minolta, Tokyo, Japan), with an 8 mm diameter viewing area and using illuminant D65. Chromatic analyses were conducted in accordance with the CIE (Commission Internationale de l'Eclairage) system of 1976. Values of L*, a* and b* were used to define a three-dimensional colour space.

e) Head space gas composition

O_2 and CO_2 content of all strawberries trays were measured using an O_2 and CO_2 meter PAK 12P (Control y Suministros S.A, Barcelona, Spain). Each tray was used only for a single determination.

f) Total phenolic content, anthocyanins content and total antioxidant activity and

Total phenolic content was obtained from 5 g of homogenate. The colorimetric reaction was developed by using Folin-Ciocalteau reactive. After one-hour reaction, absorbance was measured at 760 nm with a UV-2401 PC spectrophotometer (Shimadzu Scientific Instruments, USA). TPC was quantified by an external standard method using gallic acid and expressed as mg galic acid 100 g^{-1} fresh weight *(15)*.

Anthocyanins were extracted from 10 g of homogenate in 50 ml acidic methanol solution (0.2 % HCl), evaluated following the González-Gómez method *(10)*, absorbance was measured at 520 nm with a UV-2401 PC spectrophotometer (Shimadzu Scientific Instruments, USA). The quantification was carried out by the external standard calibration method, using cyaniding 3-O-rutinoside as standard and expressed as mg cyaniding 3-O-rutinoside 100 g^{-1} fresh weight (n=4). Total antioxidant activity was determined using a Thermo Scientific Appliskan spectrophotometer (Thermo Fisher Scientific, Waltham, Massachussets, USA), equipped with a 24-well plate. For the spectrophotometric reaction, 20 μl sample juice was added to 1 ml ABTS (2-2'-azinobis(3-ethylbenzoithiazolone 6-sulphonate) (n=4). Absorbance loss was measured at 750 nm for 20 min. Trolox was used as external standard to quantify TAA, being expressed as mg Trolox 100 g^{-1} fresh weight (Cano et al., 1998).

g) Microbiological analyses

For microbiological assessments of mesophiles, psychrotrops, moulds and yeast, the following methods according to ISO 4833 *(11)* and ISO 7954 *(12)* were used and the results were expressed as log CFU g^{-1}.

h) Firmness determination

Firmness was measured using a Stable Micro Systems Texture Analyzer TA-XT2i (Aname, Spain) through a compression assay on the whole strawberry. The force was applied to produce a 2 % deformation by a 100 mm aluminium plate. The maximum force (N) was calculated.

i) Sensory evaluation

Sensory quality was evaluated by a semi-trained panel consisting of eight members. Samples were scored for overall visual quality using an interval hedonic scale, where the extremes and center of the interval were represented as follows: 0 'very bad', 5 'limit of acceptance from the consumers point of view', and 10 'very good'. The remaining attributes, flavor and firmness, were evaluated in a 5 point scale, where 5 = fully characteristic of the product, 2.5 = moderate and 0 = not characteristic. Defects of the product, off-odors, browning and dehydration were evaluated as follows: 5 = severe, 2.5 = moderate and 0 = absence. The samples were coded with random three-digit numbers to mask the treatment identity in order to minimize subjectivity and to ensure test accuracy. All quality evaluations were performed in a sensory room.

j) Statistical analysis

For statistical studies, SPSS 18.0 software was used (SPSS Inc., Chicago, IL, USA). Correlations were estimated with the Pearson test at $p<0.05$ significance level. Data are expressed as means ± S.D. and were analyzed using a one-way analysis of variance (ANOVA). When ANOVA detected significant differences between mean values, means were compared using LSD Tukey's test.

III. Results and Discussion

a) *Total soluble solids (TSS), titratable acidity (TA) and Ph*

The results are presented in Figure 1. There were not some significant differences in TSS during storage days. The values for TSS and TA found in this study are similar to others given for this fruit *(2, 13)*. The pH of studied strawberries was very low (about 3.5) and during the storage did not change significantly ($p > 0.05$); the found values of pH were within the limits pH 3.0 to 5.0 that promote the processes of copigmentation *(1)*.

b) *Colour*

The value of a* parameter offers better the evidence of deterioration or browning of the product, so a positive a* value indicates redness on the hue circle and -a* indicates greenness. The results of the evolution of the parameter a* are shown in Figure 2. In our study, in general, a* showed not any significant differences during storage days so, we can conclude that when UV radiation is used in water as washing treatment, the pigments conservation is good. The evolution for a* found in this study has a similar behaviour to other given for minimally processed strawberries treated with chitosan as preservative *(2)*.

c) *Head space gas composition*

As one would expect a decrease in the headspace oxygen concentration along with an increase in the headspace carbon dioxide concentration was detected. The package headspace was monitored over 10 days of storage (data not shown). Starting from an atmospheric gas concentration, levels of 18-19 % O_2 and 3-4 % CO_2 within packages were established after 5 days and until the end of the storage time at 4 ºC. In this study, the values found for O_2 and CO_2 levels imply that the PP film could be adequate for passive modified atmosphere packaging of fresh cut processed *Fragaria vesca* strawberries.

d) *Phenolic content, anthocyanin pigments and antioxidant activity*

The results are shown in Figure 3. Fresh cut strawberries exhibited high amounts of phenolic compounds and showed not any significant differences during all storage days. This values are in agreement with the values found by other authors in the whole *Fragaria vesca* strawberry *(4)* and for other whole cultivars *(13)*. In this way, other authors *(7, 28)* reported a concentration of total phenolics between 1730 and 3180 mg kg^{-1} in different strawberry cultivars determined by the Folin-Ciocalteu assay. Calculated total phenolics as the sum of each individual phenolic compound quantified by HPLC *(23)*, the values ranging from 639 to 660 mg kg^{-1}. The higher phenolic concentrations found in our study, compared to those obtained by HPLC, could be attributed to the analytical method used to determine these compounds. The Folin-Ciocalteu reagent usually overestimates the content of phenolic compounds compared with the sum of the individual phenolics, since other reducing agents present in food, such as ascorbic acid, can interfere *(22)*.

Anthocyanins are responsible for the attractive red colors of strawberries. The initial concentration of total anthocyanins in strawberries agrees with the reports of other authors for whole *Fragaria vesca* strawberries *(4)* and for other whole cultivars *(13)*. A slightly decrease was observed for the evolution of anthocyanin content during storage but showed not any significant differences.

Several investigations have reported significant differences in antioxidant activity among strawberry cultivars *(17)*. In our study, fresh cut strawberries exhibited high total antioxidant activity during all storage days. Higher values were found by other authors for this cultivar *(18)*. *Fragaria vesca* fruits were 2.5 times more active than cultivated strawberries in the TEAC assay (Trolox equivalent antioxidant capacity) *(26)*. A slightly decrease was observed for the evolution of total antioxidant activity content during storage but not any significant differences were found. This decrease during storage period at 4 ºC might be due to an effect on the activity of the major enzymes involves in the functional compounds degradation.

e) *Microbiological assessment*

The increase in cut damaged surface and availability of cell nutrients, in fresh-cut products, provide conditions that increase the number and types of microbes that can be develop. The specifications proposed by E.C *(25)* were used to determine the end of the shelf-life from the microbiological point of view, which are: 6 log CFU g^{-1} for total aerobic count and mesophiles. Figure 4 indicates a slight decrease of approximately 1.5 log unit CFU g^{-1} in mesophiles, psychrotrops and yeast and moulds microbial growth after 10 days of storage when the UV radiation in the washing water was used. Higher values of psychrotrophic bacteria were found by other authors *(2)* for control samples of minimally processed strawberries. Previous results in our laboratory *(20)* concluded that the use of UV causes a microbial reduction in washing water, with possibility of reuse this water with the consequent minimization of water consumption and decrease in the wastewater discharge rates in the food industry, producing a good environmental impact.

f) *Firmness determination*

The values found are practically constant during all days of storage, not significant differences were found, however, there is a slightly decrease from day 5 due to that the minimal processing alters the integrity of the fruit (Figure 5) and induces surface damages increasing slightly the tissue respiration and leading biochemical deteriorations such as texture breakdown *(16)*.

g) Effect of washing treatment on sensory quality

The obtained results for the sensory evaluation are shown in Figure 5. The visual quality of minimally processed strawberries was excellent after washing and decreased slightly during storage. The same behaviour was found for promotion of browning in the cutting area. These samples maintained the typical flavour during storage. An off-odor was not detected in washed samples at any storage time, without evidence of anaerobic fermentations after 10 days of storage at 4 ºC. The firmness of strawberries slightly decreased during storage but a day 10, all samples maintained a moderate crispy texture without significant differences among them. Therefore, water + UV radiation did not affect the sensory quality of fresh-cut strawberries during storage.

IV. Conclusions

It was concluded that the use of UV-C radiation in the washing water was effective in reducing the microbial counts, maintaining the antioxidant compounds and the sensorial quality of the fresh-cut strawberries during the 10 days at 4 ºC. This treatment could be a good sanitizer and alternative technique for minimizing water consumption in the food industry.

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Figures

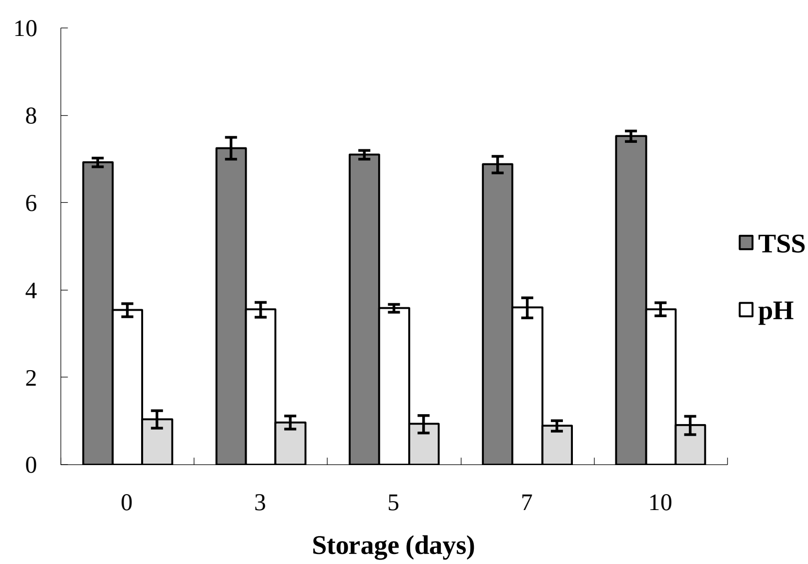

Figure 1 : Evolution of total soluble solids (TSS), titratable acidity and pH of fresh cut strawberries throughout the storage at 4 ºC for 10 days. Values are the mean of four replicates and vertical bars represent the Standard Deviation. TSS (ºBrix); acidity (g malic acid 100 g^{-1} fresh weight (fw)

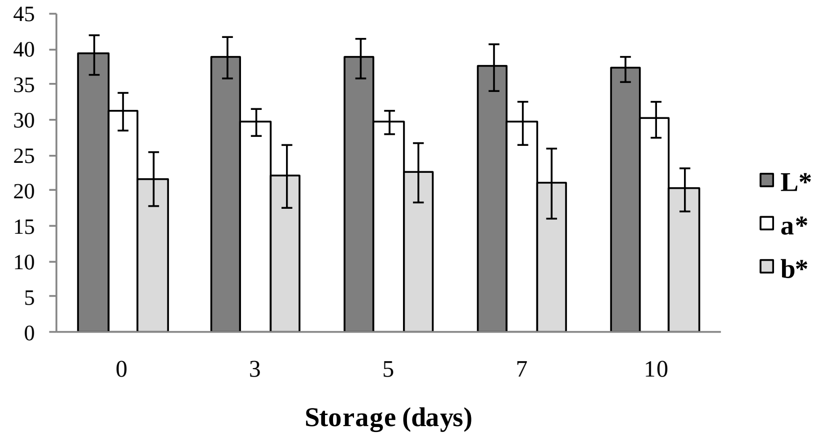

Figure 2 : Evolution of the colour parameters (L*, a* and b*) throughout the storage time at 4 °C in fresh-cut Fragaria vesca strawberries stored at 4 °C for 10 days. Values are the mean of four replicates and vertical bars represent the Standard Deviation

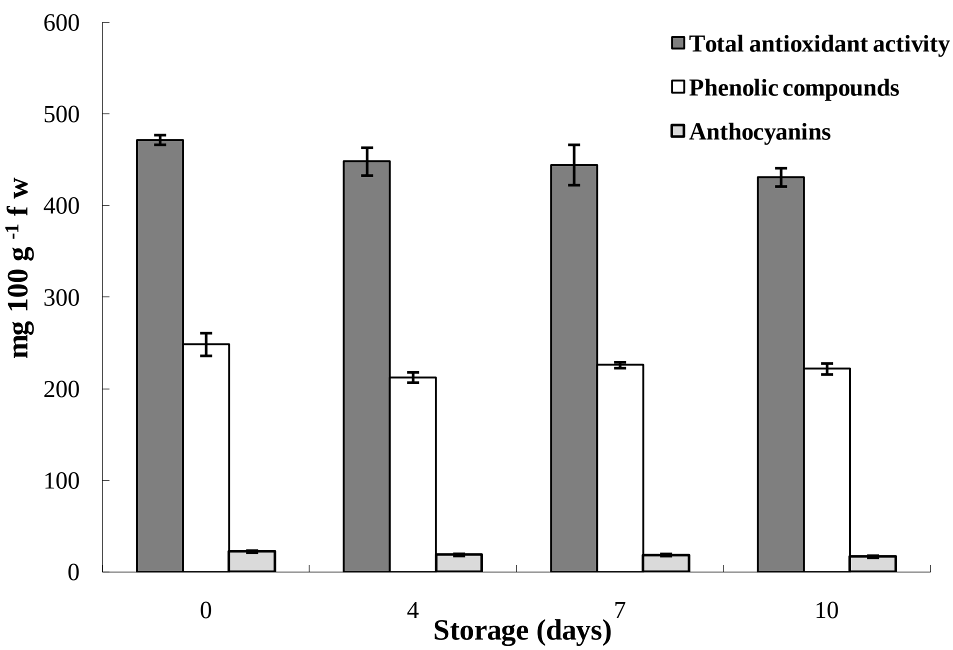

Figure 3 : Evolution of total phenolic content, anthocyanins content and total antioxidant activity of fresh cut Fragaria vesca strawberries at 4 °C throughout the storage. Values are the mean of four replicates and vertical bars represent the Standard Deviation. Total antioxidant (mg Trolox 100 g^{-1} fw); Phenolic compounds (mg galic acid 100 g^{-1} fw); Anthocyanins (mg cyaniding 3-O-rutinoside 100 g^{-1} fw)

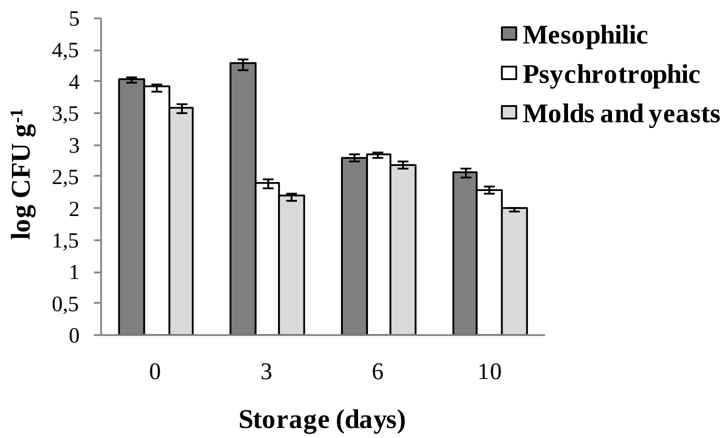

Figure 4 : Evolution of mesophilic, psychrotrophic, molds and yeasts (log CFU g $^{-1}$) counts in fresh-cut Fragaria vesca strawberries stored at 4 °C for 10 days. Values are the mean of four replicates and vertical bars represent the Standard Deviation

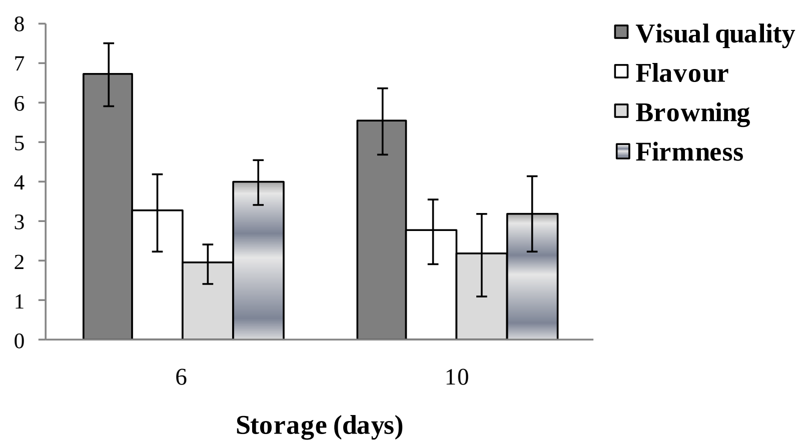

Figure 5 : Firmness and sensory quality of minimally processed Fragaria vesca strawberries stored at 4 °C for 10 days. Values are the mean of four replicates and vertical bars represent the Standard Deviation

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Participatory Agronomic Performance and Sensory Evaluation of Selected Orange-Fleshed Sweet Potato Varieties in South Western Uganda

By Turyagyenda F. Laban, Kankwatsa Peace, Muzira Robert, Kyomugisha Maggiore, Mutenyo Hellen & Muhumuza John Bosco

National Agriculture Research organization, Uganda

Abstract- There is continued demand for new varieties to satisfy the needs of farmers in Uganda for different production regions or agro ecological zones. Despite release of several improved high yielding varieties by National Agriculture Research Organization, farmers in South Western Agro-Ecological Zone have continued to rely on landraces whose production adversely is affected by both biotic and abiotic stresses. Besides, most landraces grown are white fleshed with traces of Beta-carotene. Mbarara Zonal Agriculture Research and Development Institute identified eleven sweet potato varieties, some of which orange-fleshed rich in beta carotene, to evaluate the in the zone and subsequent promotion. All the improved varieties evaluated were high yielding (11-20 t/ha) and their palatability and sensory tastes were not different from the farmer preferred local check Nderera.

Keywords: Bio-fortified, Improved, Palatability, Pro-Vitamin A, weevil damage.

GJSFR-D Classification : FOR Code: 070302

PARTICIPATORYAGRONOMICPERFORMANCEANDSENSORYEVALUATIONOFSELECTEDORANGEFLESHEDSWEETPOTATOVARIETIESINSOUTHWESTERNUGANDA

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Participatory Agronomic Performance and Sensory Evaluation of Selected Orange-Fleshed Sweet Potato Varieties in South Western Uganda

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Abstract- There is continued demand for new varieties to satisfy the needs of farmers in Uganda for different production regions or agro ecological zones. Despite release of several improved high yielding varieties by National Agriculture Research Organization, farmers in South Western Agro-Ecological Zone have continued to rely on landraces whose production adversely is affected by both biotic and abiotic stresses. Besides, most landraces grown are white fleshed with traces of Beta-carotene. Mbarara Zonal Agriculture Research and Development Institute identified eleven sweet potato varieties, some of which orange-fleshed rich in beta carotene, to evaluate the in the zone and subsequent promotion. All the improved varieties evaluated were high yielding (11-20 t/ha) and their palatability and sensory tastes were not different from the farmer preferred local check Nderera. Promotion of these vitamin rich sweet potato varieties in the zone would increase sweet potato production, household income and improve nutrition in the zone.

Keywords: Bio-fortified, Improved, Palatability, Pro-Vitamin A, weevil damage.

I. Introduction

Worldwide, Sweet potato (*Ipomoea batatas*), ranks third most important tuber crop after potato (*Solanum tuberosum L.*) and cassava (*Manihot esculenta Crantz*) (FAO, 1998). In Africa, the crop is largely grown in East Africa where it is a staple for rural communities. It forms a major part of the diet for the people of Uganda, Rwanda, Burundi and eastern Congo (Kapinga *et al.,* 2003; Rees *et al.,* 2003), and is also grown as a major income generator for the smallholder peasant farmers in these countries (Andrade *et al.*, 2009). By 2009, Uganda was reported to be the third largest producer of sweet potato with annual production of 2.7 million metric tonnes, representing almost 3% of the total world production (FAOSTAT, 2009). In Uganda, sweet potato is the third most important source of carbohydrates after banana and cassava (Yanggen and Nagujja, 2006) and is grown mainly by small scale subsistence farmers on plots that rarely exceed 0.5 ha (Kapinga *et al.,* 2003). The crop is cultivated in almost all districts of Uganda and ranking as second most important root crop after cassava.

Sweet potato provides household food security because it stores well in the soil as a famine reserve crop. The crop can be harvested in 3-6 months but can remain in the ground for "piece meal" harvesting, a common sweet potato "storage" practice in the tropics. The low level of agricultural input requirement, high productivity per unit area, good nutritional value, and increasing demand for food make sweet potato an ideal starch staple for food security in subsistence economies of Uganda (Mukasa *et al.,* 2003). Sweet potato is used for human consumption, livestock feed, and in industrial processes to make alcohol and starch, and other products such as noodles, candy, desserts, and flour.

Although the majority of sweet potato varieties are high in carbohydrates, orange-fleshed varieties also provide vitamins A and C. In addition, the green leaves of the crop can be consumed by both humans and animals providing additional protein, vitamins and minerals. In Uganda, the annual per capita sweet potato consumption is 82.5 kg ranking among countries with the highest per capita consumption in Africa (Yanggen and Nagujja, 2006). Due to the vital role of Sweet potato in the nutrition, food security and economy of the people of Uganda (Bashaasha et al., 1995), the National Agricultural Research Organization (NARO), has given high priority to research on the crop. The National Sweet potato Program of NARO has released nineteen sweet potato cultivars between 1995 and 2010 (Table 1). These developed and released varieties are superior to landraces in terms of yielding potential as well as Vitamin A content.

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Table 1 : Sweet potato varieties released in Uganda between 1995-2010

S. No	Variety	Year of Release	References
1.	Ejumula	2004	Mwanga et al. (2007)
2.	Bwanjule	1995	Mwanga et al. (2001)
3.	Dimbuka-Bukulula	2007	Mwanga et al. (2009)
4.	NASPOT 1	1999	Mwanga et al. (2003)
5.	NASPOT 2	1999	Mwanga et al. (2003)
6.	NASPOT 3	1999	Mwanga et al. (2003)
7.	NASPOT 4	1999	Mwanga et al. (2003)
8.	NASPOT 5	1999	Mwanga et al. (2003)
9.	NASPOT 6	1999	Mwanga et al. (2003)
10.	NASPOT 7	2007	Mwanga et al. (2009)
11.	NASPOT 8	2007	Mwanga et al. (2009)
12.	NASPOT 9	2007	Mwanga et al. (2009)
13.	NASPOT 10	2007	Mwanga et al. (2009)
14.	NASPOT 11	2010	Mwanga et al. (2011)
15.	New Kawogo	1995	Mwanga et al. (2001)
16.	Sowola	1995	Mwanga et al. (2001)
17.	SPK004 (Kakamega)	2004	Mwanga et al. (2007)
18.	Tanzania	1995	Mwanga et al. (2001)
19.	Wagabolige,	1995	Mwanga et al. (2001)

There is however, continued demand for superior varieties with farmer preferred sensory attributes and specific adaptation to production regions. Despite the several biofortified sweet potato varieties released by the National sweet potato breeding program, farmers in SWAEZ have continued to rely on landraces due to limited exposure of these materials to farmers for selection. Sweet potato productivity has remained low in this region. This necessitated us to carry out participatory sweet potato varieties selection so as to increase adoption of bio-fortified sweet potato varieties in the zone. The objective of this study was to evaluate agronomic performance of selected biofortified sweet potato varieties as well as their sensory acceptability to local communities in south western Agro-ecological zone.

II. Materials and Methods

a) Site

The experiment was conducted at Mbarara at Mbarara Zonal Agricultural Research and Development Institute (MBAZARDI) of National Agricultural Research Oragnization (NARO) in the South Western Agro-Ecological Zones of Uganda. The experimental site is located at 0o36' S and 30o42' E and 1443 meters above sea level. A panel of stakeholders involved in sweet potato value chain was constituted for sensory evaluation of varieties included in the study.

b) Materials and experimental design

Eleven biofortified sweet potato varieties (NASPOT1, NASPOT 5, NASPOT 8, Jewel, NASPOT 7, Ejumula, Tanzania, NASPOT 9, SPK004 (Kakamega), Naspot 10 and NKA108L) were evaluated in the study. The biofortified sweet potato varieties were obtained from the sweet potato programme at National Crop Resources Research Institute (NACRRI) at Namulonge in Uganda. For comparison purposes, one local sweet potato variety (Nderera) was included in the study, making a total of twelve sweet potato varieties. The experiment was laid in Randomised compete block design (RCBD) at a plant spacing of 1m x 1m in 4m x 4m plots in three replications. Each plot in each replication consisted of 16 mounds and three vines were planted per mound. Weeding was regulary done with a hand hoe. the experiment was repeated for three growing seasons.

c) Data collection and analysis

The agronomic performance data were collected on; Plant growthVigour on scale of 1-5 (1=Vigour very poor; 2= vigour poor; 3=Vigour neither poor nor good; 4; Vigour good; 5= Vigour very good), Total root tuber Yield (t/ha), Marketable root tuber yield (t/ha) and incidence of Sweet potato virus disease (SPVD) (percentage incidence). For acceptability and sensory evaluations for the varieties, farmers and other stakeholders including researchers, traders and consumers (participatory evaluation) were involved to determine if the varitieties were acceptable to farmers and other end users using criteria comprising of key attributes that end users consider very important in adaption and adoption sweet potato varieties. Palatability and sensory evaluation (for taste, texture and flavour) of the varieties was done at harvest. Sensory evaluation was done basing on 1-5 hedonic scale (1=dislike; 2=neithe like nor dislike; 3=Like moderately; 4=Like very much; 5=Llike extremely). All data were entered into MS excel and analysed using the GENSTAT. Sensory evaluation data were analyzed using logistic regression.

III. Results

The growth vigour performance of the varieties showed significant variation among varieties and seasons. Plant vigour was generally low ranging between 0.8 in NASPOT 5 and NASPOT 10 for season 2010A and 4.1 in NASPOT 1 for season 2010B. Across the three seasons grown, NASPOT 5 had the least (1.4) mean vigour while the local check Nderera had the highest (3.1) mean vigour. Among the biofortified varieties, Jewel showed the highest vigour (2.5) followed by NASPOT 1 (2.4), across the three growing seasons (Table 2).

Table 2 : Evaluation of plant growth vigour of 12 sweet potato varieties (scale of 1-5)

Variety	2010A	2010B	2011A	Average
NASPOT5	0.8	1.9	1.5	1.4
NASPOT8	0.9	2.9	1.9	1.9
Jewel	1.1	3.9	2.5	2.5
NASPOT9	0.8	3.6	1.6	2.0
Tanzania	1.1	2.8	1.8	1.9
NASPOT1	1.2	4.1	1.9	2.4
Kakamega	0.9	2.4	1.5	1.6
Ejumula	1.1	2.9	1.6	1.9
NASPOT10	0.8	3.3	1.3	1.8
NKA 108L	0.9	3.4	2.4	2.3
NASPOT7	1.1	2.9	1.8	1.9
Nderera	-	3.7	2.4	3.1
Mean	*1.0*	*3.0*	*1.8*	*2.0*
LSD (P≤0.05)	*0.3*	*1.2*	*0.8*	*0.2*

Viral disease incidence varied among the seasons and varieties. Season 2011A had the highest virus incidence with mean viral disease incidence of 5.1% while season 2010A had least disease incidence (1.9%). Among the varieties and across the three growing seasons, Tanzania had the highest mean viral incidence (8.3%) while Nderera (local variety) and NKA 108L had least (1.5%) mean viral incidence (Table 3). Generally, viral incidence was very low among the varieties across the three growing seasons.

Table 3 : Assessment of viral disease incidence (percent incidence) on 12 sweet potato varieties evaluated in SWAEZ in 2010 2011

Variety	2010A	2010B	2011A	Average
NASPOT 8	2.8	5.1	4.6	4.2
Jewel	1.0	3.2	3.9	2.7
NASPOT 9	0.0	4.2	5.6	3.3
Tanzania	6.9	7.9	10.0	8.3
NASPOT 1	0.0	5.0	4.4	3.1
Kakamega	3.5	6.0	3.9	4.5
Ejumula	5.3	6.9	4.4	5.5
NASPOT 10	0.0	3.2	7.8	3.7
NASPOT 5	1.4	5.6	8.9	5.3
NKA 108L	0.0	2.3	2.2	1.5
NASPOT 7	0.0	6.5	4.4	3.6
Nderera	-	2.3	0.6	1.5
Average	*1.9*	*4.9*	*5.1*	*3.9*
LSD (P≤0.05)	*7.4*	*10.5*	*6.3*	*8.1*

The highest mean total root tuber yield across all the varieties was recorded in Season 2010B (21.7 t/ha) and was least in season 2010A (13.6 t/ha). Across the three growing seasons, the results showed that the highest tuber yield (22.6 t/ha) was recorded by variety Ejumula and was least (11.5 t/ha) in NASPOT 5 (Table 4).

Table 4 : Total root tuber yield (t/ha) of 12 sweet potato varieties at MBAZARDI during 2010 and 2011

Variety	2010A	2010B	2011A	Average
NASPOT 5	13.9	8.6	13.9	12.1
NASPOT 8	12.9	24.4	18.3	18.5
Jewel	3.8	23.3	14.2	13.8
NASPOT 9	14.6	22.2	18.3	18.4
Tanzania	7.7	16.1	10.4	11.4
NASPOT 1	15.6	30.6	9.4	18.5
Kakamega	8.3	14.7	11.6	11.5
Ejumula	25.2	24.7	17.8	22.6
NASPOT 10	16.3	24.7	13.9	18.3
NKA 108L	16.7	15.8	10.9	14.5
NASPOT 7	15	25.6	20.4	20.3
Nderera	-	29.4	13.1	21.3
Average	*13.6*	*21.7*	*14.4*	*16.8*
LSD (P≤0.05)	*6.8*	*9.1*	*8.6*	*8.5*
CV %	*16.5*	*28.4*	*37.1*	*27.3*

Although Ejumula recorded the highest total tuber yield (22.6 t/ha) across the seasons, its marketable tuber yield was low (10.1 t/ha) (Table 5). The highest marketable tuber yield was recorded in Nderera (14.8 t/ha) followed by NASPOT 7 (13.1 t/ha) and NASPOT 8 (12.9 t/ha). The least marketable yield was still recorded in Tanzania with 4.6 t/ha (Table 5).

Table 5 : Marketable root tuber yield (t/ha) of 12 sweet potato varieties at MBAZARDI during 2010 and 2011

Variety	2010A	2010B	2011A	Average
NASPOT 5	8.3	5.6	1.7	5.2
NASPOT 8	6.3	19.2	13.3	12.9
Jewel	1.8	19.7	10.3	10.6
NASPOT 9	8.1	11.1	10.3	9.8
Tanzania	2.5	7.8	3.6	4.6
NASPOT 1	7.5	22.2	5.3	11.7
Kakamega	4.4	8.6	8.2	7.1
Ejumula	13.1	10.3	6.9	10.1
NASPOT 10	9	11.4	8.3	9.6
NKA 108L	12.7	12.5	8.3	11.2
NASPOT 7	4.6	18.9	15.9	13.1
Nderera	-	21.4	8.1	14.8
Average	*7.1*	*14.1*	*8.4*	*10.1*
LSD (P≤0.05)	*3.9*	*11.8*	*7.4*	*7.7*

Generally, all 12 varieties evaluated scored highly in most palatability and sensory attributes. The control variety Nderera had the highest preferences among the farmers with average score of 4.1 followed by Tanzania (3.6). Other than NKA 108L which had a score of less than 3 (Table 6), the rest had preferred traits including size, shape and texture.

Table 6 : Sensory comparison of 12 sweet potato varieties using matrix scores (1-5) in Masha and Birere sub-counties in Insigiro district during 2011B season

Variety	*Flesh colour*	*Matrix score before pealing*			*Matrix score after pealing*				*Matrix score after cooking*				
		CO	*SI*	*SH*	*CO*	*TA*	*FL*	*TX*	*CO*	*TA*	*FL*	*TX*	*Average*
NASPOT 8	*Orange*	*3.6*	*3.8*	*3.7*	*2.9*	*3.3*	*2.7*	*3.7*	*3.1*	*3.3*	*3.1*	*3.2*	*3.2*
Jewel	*Cream*	*3.4*	*3.4*	*3.6*	*3.5*	*3.6*	*4.3*	*3.7*	*3.1*	*3.2*	*3.1*	*3.2*	*3.2*
NASPOT 9	*Orange*	*3.2*	*3.3*	*3.0*	*3.3*	*2.7*	*4.0*	*2.3*	*3.9*	*3.1*	*2.8*	*3.2*	*3.3*
Kakamega	*Orange*	*3.4*	*3.0*	*3.2*	*3.3*	*3.1*	*2.7*	*1.3*	*3.2*	*3.3*	*2.6*	*2.8*	*3.0*
NASPOT 10	*Orange*	*3.4*	*3.8*	*3.5*	*3.2*	*2.7*	*3.0*	*3.7*	*3.6*	*3.2*	*3.4*	*3.4*	*3.4*
NASPOT 5	*Orange*	*3.5*	*3.2*	*3.4*	*3.6*	*3.7*	*3.7*	*2.7*	*3.0*	*2.8*	*2.6*	*3.5*	*3.0*
NKA 108L	*Orange*	*5.0*	*4.2*	*4.1*	*3.3*	*3.0*	*4.3*	*2.7*	*3.4*	*1.9*	*2.2*	*3.5*	*2.8*
Ejumula	*Orange*	*3.0*	*3.5*	*3.6*	*3.2*	*3.0*	*3.3*	*3.0*	*3.3*	*3.3*	*3.0*	*2.7*	*3.1*
Tanzania	*White*	*3.7*	*3.2*	*3.1*	*3.4*	*3.7*	*3.3*	*4.3*	*3.6*	*3.9*	*3.4*	*3.4*	*3.6*
NASPOT 1	*Orange*	*3.3*	*2.9*	*3.2*	*3.1*	*3.3*	*3.3*	*3.3*	*3.3*	*3.4*	*3.4*	*2.6*	*3.2*
NASPOT 7	*Orange*	*3.7*	*4.0*	*3.6*	*3.5*	*3.2*	*4.0*	*2.7*	*3.6*	*3.5*	*3.4*	*3.5*	*3.5*
Nderera	*White*	*4.2*	*3.9*	*4.2*	*4.0*	*3.7*	*2.7*	*3.5*	*4.1*	*4.3*	*3.9*	*3.9*	*4.1*
LSD ($P \leq 0.05$)	-	*0.6*	*0.5*	*0.5*	*0.6*	*NS*	*NS*	*NS*	*0.8*	*0.9*	*1.0*	*0.9*	-
CV (%)	-	*30.4*	*26.5*	*28.8*	*35.1*	*37.4*	*37.3*	*41.4*	*32.4*	*36.0*	*39.7*	*37.0*	-

CO=colour, SH=shape, SI=size, TA=taste, FL=flavour, TX=texture

IV. Discussion

Generally, all the varieties had low growth vigour during the three growing seasons. During the three growing seasons, there was prolonged drought spell. This could have resulted in the general low vigour among the varieties. The low vigour can also be attributed to genetic makeup of the biofortified varieties since the local variety had higher vigour than all of them. On the other hand, all varieties expressed high viral disease tolerance. Though the viruses have not been reported as major production constraint in the South Western agro-ecological zone, its management is paramount for expression of varieties' yield potential. However, all varieties were severely infested with weevils (data not shown) reducing the marketable yield. Weevils have been reported as the major constraint to sweet potato production with no resistant varieties available all over the world to date (Mwanga et al., 2009).

The biofortified sweet potato varieties evaluated recorded high yields and were preferred by farmers and other stakeholders. Their inclusion in the current germplasm grown in the region enriches the region's diversity of sweet potatoes from which selection can take place. Although Nderera, the local variety reported to have high dry matter preferred by farmers its acceptability level was not significantly different from that of biofortified orange fleshed varieties. Farmers should therefore be encouraged to grow orange flesh sweet potato and its consumption promoted since it is enriched with Pro-Vitamin A (beta carotene). It has been reported that some orange fleshed sweet potatoes have high beta-carotene content of up to 27,698 μg of retinol equivalents (RE) per 100 g fresh weight (Mwanga et al., 2007). South Western Agro-ecological zone is dominated by banana growing which is mainly carbohydrates and therefore increased consumption of orange fleshed sweet potato varieties rich in pro-Vitamin A and C would supplement the diet and reduce Vitamin A deficiencies common in the zone. Vitamin A deficiency (VAD) continues to be a public health concern in developing countries among children and women of childbearing age and is estimated to account for >600,000 deaths each year globally among children <5 y of age (Black, 2008; WHO, 2009).

The yield of the biofortified varieties was generally lower compared to earlier reports during their release (Mwanga *et al.,* 2001; 2003; 2007; 2009). This is attributed to differences in the agro-ecological conditions since these were different from the site where they were evaluated during their release. Moreover, they were affected by weevils, viral diseases and prolonged drought. Mwanga *et al* (2009) reported that sweet potato varieties NASPOT 7, NASPOT 8, NASPOT 9 and NASPOT 10 had significantly different yields at different sites and different years using five sites in Uganda. This is an indication that the yield stability of these varieties is low. In the definition of Shukla (1972), a stable variety is a variety in which yield varies relatively little around the average yield for that variety, after correction for the average differences that will always exist between environments. All the varieties were sensitive to seasonal conditions. This observation is in agreement with previous studies (Carpena *et al.* 1982, Janssens 1984, Bacusmo *et al.* 1988). Seasonal yield variations were highest in NASPOT 5. Manrique and Hermann (2002) reported that none of cultivars used in their study had satisfactory stability for total root yield and suggested the need for further study to elucidate the nature of sweet potato root-yield performance in response to varying agro-ecological conditions. Nevertheless, the varieties evaluated in this study had higher yields compared to the national average of 4 t/ha (International potato centre, 1999) and comparable yields to previously reported (Mwanga *et al.,* 2001; 2003; 2007; 2009). Although, the local variety yielded better than most biofortified varieties, it had one of the highest yield losses due to weevils implying that biofortified varieties were still more beneficial to farmers.

Contrary to the previous belief that orange-flesh sweet potatoes are not preferred by farmers due to; their very softness, low dry matter (Mwanga *et al.,* 2001), flat taste or no taste, very small size and bad flavour, there was no evidence to this during the study. Both white and cream skin flesh coloured varieties such as Nderera, Jewel and Tanzania and orange flesh varieties such as NASPOT 10, NASPOT 7 and NASPOT 1 were preferred. The only less preferred variety was NKA 108L, the rest were not significantly different in their preference attributes from the local variety. Since orange-flesh sweet potato varieties are rich in B-carotene, the precursor for Vitamin A, they can be promoted to areas were Vitamin A deficiency symptoms are prevalent. Previous studies have shown that *Beta-carotene* rich orange potatoes increased vitamin A intake among children and women of Uganda, and was associated with improved vitamin A status among children (Hotz *et al.,* 2012).

V. Conclusion and Recommendations

Given the fact most local white flesh sweet potato varieties are vitamin A defficient, the biofortified vitamin A rich sweet potato varieties are more beneficial to rural consumers whose intake of vitamin A is limited. NASPOT 1, NASPOT 7, NASPOT 8, NASPOT 9 and NASPOT 10 were all well accepted by farmers and are also high yielding. They also showed high level of virus disease tolerance. They are therefore, recommended for promotion in the South Western Agro-Ecological Zones (SWAEZ) to reduce vitamin A deficiency. A research study to determine IPM technologies for controlling weevils should be developed improve the production of these biofortified varieties

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Technical Efficiency Analysis of Tea Production in the Northern Mountainous Region of Vietnam

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Nguyen Bich Hong [α] & Mitsuyasu Yabe [σ]

Abstract- A stochastic frontier production function is used to investigate the prospect to bring tea production efficiency in the Northern mountainous region of Vietnam to higher level using a cross-section data set of 258 randomly selected farms in 2013. Research results revealed that the average output of tea farms could increase by 10.4 percent by properly using the existing technology. The technical efficiency of the sample tea farms range from 62.1 percent to 97.2 percent (average 89.6). The variables such as: pesticide, labor, and capital negatively affected tea yield. However, irrigation water and types of chemical fertilizers such as: nitrogen, phosphorous, and npk showed a positive relationship with tea yield. The study demonstrated that important factors having positive impact on technical efficiency level of tea production are applying soil and water conservation technology, accessing extension services, joining cooperatives, and gender.

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I. Introduction

Tea has a long history in Vietnam and has been cultivated and drunk there for thousands of years. Today, Vietnam is the fifth largest tea exporter in the world. Tea is grown in 39 of 64 Vietnamese provinces. The best quality products are achieved in the North area. Tea production is an important source of income. In 2012, total exported tea reached 146,700 tons and grossed 224.6 million dollars (Vietnam Tea Association 2012). Furthermore, tea production also plays an important role in generating employment. With 400,000 small households engaged in cultivation and process, tea industry created over 1.5 million jobs (Vietnam General Statistic Office, 2008). Tea is one of the five important agricultural products in Vietnam.

The Northern mountainous region, with its mountainous topography and temperate climate, is one of the main tea cultivation areas in Vietnam. It has a total of 93,000 ha under tea, accounting for 71.6 percent of the total cultivation area in Vietnam, and 64.7 percent of the country's total tea output (Vietnam General Statistic Office 2013). Tea is the largest cash crop in the region and provides income for many small households. Therefore, boosting tea production in the Northern mountainous area is expected to motivate the region's economic growth and have a positive impact on livelihood of small households.

However, Vietnamese tea production is faced with many challenges. Vietnam remains a small player in the world tea market. In 2011, Vietnamese tea production accounted for 7 percent of global tea market, much lower than China (16 percent), India (16 percent), Sri Lanka (16 percent), and Kenya (15 percent) (Potts *et al*. 2014). As Vietnam continues its drive onward into twenty-first century tea production, it is increasingly forced to compete with those top producers, many of which are achieving comparatively higher yield and more efficient production. Therefore, Vietnamese tea industry should increase production efficiency to improve its competitive edge in foreign tea markets.

Many researchers and policy makers have focused their attention on the impact that adoption of new technologies can increase farm productivity and income (Hayami and Ruttan 1985). In Vietnam, considerable work is being done to improve technology and yield in tea production. However, the implementation of these practices is lagging (Wenner. R 2011). In fact, the majority of Vietnamese tea production is done by small households who often lack money or interest in the implementation of new technology. Thus, in short run, Vietnamese tea productivity should be increased by using the existing production technology. The efficient use of existing input resources can result in a cost- effective way to increase the productivity of tea production. In designing appropriate policy measures to enable Vietnamese tea farms to increase productivity through improved efficiency, it may be useful to measure farm level technical efficiency and its determinants. Such a statement begs these questions: (1) Are tea farmers in Vietnam using their input efficiently? (2) Which factors affect the technical efficiency of tea production?

The main objective of this study is to assess whether or not the current technologies are efficient for the tea farmers in the Northern mountainous region of Vietnam. The study first analyzed the technical efficiency level of tea farmers using stochastic frontier analysis and then determined factors influencing the technical efficiency of tea farmers with two-limit Tobit regression model.

Although tea is a very promising crop not only for farmers' income but also national economy, until now there has been no obvious research concerned with the

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farm level technical efficiency and its determinants of tea production in Vietnam. This study also aims to fulfill the knowledge gap in this area.

The first section of this paper provides information on the current situation of Vietnamese tea production while the second section is analytical framework for measuring technical efficiency. In the third section, the detailed description of data and empirical model is presented. The forth section is the estimated results while the fifth section is discussion from model estimation. Some concluding remarks and recommendations are drawn in the final section.

II. Analytical Framework for Measuring Technical Efficiency

Economic efficiency takes on to increase output without using more conventional inputs. As farmers cultivate their crops with the existing technology inefficiently, applying new technologies results in less cost-effective than using the existing technology (Bellbase and Grabowki 1985; Shapiro 1977). Economic efficiency can be classified in two parts: technical efficiency and allocative efficiency. Technical efficiency measures the ability of a farmer to achievethe maximum output with given and obtainable technology, while allocative tries to capture farmers' ability to apply inputs in optimal proportions with respective prices (Farrell 1957; Coelli *et al.* 2005).

Measuring technical efficiency is to use inputs and output quantity without introducing their prices. Technical efficiency can be decomposed into three components such as: scale efficiency (the potential productivity gain from achieving optimal size of a firm), congestion (increase in some inputs could decrease output) and pure technical efficiency (Farrell 1957).

There are two methods widely used in the literature to estimate technical efficiency. The first one is an econometric approach - Stochastic Frontier Analysis (SFA) that simultaneously introduced by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977). The second one is non- parametric approach or mathematical programming - Data Envelopment Analysis (DEA). Two methods have partial strength and weakness. The econometric method is stochastic and parametric. It distinguishes the effects of noise with the effects of inefficiency and confound the effect of misspecification of functional form with inefficiency, but it generates good results for models that are single output and multiple inputs. Conversely, the mathematical programming approach is not stochastic and not parametric. It cannot separate the effects of noise and the effects of inefficiency during the calculation of technical efficiency, and it less sensitive to the type of specification error (Kebede 2001). Its advantage is that multiple inputs and output can be considered simultaneously, and inputs and outputs can be quantified using different units of measurement.

Since tea production in Vietnam is an example of single output and multiple-input production, this study focuses on the use of an econometric approach for measuring technical efficiency based on the production frontier model. A production frontier model can be written as:

$$Y_i = f\left(X_{ij}\,; \beta\right) + \varepsilon_i \qquad (1)$$

Where Y_i is output of the *i*farms, X_{ij} is a vector of inputs used by farm *i*, and ε_i is a "composed" error term. The error term ε_i is equal to $v_i - u_i$.The term v_i is a two-sided ($-\infty < v_i < \infty$) normally distributed random error ($v \sim N[0, \sigma_v^2]$) that represents the stochastic effects outside the farmer's control (e.g., weather; natural disasters, and luck), measurement errors, and other statistical noise. The term u_i is a one-sided ($u_i \geq 0$) efficiency component that represents the technical inefficiency of farm (Coelli *et al.* 2005). The distribution of term u_i can be half-normal, exponential or gamma (Aigner *et al* 1977; Meeusen and Broeek 1977). The assumption of term u_i in the study is half-normal distribution ($u \sim N[0, \sigma_u^2]$) mainly used in the other studies. The two components v_i and u_i are also assumed to be independent together.

Equation (1) estimated by the maximum likelihood analysis creates consistent estimators for β, λ, andσ where β is a vector of unknown parameters, $\lambda = \sigma_u/\sigma_v$,$\sigma^2 = \sigma_u^2 + \sigma_v^2$.

According to Battese and Corra (1977), the ratio variance parameter γ which relates to the variability of u_i to total variability σ^2 can calculated in the following manner:

$$\gamma = \sigma_u^2/\sigma^2 \qquad (2)$$

So that $0 \leq \gamma \leq 1$

If the value of γ is equal to zero, the difference between actual farmer yield and the efficient yield is entirely due to statistical noise. On the other hand, a value of one would indicate the difference attributed to the farmers' less than efficient use of technology i.e. technical inefficiency (Coelli *et al.* 2005).

The technical inefficiency of individual farms can be estimated by using conditional distribution of u_i given the fitted values of ε and respective parameters (Jondrow *et al.* 1982). If we assume that v_i and u_i are independent each other, the conditional mean of u_i given ε is identified by:

$$E(u_i|\varepsilon_i) = \sigma^* \left[\frac{f^*(\varepsilon_i\lambda/\sigma)}{1-F^*(\varepsilon_i\lambda/\sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \qquad (3)$$

Where: $\sigma^{*2} = \sigma_u^2\sigma_v^2 \,/\, \sigma^2$, f^* is the standard normal density function, and F^* is the distribution function, both functions being estimated at $\varepsilon\lambda/\sigma$.

With the assumption of half-normal model, a simple z-test will be used for examining the existence of technical inefficiency, the null and alternative hypotheses are: H_0: $\lambda = 0$ and H_1: $\lambda > 0$ (Coelli *et al.* 2005). The test statistic is:

$$z = \frac{\tilde{\lambda}}{se(\tilde{\lambda})} \sim N(0,1) \quad (4)$$

: $\tilde{\lambda}$ is the maximum likelihood estimator of λ and $se(\widetilde{\lambda})$ is the estimator for its standard error.

The technical efficiency of farm will be determined by using the following equation:

$$TE_i = exp(-\hat{u}_i) = exp(-E(u_i|\varepsilon_i)) \quad (5)$$

The *TE* score is between zero and 1. A farm is fully efficient if it equals to 1 and fully inefficient if its value is zero.

To investigate the relationship between farms' technical efficiency and various farmers' socio-economic factors and specific farm characteristics, a two-limit Tobit regression model was applied as the second step analysis because the efficiency scores from stochastic frontier analysis are limited between 0 and 1 (Bravo-Ureta and Pinheriro 1997; Binam *et al.* 2003; Khai *et al.* 2008; Nyagaka *et al.* 2010). Therefore, a Tobit regression model was used in this study. According to Tobin (1958), a Tobit regression model can be specified in the following form:

$$TE_i = \delta_0 + \sum_i \delta_i W_i + e_i$$

Where: TE_i is the technical efficiency scores of each farm obtained from the function (4) as dependent a variable, W_i is the variables representing socio-economic characteristics of farmers and farms, δ_i is a vector of unknown parameters to be estimated, and e_i is error term that represents other factors outside model.

The maximum-likelihood estimates of parameters of function (1), the farm-level TE in function (4), and Tobit regression estimates in formula (5) are achieved by using STATA version 13 software.

III. Research Area, Empirical Model and Data

a) Research area

Thai Nguyen is a province in the Northern mountainous region of Vietnam. With 18,000 ha of tea trees, Thai Nguyen is the second largest tea plantation area in Vietnam. However, it is the largest province in tea production with about 172,000 tons per year (Vietnamese General Statistic Office, 2011). The suitable natural conditions and temperate climate make Thai Nguyen tea have the finest quality throughout Vietnam. Therefore, this research was conducted in Thai Nguyen province. Four representative communes of two famous tea-producing districts (Dong Hy district and Thai Nguyen city) in Thai Nguyen province were chosen for the survey. The selected tea farms are representative of topographical conditions in tea production areas of Thai Nguyen province.

Tan Cuong and PhucXuan commune are administratively in the Thai Nguyen City. Tan Cuong is the most well-known for having the highest tea quality in Vietnam. Most of the tea farms are situated along the sides of the Cong river where fields are flatter (with 20% slope). Whereas, in the PhucXuan commune, tea is grown on hillsides and uplands.

Two communes, Minh Lap and Song Cau, are in Dong Hy district. Minh Lap commune is located about 24 km east of Thai Nguyen town (the center of Thai Nguyen city) and borders the sides of the Cau river. Most of the tea farms in the Minh Lap commune are on uplands and hillsides with slopes ranging from 15% to 30%. The Song Cau commune, on the other hand, is located in the Northeast and about 20 km from the Thai Nguyen town.Tea farms in the Song Cau commune are similar to those in the Minh Lap.

The primary data for this study were collected in a field survey through direct interview with tea farmers from April to December 2013 by a group of enumerators. A pre-test was made to revise the questionnaire before the formal survey. A total of 258 tea growers were selected following a random sampling procedure.

The questionnaire in this study was structured to get responses from the selected tea farmers on their farming activities. An attempt was made to collect information on inputs and cost used for tea production as well as tea outputs. Socio-economic data of the farmers and tea farms' characteristics such as age, gender, level of education, ethnicity, farming experience, participation in cooperative, household size, farm size, agricultural income, off-farm income, tea age, slope, number of methods to control erosion and conserve water resource and accessing extension services were also collected. This is expected to increase the explanatory power of the analysis significantly.

b) Empirical model

There are several functional forms for estimating the physical relationship between inputs and output. According to Hanley and Spash (1993), Cobb-Douglas functional form is more popularly applied than other forms, if there are three or more independent variables in the model. Therefore, in this study, Cobb-Douglas production function with ten independent variables was applied. The study normalized the data set by dividing output and inputs by land input variable, resulting in dropping this variable in the regression model. The Cobb-Douglas stochastic frontier function was written as:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{10} \beta_{ij} \ln X_{ij} + v_i - u_i$$

Where: $Y_i$is fresh tea yield (kg/ha);

X_{ij} is the ten used inputs including: *Nitrogen fertilizer(kg/ha), Phosphorous fertilizer (kg/ha), Potash fertilizer (kg/ha), NPK fertilizer (kg/ha), Animal fertilizer (kg/ha), Pesticide (liter/ha), Labor used for tea production (man-day/ha), Irrigation water used for tea production (m³/ha), Capital (Values of machineries and tools for tea production were calculated in Vietnamese currency - thousand VND/ha), and Other cost (calculated in Vietnamese currency - thousand VND/ha).*

v_i is a two-sided ($-\infty < v_i < \infty$) normally distributed random error thatrepresents the stochastic effects outside the *i* farmer's control;

$u_i$is a one-sided ($u_i \geq 0$) efficiency component that represents the technical inefficiency of the *i* farm.

In the second step, theTobit regression function with a dependent variable of technical efficiency and fifteen independent variables are estimated to determine factors affectingtechnical efficiency of Vietnamese tea production. The regression function is given by:

$$TE_i = \delta_0 + \sum_{k=1}^{15} \delta_k W_{ik} + e_i$$

Where: TE_i is the level of technical efficiency; W_{ik} is the variables representing socio-economic characteristics of farmers and tea farms to explain technical efficiency: *Age* (the age of household head (years)) (*k=1*), *Gender* (gender of household head (dummy variable,1= male, 0=female) (*k=2*), *Education* (the number of completed years of schooling of household head) *(k=3)*, *Household size* (the number of family members in persons) *(k=4)*, *Ethnicity* (ethnicity of household head (dummy variable,1=*Kinh* ethnicity, 0= Otherwise) *(k=5)*, *Experience* (the number of tea growing years) *(k=6)*, *Tea age* (the age of tea tree in years) *(k=7)*, *Slope* (slope of tea farms, degree) *(k=8)*, *Soil and water conservation* (SWC) (dummy variable is used to capture whether farmer applied any SWC technologies on their fields such as : barrier to water movement, soil bund, stone bund, contour ridge, hedge grow, planting tree, grass trip, and digging hole to store rainwater, 1= farmer employed SWC technology, 0=otherwise) *(k=9)*, *Farm value* in natural log (the total value of agricultural products gained by farmers) *(k=10)*, *Non-agri. Income share* (proportion of total farmer's income from non-agricultural sources) *(k=11)*, *Labor-land ratio* (Ratio of labor to land) *(k=12)*, *Extension* (dummy variable, 1 = access to extension service, 0= otherwise) *(k=13)*, *Cooperative* (dummy variable, 1= farmer joining in cooperative, 0=otherwise) *(k=14)*; *Farm size* (ha) *(k=15)*.

e_i is error term that represents other factors outside model.

c) Data

Table 1 presents the descriptive statistics of some important variables applied in stochastic frontier production model and some specific farm characteristics.

The results show that the average tea yield was approximately 35,351.16 kilograms, with a range of 4,350 kilograms to 57,870 kilograms, and the standard deviation among yield levels was 16,883.99 kilograms. The large variability in standard deviation revealed that the sample farmers used inputs in different ways, which tended to affect their yield levels. Fertilizer is an important input to increase the productivity of tea. It was found that the major components of fertilizer used in tea farms were nitrogen, phosphorous, potash, and animal fertilizer. There was a high variation in the amount of fertilizer application per farm. Some farmers did not apply some kind of fertilizers, while others used significant amount. The average use of pesticide is approximately 67.43 liters per hectare, with a range from 0 liter to 216 liters, representing a large variability among farms. This variability may depend on farm size and farmers` attitude and preference regarding to pesticide application. The average utilization human labor per hectare including hired and family labors was approximately 1,647.5 man-days with the minimum at 332 man-days and the maximum at 3,554.5 man-days, indicating that farming activities are highly labor intensive.The average of irrigation water per hectare was between 1000 m^3 and 14,114 m^3 with a mean of 5,595.53 m^3, suggesting a wide range variation among farms.

The average education level is around 10 years, suggesting that most of tea farmers graduated secondary school in Vietnamese education system. The results also shows that farmers have much experience on tea cultivation with the mean nearly 22 years. The average area of tea farmer is around 0.26 ha with a range of 0.05 ha to 0.60 ha, suggesting the big variability of sizes among tea farmers in Vietnam. The results reveals that tea farmers in the Northern mountainous region of Vietnam have basic education leveland much experience in tea production, but have small-scale tea farming. The mean tea age in the sample is quite young (around 15 years). According to Do and Le (2000), the most productive period of the tea age's life is from 10 to 30 years old. The tea age in the sample had stands ranging from 8-36 years old suggesting that most survey tea farms are in the most productive period. The total value of farming that farmers earn from agricultural activities is averagely 77,193.16 thousand VND per hectare, while the average of off-farm income is 0.08. This suggests that tea production brings major income for farmers in the region.

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Table 1 : Description of Variables

Descriptive of variables	Mean	Std. Dev	Min	Max
Tea production characteristics				
Fresh tea yield (kg/ha)	35,351.16	16,883.99	4,350.00	57,870.00
Nitrogen fertilizer (kg/ha)	1,104.50	773.84	0	3,226.50
Phosphorous fertilizer (kg/ha)	2,718.73	2,990.27	0	10,000.00
Potash fertilizer (kg/ha)	212.48	267.94	0	967.50
NPK fertilizer (kg/ha)	2,025.38	2,335.61	0	9,260.00
Animal fertilizer (kg/ha)	4,688.76	6,828.95	0	20,750.00
Pesticide (liter/ha)	67.43	58.39	0	216.00
Labor (man-day/ha)	1,647.50	855.32	332.00	3,554.50
Irrigation water (m^3/ha)	5,595.53	4,051.05	1,000.00	14,114.00
Other cost (thousand VND/ha)	4,776,16	6,671.50	0	17,640.00
Capital (thousand VND/ha)	4,404.04	4,027.85	0	13,261.50
Household head characteristics				
Age (years)				
Education (years)	10.09	2.28	5.00	18.00
Experience (years)	21.86	8.77	5.00	50.00
Tea farm characteristics				
Farm size (ha)	0.26	0.14	0.05	0.60
Tea age (years)	14.79	7.77	3.00	36.00
Farm value (thousand VND/ha)	77,193.16	36,960.03	4,500.00	352,000.00
Non-agricultural income share	0.08	0.13	0	0.59

Note: a man-day unit = 8 working hours of an adult
Source: Author's estimation

IV. Estimated Results

a) Stochastic frontier production model

In order to control for data reliability and validity, measurement and sampling errors and obtaining unbiased estimates, a number of tests were used. The Variance Inflation Factor (VIF)) procedure applied to detect multicollinearity and was preferred over the correlation coefficient method which fails to yield conclusive results (Pindyck and Rubinfield 1981). If the VIF is greater than 10, then there is a potential multicollinearity problem (Neter *et al.* 1989). No serious multicollinearity problem among variables in the sample were detected by the VIF test. All independent variables had VIF less than 10, and the mean VIF was 2.71.

Table 2 : OLS and stochastic frontier production estimates

Variables	OLS		Stochastic frontier	
	Coefficients	t- value	Coefficients	z-value
Nitrogen fertilizer	0.0950***	14.74	0.0936***	14.92
Phosphorous fertilizer	0.0074***	2.81	0.0077***	3.01
Potash fertilizer	-0.0012	-0.35	-0.0008	-0.25
NPK fertilizer	0.0724***	11.02	0.0688***	10.52
Animal fertilizer	0.0028	1.26	0.0034	1.58
Pesticide	-0.0345***	-3.36	-0.0355***	-3.85
Labor	-0.0865***	-4.06	-0.0946***	-4.41
Irrigation water	0.1883***	5.49	0.1944***	5.97
Capital	-0.0104***	-3.39	-0.0101***	-3.42
Other cost	-0.0036	-0.64	-0.0030	-0.55
Constant	8.5852***	31.63	8.7249***	33.04
Function of coefficient©	0.2297			
R^2	0.9494			
F-statistic***	463.2400			
F- critical value	2.3930			
σ_v			0.1216	
σ_u			0.1434	
σ^2			0.0354	
$\lambda = \sigma_u/\sigma_v$			1.1179	
$\gamma = \sigma_u^2/\sigma^2$			0.5809	
$se(\tilde{\lambda})$			0.0462	

*Note: *** indicate statistical significance of the 0.01 level, © indicate the sum of estimated coefficients*
Source: Author's estimation

The OLS estimate for choosing the relevant variables and stochastic frontier production for estimating technical efficiency are shown in Table 2. The coefficient R^2 is equal to 0.9494, showing that around 94.94 percent of the dependent variable is explained by independent variables in the OLS model.

The presence or absence of technical inefficiency was tested in the study using *z* test. The null hypothesis is that there is no inefficiency effect in the model. The estimation result from function (3) shows that $z_{statistic} = \frac{\tilde{\lambda}}{se(\tilde{\lambda})} = \frac{1.1179}{0.0462} = 24.20$. At the significance of 0.01 level, the critical value $z_{\alpha/2} = 2.58.$ The calculated value $z_{statistic}$ is greater than $z_{critical\ value}$. Therefore, the null hypothesis was rejected at 0.01 level, suggesting the presence of technical inefficiency effect for tea farmers in the Northern mountainous region of Vietnam. Gamma (γ) is equal to 0.5809, which means that 58.09 %of the total variation of output levels is due to technical inefficiency.

A check for evidence of constant returns to scale among the sample implemented using F test. The restricted squares regression with the null hypothesis of constant return to scale was estimated. The computed F statistic of 581.44 was larger than the critical value F at the 1 percent level of significance. Thus, the null hypothesis is rejected and the study concluded that technology does not exhibit constant return to scale. In addition, the sum of the elasticity of all inputs was 0.2297. It shows that the possibility of Vietnamese farmers decrease returns to scale in tea production. Decreasing returns to scale suggests that increasing all inputs by a given proportion leads to a less than proportionate increase in output.

The results show that the coefficients estimated in models were statistically significant at 0.01 level. As this study used Cobb-Douglas production frontier function, the coefficient value of the variables can be used as direct elasticity of the function. The elasticity of independent variables represents how proportion changes in fresh tea yield if the inputs change in the production process. It can be seen from Table 2 that input variables such as: *Nitrogen fertilizer, Phosphorous fertilizer, NPK fertilizer,* and *Irrigation water* had significant positive impact on tea yield. The elasticity of *Irrigation water* (0.1883) was highest. This implies that for tea farmers 1 percent increase in irrigation water will lead to 0.1883 percent increase in fresh tea yield. The positive coefficients of *Nitrogen fertilizer* (0.0936), *Phosphorous fertilizer* (0.0077) and *NPK fertilizer* (0.0688) indicate that one percent increase in the amount of each kind of these fertilizers will lead to the increase in tea yield by 0.0936 percent, 0.0077 percent, and 0.0688 percent, respectively. Conversely, factors such as *Pesticide, Labor*, and *Capital* had negative effects on tea yield. The *Pesticide, Labor*, and *Capital* had partial output elasticity of about -0.0355, -0.0946, and -0.0104.This implies that 1 percent increase in *Pesticide, Labor*, and *Capital* will lead to a fall in tea yield by 0.0355 percent, 0.0946 percent, and 0.0104 percent.

b) Frequency distribution of Technical efficiency

Based on the estimation of the production frontier function, the frequency distribution of the technical efficiency of tea farming is presented in Table 3.

Table 3 : Frequency distribution of technical efficiency for tea farming

Efficiency level (%)	Frequency	Relative frequency (%)
≤50	0	0.00
>50≤60	0	0.00
>60≤70	2	0.78
>70≤80	5	1.94
>80≤90	107	41.47
>90≤ 100	144	55.81
Total	258	100
Minimum (%)	62.1	
Maximum(%)	97.2	
Mean (%)	89.6	

Source: Author's estimation

The technical efficieny (TE) of Vietnamese tea farmers ranges from 62.1 percent to 97.2 percent, with an average of 89.6 percent, suggesting that there was significant variation in technical efficiency among tea farmers. The highest frequency range of TE more than 90 percent comprises 144 farms, which is 55.81 percent of the total. None of farms have TE score lower than 60 percent, indicating that most tea farms in the North region achieve rather high technical efficiency in production. The results also show that the average technically efficienct farmers could reduce their cost by 8 percent [{1-(89.6/97.2)}*100] (Bravo-Ureta and Pinheiro 1997) if they could achieve maximum level of technical efficiency. Similarly, the most technically inefficient farmers could enjoy 36 percent cost savings [{1-(62.1/97.2)}*100] if they achieve the most technical efficient counterparts.

c) Efficiency effects model

To analyze which factors could have an impact on the tea production's technical efficiency, the Tobit model is applied with TE as a dependent variable and some key socio-economic independent variables presented in the equation (8), instead of the OLS estimate producing biased results, often toward to zero (Bravo-Ureta and Pinheiro 1997).

Table 4 : Two-limit Tobit estimates of the sources of technical efficiency

Variables	Explanation	Coefficient	t-value
Age	Household head age (years)	0.0001	0.58
Gender	Household head gender (1=male, 0=female)	0.0135***	2.70
Education	Household head education level (years)	0.0001	0.12
Experience	Household head experience in tea farming (years)	-0.0002	-0.92
Ethnicity	Household head ethnicity (1=Kinh, 0= otherwise)	0.0020	0.58
Household size	Number of member per household	-0.0016	-1.25
Farm size	ha	-0.0406	-1.13
Labor-land ratio	The ratio of labors and land	0.0003	1.53
Tea age	The age of tea tree in years	0.0002	1.11
Slope	Slope of tea field, degree	0.0021	0.89
Soil and water conservation	1=farmer employed SWC technology,0=otherwise	0.0267***	12.71
Farm value	Total value of agricultural product in natural logarithm	0.0240	3.16
Non-agricultural income share	Proportion of total income from non-agricultural sources	0.0148	1.27
Extension	1= farmer access to extension service, 0=otherwise	0.0105***	2.28
Cooperative	1= farmer join cooperative, 0=otherwise	0.0249***	3.76
Constant		0.6990***	16.99

*Note: *** indicate statistical significance of the 0.01 level*
Source: Author's estimation

The sign of the variables in the efficiency model is very important in explaining the observed level of technical efficiency of the farmers. A positive sign on the coefficient implies that variables had an effect in increasing technical efficiency, while a negative coefficient significant the effect of reducing technical efficiency. The parameter estimates of Tobit function are performed in the Table 4. Coefficients of *Soil and water conservation*, *Extension,* and *Cooperative* variables had positive significant effects on technical efficiency at the level of 1 percent. The coefficient of *Soil and water conservation* variable is statistically positive significant and biggest compared to other variables at the level of 1 percent. The more soil and water conservation methods applied in farm, the higher technical efficiency of households. The coefficient of *Extension* had positive effect to technical efficiency as expected. Farmers who access to extension services cultivate tea better and more efficiently than others. One of the variables most worth mentioning in relation to technical efficiency is *Cooperative.* Its estimation coefficient shows a significant positive effect to technical efficiency, signaling that famers participating in cooperative could produce tea more efficiently than others. Similarly, *Gender* had positive effect on technical efficiency, statistically significant at the level of 1 percent. The positive coefficient of *Gender* implies that male head households are relatively technically efficient than their female counterparts.

V. Discussion

Efficiency is an important factor of productivity growth as well as stability of production. This study estimated the technical efficiency of tea production in the Northern mountainous reion of Vietnam using stochastic frontier approach. The mean technical efficiency of tea production in this region was found to be 89.6 percent. It is clear that there are opportunities for tea growers to increase the productivity by 10.4 percent through using properly the available inputs and technology. In addition, this result indicates that Vietnamese tea farming is relatively efficient than some countries` tea production such as: Srilanka, Bangladesh and India. Basnayake *et al*. (2002) showed that the technical efficiency of small tea producers in Sri-Lanka was on average approximately 65 percent. For Bangladesh, the average technical efficiency was about 59 percent following by Baten *et al.* (2010). For India, Harisdas *et al*. (2012) found an average technical efficiency of 84.53 percent.

Agricultural production is a process of combining various inputs such as: seed, fertilizer, pesticide, labor, irrigation water, and machinery. These inputs are considered as important variables in production efficiency analysis. This study finds that irrigation water, fertilizer (nitrogen, phosphorous, npk), pesticde, labor and capital had significant impact on the efficiency of tea production.

The most important input having positive and siginificant effect on tea yield was *Irrigation water*. This indicates that the more irrigation water use, the higher tea yield. Although tea is an upland crop, it still favors warm and humid growing conditions. Irrigation becomes more esstential for tea production in the Northern region of Vietnam during the dry months (September to December) of the year (Do and Le 2000). Nghia (2008) using dummy variable in production frontier model showed that irrigated tea fields in the Northern mountainous region of Vietnam are more efficient production than non-irirgated fields. Finding of this study makes a strong case in favoring construction of proper irrigation system to all tea farms in Vietnam.

The use of chemical fertilizer is known to be a commonly used method in increasing productivity and in the intensification of agriculture production. Some of studies such as: Basnayake *et al*. (2002), Baten *et al.* (2010), and Harisdas *et al*. (2012) used the total amount of chemical fertilizer in prodcution frontier model to estimate the effect of this fertilizer on tea yield. In fact, tea plant need large amount of nitrogen, phosphorous and postasium for growth. The deficiency of these nutrients could adversely affect the yield of tea. The interesting of this study is that the impact of Nitrogen, Phophorous, Postasium, and NPK fertilizer on tea yield in stochastic production frontier model was analyzed independently. The positive coefficient of *Nitrogen fertilizer, Phosphorous fertilizer, NPK fertilizer* variable indicates that increasing productivity of tea are largely dependent on the type and amount of chemical fertilizer applied. This result will provide useful information for tea farmers to achieve proper balance of chemical fertilizer which is very essential to increase productivity and maintain soil fertility sustainability.

On the contrary, *Pesticide* variable had negative effect on tea yield. The negative and unexpected sign of pesticide signals that this chemical input has been over-utilized in tea disease control. Several factors may contribute to this overall pattern. Interviews with tea farmers show that they consider pesticides to be essential tools in avoiding crop failures and securing their income. 70 percent of farmers in the sample believe that the more frequently they apply pesticide the more effective pest control will be, proceed to, minimize economic risks and maximize yields. Besides, to attract the customers and motivate them to pay a higher price, tea farmers use chemical pesticides much to get more aesthetic appearances in tea buds. This excessive pesticide application of tea farmers will have strongly affect not only tea quality but also environment (through contaminating soil, air and water) and the life of plants and animals, including humans. Therefore, it is important to promote the implementation of integrated pest management (IPM) practices in order to reduce the dependence of tea farmers on chemical pesticides.

Similarly, *Labor* variable showed a negative and significant impact on tea yield. There are some studies related to agricultural sector (Battese and Broca 1997; Cuesta 2000; Zhu and Lensink 2010) with this non-normal sign of labor. This result implies that increasing labor is not critical way for increasing tea yield. This input is at macro level and we can observe decreasing returns to scale when adding more working days into tea production. The possibility of decreasing returns to scale in Vietnamese tea production was proved in the estimated results section. The *Capital* variable also had negative and significant effect on tea yield. This implies that there would be no significant increase in tea yield even if the investment in machinery would increase. Vietnamese tea farmers tend to excess current capital, which is either not used or not fully used in actual production. According to Pindyck (1991), when capital investment is often an irreversible decision, excess capital tends to persist. Therefore, these findingssuggest that tea farmers have wide chance to increase tea yield through properly utilizing their current labor and machineries.

For policy purposes, it is very useful to determine which factors of farmers' socio-economic and farm characteristics have impact on the technical efficiency of tea production. Using two-limit Tobit model, this study reveals that *Soil and water conservation, Extension, Cooperative,* and *Gender* variables had positive and significant effect on the technical efficiency of tea production.

The positive effect of *Soil and water conservation* implies that adoption of SWC technologies enhance productivity of tea production in the Northern mountainous region of Vietnam. This result is consistent with Dang (2002), Solis *et al.* (2006), and Mugonola (2013). In recent years, soil erosion resulting from bad farming practices on sloping lands, without attention to soil conservation, has been known to be a serious problem in the Northern mountainous areas of Vietnam. Soil erosion causes loss of productivity at all levels in this region (Thao 2011). In addition, there are constantly growing risks of severe droughts and water shortage for irrigation and changing climate in the North region of Vietnam (FAO 2011). Therefore, the promotion of soil and water conservation practices is very important measure to produce tea efficiently and sustainability.

This study also shows that tea farmers who access to extension services produce more efficiently than non- accsess farmers. Kalijaran (1991), Xu and Jeffrey (1998), Al-Hassan (2008), Saigenji and Zeller (2009), and Nyagaka *et al.* (2010) also found that agricultural extension services could help improving technical efficiency. Agricultural extension policy was designed in Vietnam to develop agriculure production in sustainable way. Tea production is one of the most important sectors implementing this policy. Extension service includes serveral features such as: training courses or technical instruction on tea cultivation (land preparation, planting etc.), training on modern techniques of application of fertilizer and pesticde, training on harvesting and conservation, provision of information on tea market and sale skills. Extension is essentially education and it could bring positive behavioral changes among farmers. Thus, it is important for Vietnamese tea farmers to have easy access to extension services in order to optimize on-farm technical efficiency and productivity, given the limited resources available.

The next findding of this study is that tea farmers joinning cooperatives could operate at higher level of technical efficiency. In recent years, Vietnamese tea cooperatives played an important role in increasing farmers' income through their improvement of production techniques and machines, knowledge about financial management, and market access capacity. Infact, farmers who joined or formed cooperatives in Vietnam are given priority to attend training courses about production technique and financial management which are funded by the government and other supporting organizations. In these courses, farmers were taught expenditure management, modern tea planting techinques, use of pesticide, integrated pest control and so on. These tea cooperatives also help members establish contracts with other chain actors i.e. supplier of farm inputs and other materials for tea farming; processors; wholesalers; distributors and retailers, develope policies and procedures for procurement; storing and packing as well as support members in equiping sieving machine; vacuum packaging machine and scenting machine. In addition, when participating in cooperatives, Vietnamese tea farmers have more opportunities to exchange information with other members on input markets and services. This enable farmers to adjust their production more effectively. Rahman (2003) also indicated that exchange information on input markets among cooperative members such as timely availability of fertilizers, pesticides and seed at competitive prices may positively affect to their production efficiency. This result is sufficient enough to encourage Vietnamese tea farmers join or form cooperatives.

The final result of this study is female household heads are relatively techncial inefficient than their male counterparts. This result is consistent with the findings of Due and Gladwin (1991) and Akinwuni and Djato (1997). Gender differences in agricultural productivity have been shown to be due to differences in the intensity of use of productive inputs such as: fertilizer, manure, land, credit, extension training, and education rather than differences in the management styles of men and women (Quisumbing 1996). Many factors explain the weakness of women's productivity. Women farmers lack access to cash or credit to acquire modern yield-increasing inputs of production, they tend to produce less (Gladwin 2002). The level of productivity of women is constraint because most agricultural technologies designed based on the assumption that farm mangers are men (Balakrishnan 2004). In reality, women farmers in the study site lack access to inputs, credit, and extension training because most of their time spends on doing housework like cooking, cleaning, washing, and caring children, apart from plucking and weeding possible during the lean season. Most of work in tea cultivation such as: buying inputs, fertilizing, pruning, spraying, managing fund, joining training courses are done by male farmers. Therefore, to improve women farmers' productivity in the region, women need to better support to increase access to factors of production such as: land, credit, inputs, information and technology.

VI. Conclusions and Policy Implications

This study sought to estimate tea production's technical efficiency and its determenants in the North mountainous region of Vietnam using stochastic frontier analysis. The estimated mean technical efficiency level is 89.6%, suggesting that increase output and decrease cost could be obtained by using the available technology. There was big difference in technical efficiency among farmers in the sample, suggesting the potential ability of output increase by using inputs more efficiently.

The study further shows that increasing tea yield depends on the quantity of irrigation water as well as the type and quantity of chemical fertilizers (nitrogen, phophorous, npk). Given the importance of farm inputs in raising tea productivity, further policies should be aimed at increasing investment in irrigation and increasing farmers' access to chemical fertilizers at affordable price. We suggest that the government should focus on stabilizing price of chemical fertilizers through intensifying quality control of chemical fertilizer circulated on the market, controlling the chemical fertilizers production activities; regulating and balancing the supply and demand of chemical fertilizers through reserving and regulating the chemical fertilizers import resources through tax policies and having support policies to improve the capacity of the distribution system. Moreover, the negative and significant impact of pesticide and capital on tea yield show that these resources are over-utilized or inefficiently used. Thus, the government should concentrate on technical assistances for tea farmers such as: effective pesticide application and capital management techniques and integerates pest management pratices.

The farmers' socio-economic and farm characteristics such as: applying soil and water conservation technology, accessing to extension services and participating in cooperative were found to be significant in increasing technical efficiency level of tea production in the region. To improve technical efficiency, the government should encourage farmers practice soil and water conservation technology, implement extension services widely, and promote farmers join cooperatives. The study also reveals that women tea farmers tend to produce less efficiently than their male counterparts. Policies which aim at increasing female farmers' accessing to production inputs as well as extension services will be useful for increasing technical efficiency of tea production.

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Harvesting the Benefits of Inventions in China: Making a Case for the Promotion of Reverse Engineering in Nigeria

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Abstract- Innovation and technology are important catalyst in wealth creation and development of societies and nations. Progress in science is advanced by dissemination of know-how, whether by original innovation or by reverse engineering of existing technology. While original innovation is the standard in this regard, the open secret to boosting economic growth has been said to be reverse engineering, which basically involves the creation of inventions and innovations from the study of existing technology. Reverse engineering is said to lead to faster development and innovations as the creations are based on an existing design and less time and fund is spent on trial and error while working on original inventions. China is one of many nations that discovered this well kept open secret decades ago and are currently harvesting the benefits of its use. It has used reverse engineering to rise and transform itself from a developing nation to one of the largest economies in the world, with the highest economic growth rate in the world today. Nigeria, on the other hand can at best be described as a new born, where reverse engineering for economic growth is concerned.

Keywords: benefits, inventions, china, reverse engineering, nigeria, economic growth.

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HARVESTINGTHEBENEFITSOFINVENTIONSINCHINAMAKINGACASEFORTHEPROMOTIONOFREVERSEENGINEERINGINNIGERIA

Strictly as per the compliance and regulations of :

Harvesting the Benefits of Inventions in China: Making a Case for the Promotion of Reverse Engineering in Nigeria

Dr. K. M. Waziri [α] & Mrs. O.F. Awomolo LL.M [σ]

Abstract- Innovation and technology are important catalyst in wealth creation and development of societies and nations. Progress in science is advanced by dissemination of know-how, whether by original innovation or by reverse engineering of existing technology. While original innovation is the standard in this regard, the open secret to boosting economic growth has been said to be reverse engineering, which basically involves the creation of inventions and innovations from the study of existing technology. Reverse engineering is said to lead to faster development and innovations as the creations are based on an existing design and less time and fund is spent on trial and error while working on original inventions. China is one of many nations that discovered this well kept open secret decades ago and are currently harvesting the benefits of its use. It has used reverse engineering to rise and transform itself from a developing nation to one of the largest economies in the world, with the highest economic growth rate in the world today. Nigeria, on the other hand can at best be described as a new born, where reverse engineering for economic growth is concerned. This article takes a look at reverse engineering, its use in China and the benefits of same to the Chinese economy, with a view to making a case for the use of reverse engineering to boost economic growth in Nigeria.

Keywords: benefits, inventions, china, reverse engineering, nigeria, economic growth.

I. Introduction

Reverse engineering is simply "trying to figure out how something works." [1] It is the process of discovering the technological principles of a human (or non-human) made device, object or system through analysis of its structure, function and operation. It often involves taking something (e.g., a mechanical device, electronic component, biological, chemical or organic matter or software program) apart and analyzing its workings in detail to be used in maintenance, or to try to make a new device or program that does the same thing without using or simply duplicating[2] (without understanding) the original.[3]

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Reverse engineering is said to be fundamentally directed to discovery and learning, as engineers learn the state of the art by reverse engineering others' products, [4] and has been described as the important supporting technology which digests and absorbs advanced technology and shortens the cycle of product design development. [5] It leads to creation of new goods/products, new processes and new knowledge, which are major sources of technical change. [6]

The process is mainly undertaken with the end aim of learning how to build a technology or make improvements to it[7] and It is one of the endorsed and

[1] Jones, P. (2005). Software, reverse engineering and the law. Retrieved on 21/12/14, from http://lwn.net/Articles/134642/.htm

[2] Uhrich, C.L. (2001). Economic Espionage Act--Reverse Engineering and the Intellectual Property Public Policy. *Michigan Telecommunications and Technology Law Review. 7;1.* 147-190.

[3] See generally on definitions of reverse engineering: Dehaghi, M.R and Goodarzi, M. (2011). Reverse Engineering: A Way of Technology Transfer in Developing Countries like Iran. *International Journal of e-Education, e-Business, e-Management and e-Learning, 1;5.* 347-353; Aginam, E. (2014). Coscharis boosts Covenant University with reverse engineering solution. Vanguard Online Newspaper, 15th September, 2014. Retrieved on 23/11/14 from http://www.vanguardngr.com/2014/09/coscharis-boosts-covenant-university-reverse-engineering-solution/.htm; Khalili, A.H., Maleki, A and Ayatollahi, A. (unknown). Using Combination of Reverse Engineering and Value Engineering for Improvement in Designs, Construction Projects and Manufacturing Industries. *Proceedings of the 41st International Conference on Computers & Industrial Engineering. 518-523*;

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[6] See generally on its benefits: Guellec, D., & van Pottelsberghe, B. (2001). R&D and Productivity growth: Panel Data Analysis of 16 OECD countries. *OÉCD Economic Studies* No. 33. Cited in Akinwale, Y. O; Dada, D.A, et. al. (2012). Op. cit.; Khalili, A.H., Maleki, A and Ayatollahi, A. (unknown) . Using Combination of Reverse Engineering and Value Engineering for Improvement in Designs, Construction Projects and Manufacturing Industries. *Proceedings of the 41st International Conference on Computers & Industrial Engineering. 518-523;* Samuelson, P & Scotchmer, S. (2001). Op. Cit.

[7] See generally: Franks, L.S. (2014). The Art of Reverse Engineering. Retrieved on 23/11/14, from http://www.contrarianprofits.com/e-letters,rogue-capitalists-daily/the-art-of-reverse-engineering/.htm; Khalili, A.H., Maleki, A and Ayatollahi, A. (unknown). Using Combination of Reverse Engineering and Value Engineering for Improvement in Designs, Construction Projects and Manufacturing Industries. *Proceedings of the 41st International Conference on Computers & Industrial Engineering. 518-523.*

legally acceptable means of extracting know-how or knowledge for creation of innovation from a human-made artefact or product, even if the intention is to make a product that will draw customers away from the original product.[8]

In its purest form, an innovator following this path buys, begs, borrows, or steals[9] a product or a system, takes it apart to understand how it works, and duplicates it, usually making it better or upgrading it. By doing this the innovator avoids the design and engineering phase of independent, new or original innovation[10] by using a design originated by somebody else.[11]

When a new product is created as a result of reverse engineering, same is regarded as innovation as well and can be protected by patent under intellectual property[12] in order to generate profit which can be re-invested to create more innovation or channeled into other sectors of the economy to generally boost same.[13]

[8] Samuelson, P. & Scotchmer, S. (2002). Op. Cit.

[9] Though the writers hold a firm view that stealing an existing product for the purpose of reverse engineering should be discouraged.

[10] Which usually takes a lot of time, because of the trial and errors in the process of coming up with a new invention and requires a lot of resources and funds until the perfect creation is achieved. We are however not unaware that reverse engineering also entails a detailed study of the item in question and an unpredictable amount of time, effort and cost to produce. It however, still costs less funds and time as a result of less trial and error. See: Cheung, K & Lin, P. (2004). Spill over effects of FDI on innovation in China: Evidence from the provincial data. *China Economic Review 15. 25– 44*

[11] Forden, G. (2007). How the World's Most Underdeveloped Nations Get the World's Most Dangerous Weapons. Retrieved on 24/11/2014, from http://web.mit.ed/stgs/pdfs/TandC_essay_on_WMD.pdf

[12] Intellectual property for this purpose can be defined simply as proprietary information and other kinds of assets that are made protectable for a period of time under law, such that during their period of protection, only the owners of the said property have exclusive rights to same and may use them for economic gain. Depending on its type, intellectual property derives its value from a bundle of nearly exclusive rights defined by statute, common law, or contract. Patent is that form intellectual property given to the owners or creators of inventions, such that the holders of this patent are given certain exclusive ownership and use rights for a period of time specified by the law. Generally, upon the grant of patent, the owner possesses a monopoly over the product extending from the issue date to the expiration of the time as prescribed by the law. This monopoly gives the patent holder the right to exclude others from making, using, selling, or importing any product covered by a claim of the patent. The patentee(s) in this case can also charge a higher price or enjoy a lower marginal cost while excluding others from doing so. See generally on the above: Uhrich, C.L. (2001). Op. cit.; Zhang, H. (2014). Patent Institution, Innovation and Economic Growth in China. Retrieved on 24/11/14, from http://press.anu.edu.au/wp-content/uploads/2014/07/ch20.pdf

[13] All the reverse engineer really has to do to qualify as a creator of invention, is to change one little angle somewhere and it becomes a new design, that can be patented and used to generate profit for the use of the country to boost other aspects of its economy. See: Anuforo, E. (2011). The imperatives of science, technology to national economic development, by Adewoye. *Guardian online news. 9th May, 2011.* Retrieved on 24/11/2014, from http://www.nigerianhomepage.biz/business-in-nigeria/3738-the-imperatives-of-science-technology-to-national-economic-development-by-adewoye.html

It has therefore been seen as a source of vast development of technology all over the world,[14] and an economically proven as well as legally acceptable[15] way of boosting economic growth.[16] Here, we recall, that it is well known that one of the influential factors that could lead to economic growth is the improvement of technology.[17] This could increase productivity with the same levels of labor, thus accelerating growth and development.[18]

In under developed countries therefore, reverse engineering is viewed as a short-cut method for access to technology, its development and completion. By use of this method, underdeveloped countries can decrease the technologic gap between themselves and industrial countries.[19] This is because it has been shown to be one of the fastest ways to discover what is in a component, in order to improve on it and use the knowledge gained there-from for further advancement of technology. It thrives where there is a good working system that boosts Research and Development (R&D)[20] and its existence helps nations to develop new technologies, create opportunities and improve their

[14] See: Anuforo, E. (2011). Ibid. See also: Abbot, J. (2003). Reverse Engineering of Software: Copyright and Interoperability. *Journal of law information and science.* 14; 7, where he opined that reverse engineering plays a crucial role in the development of new or competing programmes because it is often the only way to reveal the ideas underlying computer programmes. We can draw inference from this as well, for the fact that reverse engineering plays a crucial role in the development of new or competing technology because it is often the only way to reveal the ideas underlying existing technology, with an aim of making it better or more cost effective…generally improving technology day by day.

[15] The purchaser of a machine embodying a patented invention, for example, is generally free to disassemble it to study how it works under the first sale principle of patent law. See: Cohen, J.E & Lemley, M.A. (2000), Patent Scope and Innovation in the Software Industry. *California Law Review. 89;1.* 30-35.

[16] Samuelson, P. & Scotchmer, S. (2001). Op. Cit. Akinwale, Y. O; Dada, D.A, et. al. (2012). Op. Cit.

[17] This is especially because trade in technology goods and services which are knowledge-intensive, tends to be among the fastest-growing in international trade. See: Maskus, K. (2000a) "*Intellectual Property Rights in the Global Economy*", Institute for International Economics, Washington DC, pp.73-79.

[18] Agarwal, P. (2012). Factors leading to Economic Growth. Retrieved on 14/01/15, from http://www.intelligenteconomist.com/factors-leading-to-economic-growth/?hvid=30dnPK; Akinwale, Y. O; Dada, D.A, et. al. (2012). Understanding the Nexus of R&D, Innovation and Economic Growth in Nigeria. *International Business Research. 5;11.* 187-196.

[19] Khalili, A.H., Maleki, A and Ayatollahi, A. (unknown) . Using Combination of Reverse Engineering and Value Engineering for Improvement in Designs, Construction Projects and Manufacturing Industries. *Proceedings of the 41st International Conference on Computers & Industrial Engineering. 518-523.*

[20] Research and Development (R&D) here refers to "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications". See: Organization for Economic Cooperation and Development (OECD). (2002). *Proposed Standard Practice for Surveys on Research and Experimental Development* (6th ed.) p. 30.

technological positions on the global scene. [21] Developing countries can use reverse engineering to their benefit by creating innovative products there-from, guaranteeing intellectual property protection of same, using the products for their own markets, and then also exporting them to developed countries.[22]

This innovation which not only determines the extent to which these countries can assimilate and apply foreign technology,[23] but is also the end result of the above described process, has been a key driver of economic growth in most advanced countries and China has risen to the top of the list of countries that have soared to a great economic height worldwide, in so little time, using reverse engineering as a tool for boosting innovations. They gave special attention to their technological development using reverse engineering and this led to a significant increase in their economic growth.

Their path to technology innovation was a result of designs being imported into the country where Chinese engineers were waiting to redesign and re-engineer products, in such a way as to be able to manufacture them quicker and at more affordable prices, thereby making such products more competitive in the global marketplace.[24] In this way, China gradually set itself up to be one of the most robust economies in the world, which goal it has now achieved, being the second largest economy in the world.[25]

The rapid growth of their economy as a result of the benefits of reverse engineering reflects the government's strong focus in this area explains why China's GDP growth rate accelerated strongly in 2009 even as growth rates in most other economies suffered significantly. [26] It is apparent now that the biggest contributors to China's economy are the benefits derived from their reverse engineering[27] activities.

The Nigerian economy in contra-distinction to that of China is a growing economy which has so far focused solely on one aspect and has therefore not made any head way with regard to competition in the international markets. One of the questions that have always been raised is how Nigeria can decrease the technological distance between it and other developed countries in the shortest time, in order to have a suitable share in the global business and compete in the global market. It is evident from the growth of the Chinese economy as a result of the large harvest raked in from the benefits of reverse engineering, that one way Nigeria can achieve its goal above stated is through reverse engineering.[28]

Though the Nigerian government has now begun to lay more emphasis on the technology sector,[29] with the aim of moving the economy from the traditional low-level of productivity to a more automated and efficient system of mass production of goods and services, [30] the use of reverse engineering is still generally foreign, such that in addition to other hindering factors, the performance of the sector leaves much to be desired as general output, capacity utilization and sector contribution to GDP are still comparatively low.

It is in view of the above that there is a need to make a case for the use of reverse engineering to boost economic growth in Nigeria, as with the case in China.

II. The Economic Growth in China

Economic growth is the increase in the market value of the goods and services produced by an economy over time. Economic Growth is conventionally measured as the percent rate of increase in real gross domestic product (GDP)[31] or an increase in national output and national income.[32]

It goes without saying that China which is one of the two most populous countries in the world and accounts for 20.4% of the world's population has not always been the economic world power that it is now,

[21] Charpie, R. A. (1970). Technological Innovation and the International Economy. In M. Goldsmith (Ed.), *Technological Innovation and the Economy.* London: Wiley-Interscience.

[22] PLATT, J.R. (2010). **Reverse Innovation: Changing the Path of Global Development**. *IEEE-USA Todays Engineer, May, 2010.* Retrieved on 21/11/14, from http://www.todaysengineer.org/2010/May/Reverse-Innovation.asp

[23] Radovesic, S. (1999) "*International Technology Transfer and Catch-up in Economic Development*", Elgar. Cheltenham. p.242. Also Saggi, K. (2000) "*Trade, Foreign Direct Investment and International Technology Transfer: A Survey*", World Bank, Washington DC. and Rosenberg, N. (1982) "*Inside the Black Box; Technology and Economics*", Cambridge University Press, Cambridge.

[24] Rosenstein, A. (2014). Chinas integration into the global economy: who should be worried? Retrieved on 15/1/15, from http://www.anarosenstein.com/chinas-integration-into-the-global-economy-who-should-be-worriednew-page/

[25] China's technological advantage is said to be the major factor that has accompanied its rise to be the world's second-largest economy. See: Lague, D. (2013). China eyes $3.5 billion Russian arms deal despite ire over Sukhoi copy. Retrieved on 21/11/14, from http://www.reuters.com/article/2013/03/27/us-china-russia-arms-idUSBRE92Q0PE20130327

[26] Durden, T. (2014). China Will Revise Its GDP Definition Until Its Hits Government "Growth Targets", Goldman Explains. Retrieved on 24/11/2014, from http://www.zerohedge.com/news/2014-09-02/china-will-revise-its-gdp-definition-until-its-hits-government-growth-targets-goldman

[27] Ibid.

[28] See: Dehaghi, M.R and Goodarzi, M. (2011). Op. Cit.

[29] The government recently approved the National Research and Innovation Fund (NRIF) which is a product of the new national STI policy tailored towards economic transformation and the development of STI in the Nation. See: Akinwale, Y. O; Dada, D.A, et. al. (2012). Op. Cit.

[30] See: Malik, A., Teal, F. and Baptist, S. (2006) *The Performance of Nigerian Manufacturing Firms: Report on the Nigerian Manufacturing Enterprise Survey.* Centre for the Study of African Economies University of Oxford; United Kingdom.

[31] Agarwal, P. (2012). Op. Cit.

[32] Economicshelp.org. (unknown). Causes of Economic Growth. Retrieved on 14/01/15, from http://www.economicshelp.org/macroeconomics/economic-growth/causes-economic-growth/

with economic growth rates more than three times faster than the world average.

The gradual growth of the Chinese economy, started as far back as the 70's, when it began to move to a market economy and to open itself up to the rest of the world. Its pace of reform speeded up in the 1980s and the in 1990s when they began exporting commodities which had been reverse engineered to compete with existing technology. As a result of the robustness of their labour market, foreign companies in partnership with China sent spare parts and already finished products for coupling and putting together in the Chinese industries. Export processing therefore began at the low end with steel production, automotive, and traditional industries and developed into globalized production of high-end goods. [33] Several steps subsequently taken, included the proliferation of special economic zones, increasing receptivity to direct foreign investment, and the decision to join the World Trade Organization in 2001.

Apparently, the turn-around in the economy of China began when they started strengthening their innovation systems through public and private investment in research infrastructure, systematic borrowing from overseas through licensing and other channels and the acceleration of technological progress with the propagation of reverse engineering which eventually enabled them to cross the threshold and become a member of the club of high income economies.[34]

China is now a major global player on the world trade and investment scene. The speed, scope, and scale of its entry into the global system are unprecedented in economic history. It has been growing at 8% to 10% per year since the late 1970s and has become the third largest exporter of merchandise goods. It has earned the reputation as the manufacturing center for the world.[35]

In 2006, the Chinese State Council unveiled the Medium and Long-Term Plan(MLP) blueprint which among other things contained a set of scientific and technological benchmarks to be met by the year 2020. The blueprint was created as a vehicle for establishing China as a science and technology world power. The plan focused on 11 key sectors for using technology development and innovation to solve China's problems. The plan was created to *inter alia,* decrease China's overall dependence on foreign technology to a percentage less than 30% from approximately 60% in 2006.[36]

The plan called for Chinese original innovation or in other words for national entrepreneurs to create their own intellectual property and enrich the state. The government did not however rely solely on creations and inventions from scratch, but also considered reverse engineering, that is slightly altering and enhancing foreign technology as a means of innovation creation as well. The plan in its interpretation of indigenous innovation also included the "enhancing of original innovation through co-innovation and re-innovation based on the assimilation of imported technologies.[37] This full frontal power basically empowered Chinese manufacturers to obtain foreign products and innovations, re-engineer them to make them Chinese and if possible, sell them at a lower cost using cheaper materials thus boosting the said products in the market and increasing the country's exporting power for the said products.

In other to protect their innovations derived from reverse engineering so as to give them a greater fighting chance in the competitive market, they had recourse to intellectual property.[38] Intellectual property law helped fulfil China's further aspira87tions for growth of its economy, as the products created as a result of reverse engineering were patentable, allowing them thrive in the competitive world market. In 2010 therefore, China passed the United States and Japan as the world's largest filer of patent applications.[39]

As a result of all this, China averaged economic expansion of around 10% a year over the past three decades, pushing it up the list of biggest economies and boosting household wealth.[40] The rapid per capita growth rate in China has helped to lift many people out of poverty. The share of persons below the international poverty line of $1day has been reduced to just 17% in China.[41] Its economy, gauged by nominal GDP, grew by a phenomenal 10.3 per cent in 2010 as against 9.2 per cent in 2009, according to IMF data which also shows that global growth in 2010 was largely propelled by China and United States of America[42]

[33] Rosenstein, A. (2014). Op. Cit.

[34] Worldbank.org. (2011). China's Growth through Technological Convergence and Innovation. World Bank Supporting Report 2. 161-228. Retrieved on 24/11/14, from http://www.worldbank.org/content/damWorldbank/document/SR2--161-228.pdf

[35] Dahlman, C.J. (2007). China and India: Emerging Technological Powers. *Issues in Science and Technology*. Retrieved on 24/11/2014, from http://issues.org/23-3/dahlman/

[36] Rosenstein, A. (2014). Op. Cit.

[37] Ibid.

[38] Coming up with policies which empowered their citizens to go around patents of foreign products, but protect their own patents, allowing them to reach their targeted profits from their innovations. This has given China an advantage in copying and reverse engineering foreign technology. See: Dahlman, C.J. (2007). Op. Cit.

[39] Segal, A. (2011). Why American innovation will beat out China's. *CNN online news, 10th March, 2011*. Retrieved on 23/11/2014, from http://globalpublicsquare.blogs.cnn.com/2011/03/10/why-american-innovation-will-beat-out-china/

[40] Yan, S (2015). China posts its worst growth in 24 years. *CNN online news report, 20th January, 2014*. Retrieved on 20/1/2015, from http://money.cnn.com/2015/01/19/news/economy/china-gdp/

[41] Dahlman, C.J. (2007). Op. Cit.

[42] African Development Bank Group. (2013). Economic Report on Nigeria. 1;1. Retrieved on 24/11/14, from

China is now recognised world-wide as the world's second-largest economy[43] and even though their growth rate reduced at the end of 2014, China is still growing more rapidly than any other major economy[44] in the world, including the United States.[45]

III. Reverse Engineering, Inventions and China: Harvesting the Benefits

Reverse engineering, as discussed above, is basically the process of invention by starting with a known product and working backwards to divine the process which aided in its development or manufacture.[46] It is as far as it goes, a legitimate means of creating innovation and is an economically valuable activity that encourages fresh innovation.[47] In 1989, the U.S. Supreme Court decision, in *Bonito Boats, Inc. v. Thunder Craft Boats, Inc.*, [48] characterized reverse engineering as "an essential part of innovation," likely to yield variations on products that "could lead to significant advances in technology." The Court added that "the competitive reality of reverse engineering may act as a spur to the inventor" to develop patentable ideas.[49]

It has been said that since its inception in 1949 as the People's Republic of China, the country has been reverse engineering.[50] They have successfully shown the world that the above arguments with regard to the contributions of reverse engineering to innovations and inventions and therefore economic growth, is far from being a myth. It is in fact, reality, as it is not news that the Chinese economy is currently harvesting the benefits of its focus on its technology/manufacturing sector via propagation of reverse engineering.

They simply used reverse engineering as a means of technology absorption from foreign countries and to improve learning in these aspects in their country, thereby building their technological capabilities, [51] following a simple four-stage development process which saw them gather in more and more profits and benefits to their economy with every stage:[52]

The first stage is an awareness stage, which involves their recognition that a product had been introduced into the market that is potentially worth the time, expense and effort of reverse engineering. To succeed in doing this (constantly keeping track of recent technologies) they had to encourage foreigners into their borders to invest through good Foreign Direct Investment (FDI) policies and open up their borders to allow for spill-over of technologies through relationship ties between them and other developed nations.[53] This has generally benefitted them as the entry of multinational companies into the economy not only boosted investment and returns to their economy, but also led to certain infrastructural and technical development, aside its direct contribution to the possibility of reverse engineering products.

Second is the reverse engineering stage, which began with the obtaining of the innovator's product[54] and continues with the disassembly and analysis of the said product to discern of what and how it was made. To do this effectively, the government put a lot of funds

http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Nigeria_-_Economic_Review_-_Volume_1_-_Issue_1_-_September_2013.pdf

[43] Yan, S (2015). Op. Cit.

[44] Ibid.

[45] Censky, A. (2012). U.S. companies betting big in China. Retrieved on 21/11/14, from http://money.cnn.com/galleries/2012/news/economy/1204/gallery.us-companies-in-china/

[46] See the American case of Kewanee Oil Co. v. Bicron Corp., 416 U.S. 470, 476 (1974), where reverse engineering was defined as such.

[47] Samuelson, P. (1998). Intellectual property and economic development: opportunities for China in the information age. *Paper prepared for the 1998 International Symposium on the Protection of Intellectual Property for the 21st Century, October 28-30, 1998, in Beijing, PRC*. Retrieved on the 14/01/15 from http://people.ischool.berkeley.edu/~pam/papers/chinaip.html

[48] 489 U.S. 141, 160 (1989),

[49] Ibid. 489 U.S. at 160

[50] Franks, L.S. (2014). The Art of Reverse Engineering. Retrieved on 23/11/14, from http://www.contrarianprofits.com/e-letters,rogue-capitalists-daily/the-art-of-reverse-engineering/.htm

[51] Kumar, N. (2014). Enabling Policies for Transfer of Technology for Development. Being a presentation at the WTO Workshop on Trade and Transfer of Technology Geneva, 16 June 2014. 3.

[52] China was basically eating their cake and having it, in a very circular motion that benefitted them at every stage, as we shall soon discover form subsequent stages as well.

[53] Through the integration of the local market with the international operators, labour mobility between subsidiaries and indigenous firms resulting in knowledge spill-over, learning from the demonstration of new technologies represented in foreign subsidiaries and when indigenous firms receive technical assistance. UNCTAD (2005) emphasizes that FDI-led Technology spill-over can play a significant role in the productivity growth of indigenous enterprises in a host economy. See generally: UNCTAD, (2005) *Report of the Commission on Investment, Technology and Related Financial Issues, 8*th session, Trade and Development Board, Geneva; Available at *http://www.unctad.org/en/docs/c2d60&c1_en.pdf cited in* Dutse, A.Y, Okwoli, A.A and kurfi, A.K. *(2011).* Promoting FDI-related Technology Spill over in Nigeria's Manufacturing Sector: Active-firms Targeted Policy Approach. *IPEDR vol.10. IACSIT Press, Singapore.* Xu, B. (2000) Multinational enterprises, technology diffusion, and host country productivity growth', *Journal of Development Economics*. 62. 477–493; Sun, Y. (2010) What Matters for Industrial Innovation in China: R&D, Technology Transfer or Spill over Impacts from Foreign Investment? *International Journal of Business and Systems Research, 4;5/6.*

[54] In the process of obtaining technology, the government of China left no stone unturned as they took all steps necessary, by licensing, buying, borrowing and they were even accused of stealing certain designs, but this did not deter them. The Chinese government for instance, was accused of theft by way of reverse engineering a fighter jet known as the Shenyang J-15 carrier-based fighter from the model of a Russian fighter jet. Meanwhile, the fact remained that stolen or not, the Chinese have been credited with the development of the new J-15 which they argued in the People's Daily–a state media organization–is more advanced than the Su-33. See: Majumdar, D. (2012). China upset at being called out for reverse engineering Su-33. Retrieved on 23/10/14, from http://www.flightglobal.com/blogs/the-dewline/2012/12/china-upset-at-being-called-out/.mht

into the boost and support of reverse engineering by increasing spending on R & D,[55] as well as on the technical training of the upcoming generation, especially in more advanced countries.[56] This allowed them to have the technical know-how for the actual understanding of technology and improvement of same. These steps aside from contributing to reverse engineering in China, also led to actual original innovations from China and has also ensured continuity in the growth of the technology and manufacturing sector, as knowledge passed on from generation to the other basically has seen the Chinese technology and manufacturing sector maintaining its lead and competing favourably in the world economy.

Third is the implementation stage which follows after a successful reverse engineering of the innovator's product. In this case, the knowledge acquired from the reverse engineering process is put to work in designing and developing a new product/invention to compete in the same market. Suffice it to say that this was the power house of the reverse engineering process. It was at this stage that it was ensured that whatever product was invented from the reverse engineering process was such that could boast of being a timely product at the level of international standards and one that could better satisfy the customer's needs by ensuring better performance, adding characteristics and eliminating deficiencies of the product, while also satisfying the needs of the market by changing or improving of the technology or reducing cost of same.[57] The steps taken by the Chinese government as highlighted above basically assisted with the achievement of this phase/stage as well.

The fourth stage is the introduction of any new product, the result of reverse engineering to the market[58] where it competed with existing products. Here, the admirable quality of China was its application of intellectual property to make its products have a better fighting chance at generating profit in the world economy. Intellectual property was used to further derive the benefits of their inventions and protect same from infringement, while ensuring the legalisation of the use of reverse engineering to create innovations. The Chinese patent regime was in furtherance of this, designed to protect attempts by Chinese companies to replicate foreign products.[59] This in turn encouraged the creation of more innovations and inventions and therefore the filing of more patent[60] and therefore as well, the raking in of more profit to further boost the Chinese economy by channelling it to the improvement of other sectors of the economy as well. The more affordable or better improved products were a hit on the international markets, thereby allowing companies to make huge profits which were re-invested in expansion of industries, leading to more employment of labour and reduction in the poverty level in the Country and ultimately increasing the Gross Domestic Product (GDP) of the country and fuelling its economic growth.

China has therefore as a result of reverse engineering and the accompanying steps above, made great strides in reforming its economy and becoming a major force in the world economy.[61] They have now successfully developed mechanisms for replicating products at drastically lower prices and this has opened up their market for the greater percentage of the world population, looking to have the best of the world's comforts at the most affordable rates,[62] such that since it launched major economic reforms in the late 1970's, its economy has experienced tremendous growth,[63] and has not relapsed.

IV. Nigeria's Economy in Perspective

The Nigerian economy has so far in its history, portrayed the role of a dysfunctional seesaw, with only

[55] They gradually increased their spending on R & D activities, such that spending on R&D as a percentage of China's GDP tripled over in the past 15 years from half a percent to 1.5% and it is predicted that by 2020, about 2.5% of China's GDP which will have also increased considerably, will likely go to R&D. See: Franks, L.S. (2014). Op. Cit.

[56] China has been sending more tertiary level students abroad for education and training. In 2004, more than 15% of all the 2.7 million students studying outside their home country were from China. See: Dahlman, C.J. (2007). Op. Cit.

[57] Dehaghi, M.R and Goodarzi, M. (2011). Op. Cit.

[58] See generally on the above stages: Samuelson, P & Scotchmer, S. (2001). Op. Cit.; Sha, L. (2012). Op. Cit.

[59] The Chinese patent law for instance adopted what has been described as the utility model of patents which only require vague descriptions of products, thereby allowing people to file patents on products already owned by others by merely changing a few minute details. The Patent law also allows the use of domestic patents to retaliate against foreign companies that file intellectual property infringement lawsuits offshore that stymie the international expansion plans of Chinese companies. Then in addition, the law uses the European "first to file" policy in registration of patent rather than the "first to invent" policy used in the United States, which allows Chinese companies to file patents on products they did not necessarily design if they beat the actual owners to the punch. Finally, defines invention as including "any new technical solution relating to a product, process or improvement…" These Chinese patent rules were designed to help natively conceived products and block those that were not wholly designed and produced in the country from having ground in the Chinese markets. This model is similar to that used by the Germans. See: Rosenstein, A. (2014). Op. Cit.

[60] Indeed, the number of patents filed by the Chinese has increased rapidly in recent years and as stated earlier, China shocked the world as a matter of fact, when in 2010 they passed the United States and Japan as the world's largest filer of patent applications. See: Durden, T. (2014). Op. Cit.; Franks, L.S. (2014). Op. Cit.

[61] Samuelson, P. (1998). Op. Cit

[62] African Development Bank Group. (2013). Economic Report on Nigeria. 1;1. Retrieved on 24/11/14, from http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Nigeria_-_Economic_Review_-_Volume_1_-_Issue_1_-_September_2013.pdf

[63] Gao, L. (1998). China's Intellectual Property System in Progress. *China in the world trading system: defining the principles of engagement*. Abbott, F. M. ed. 128. Cited in Samuelson, P. (1998). Op. Cit.

one of its arms working and consistently moving its riders up and down without any warning. The very young economy continues to grapple with a number of challenges that has hampered efforts at economic growth.

The Nigerian economy is yet to achieve the necessary structural changes that will spring it to a rapid and sustainable growth and development. Aside disarticulated and narrow productive base, sectoral linkages in the economy are weak. Primary production comprising agriculture, mining and quarrying inclusive of oil and gas dominate national output while the manufacturing sector role in the economy is decidedly small in terms of share of gross output, contribution to growth, foreign exchange earnings, government revenues and employment generation.[64]

The economy also faces monumental challenges in the form of dilapidated and chronically non-functional infrastructure. [65] The decay in the country's infrastructural base reflects decades of poor maintenance and weak technological base. The weak technological base is a consequence of low research and development efforts and disconnect between research findings and industry. The private sector is equally weak and diffuse with poor response record to industrial incentives.[66] All sectors of the economy are affected by deep seated corruption,[67] lack of proper management of resources, lack of foresight and bad leadership.[68]

Although the economy experienced respectable GDP growth rates, averaging over 6.5 percent per annum between 2006[69] and 2010, this growth did not spawn corresponding employment nor resulted in attenuation of poverty. Moreover, growth rates of the non-oil output remains unsatisfactory and the even more recent fall in oil prices has taken a huge tow on the country. Concomitantly, there has been gradual decline in the level of competitiveness of the Nigerian economy to the extent that the country has become one of the least competitive economies in Africa. The narrow base of government revenue and the near monolithic nature of exports constitute additional challenges confronting the economy.[70]

The oil sector growth performance which is the focal point of the economy and has been greatly relied on for the funds of the government was not as impressive with 3.4%, -2.3% and 5.3% estimated growth rates in 2011, 2012 and 2013, correspondingly. Growth of the oil sector has been said to have been hampered throughout 2013 by supply disruptions arising from oil theft and pipeline vandalism, and by weak investment in upstream activities with no new oil finds.[71] Besides, the over reliance on the country's oil sector without attempts at sustainable use of the natural resource has been said to spell doom for the country and it has been predicted that Nigeria has only about three decades to exhaust its crude oil reserves.[72]

In the light of the fast rate of depletion of this natural resource and the failure of the Nigerian economy as stated above, in global competitiveness, it has become imperative for Nigeria to source for other means such as the use of reverse engineering to boost innovation as a vital tool for accelerating their economic growth. Meanwhile, Nigeria is yet to fully harness reverse engineering to boost its economy. Veritable tools such as reverse engineering have been given little or no attention by the Nigerian government in the past, especially as the major focus has been on the oil and gas sectors of the economy.

Though the government of Nigeria is said to have begun to set up policies that prescribe the attraction of FDI and the integration/absorption of related technology spill over,[73] there is still a lot to be done in this regard, especially on the use of reverse engineering to boost economic growth in Nigeria.[74]

[64] African Development Bank Group. (2013). Op. Cit.

[65] Nigeria depends heavily on imports and this has drastically affected infrastructural development. Its dependence on the developed nations has inhibited the evolution of its engineering infrastructural base. See: Siyanbola, W.O, Egbetokun, A.A, et.al. (2012). Indigenous Technologies and Innovation in Nigeria: Opportunities for SMEs. *American Journal of Industrial and Business Management*. 2, 64-75.

[66] African Development Bank Group. (2013). Op. Cit..

[67] Abasiekong, O. 2012. The Nigerian leadership debacle. *The Nigerian Voice,* 8 August 2012. Retrieved on 23/6/14, from http://www.thenigerianvoice.com/news/96035/1/the-nigerian-leadership-debacle.html

[68] Waziri, K. M. & Awomolo, O. F. (2014) Protection of Traditional Knowledge in Nigeria: Breaking the Barriers. *Journal of Law, Policy and Globalization.* 29. 176-186.

[69] It is worthy of note that Yauri had reported about this time that FDI-related foreign economic policies received most significant attention of the Nigerian government in the last decade and a half before that year. See: Yauri, N. M. (2006) Foreign Direct Investment and Technology Transfer to Nigerian Manufacturing Firms-Evidence from Empirical Data, *Central Bank of Nigeria, Economic and Financial Review, 44;2. 18-38;*

[70] African Development Bank Group. (2013). Op. Cit.

[71] Ibid.

[72] See generally: Anon. 2012. Rescuing the Economy from Looming Debacle. *Thisdaylive online newspaper.* 25 Dec 2012. Retrieved on 23/6/14 from http://www.thisdaylive.com/articles/rescuing-the-economy-from-looming-debacle/134462/.htm; Abasiekong, O. 2012. Op. Cit.; Waziri, K. M. & Awomolo, O. F. (2014) Op. Cit.

[73] UNCTAD, (2009) Investment Policy Review–Nigeria; Available at *http://www.unctad.org/en/docs/diaepcb20081_en.pdf. cited in* Dutse, A.Y, Okwoli, A.A and kurfi, A.K. (*2011).* Op. Cit..

[74] For instance there exists in Nigeria, the National Agency for Science and Engineering Infrastructure (NASENI), which it is said has as part of its scope of duties the propagation of the use of reverse engineering. However, in an interview with the Guardian news, the director of the agency, Prof. Olusegun Oyeleke Adewoye, stated that though the agency was created majorly for reverse engineering, a lot of head-way has not been made by it because the successive governments in the country, with their different agendas and policies usually do not abide by the law establishing NASENI, especially with regards to finance and funding. See: Anuforo, E. (2011). Op. Cit.

V. Prospects for Nigeria: Making a Case for use of Reverse Engineering in Nigeria

Nigeria as a Country still has ways to go with regard to the use of reverse engineering for technology development and general increase of its GDP. While steps have been taken by the government in this regard, not much success has been registered.[75]

Using this reverse engineering, Nigeria can design and mass produce several products,[76] which are currently being mass imported at costly rates into its borders from other more technology manufacturing and patenting countries, such as fashion wrist watches, safety pins, textile materials, toys, electronics, utility equipment, cars, ships, trains, auto spares, electrical, mechanical and scientific equipment, ICT equipment parts, weapons, and so on.

Recently, it was reported that Coscharis Technologies Limited deployed a state of the art-reverse engineering technology at the Covenant University, Otta, Nigeria.[77] This was said to have been done with the aim of bringing up a technology development and improvement conscious generation, by catching them young. Such step will aid with training capable hands in the reverse engineering market, so that Nigeria can focus on it and boost it as a veritable tool for economic growth in Nigeria, just as successfully done by China.

If truly, one of the Nigerian 2020 goals includes the raising the capacity for a knowledge-based and innovation-driven economy, then reverse engineering must be promoted as it leads to innovation,[78] which ultimately leads to economic growth. Consider the analysis below:

a. Innovation is the same thing as invention, which leads to the right to patents and generation of income from use of such innovation, while same is protected by intellectual property.
b. Such generated income can be channelled towards further research and further innovation and further generation of income.
c. Such income can also be injected in to boost other aspects of the economy of the country in other to further diversify same and generally boost income.
d. On the other hand, the ability to create such innovations reduces reliance on other countries for the production of such commodities and therefore reduces reliance on imports.
e. Meanwhile, it increases the ability of the country to create commodities for exports especially where more efficient and advanced technology is developed as a result of the reverse engineering process and this in turn generates income for the country thereby boosting the economy.
f. It also reduces the level of poverty and unemployment as the fostering of the process creates more opportunities for the knowledge and skill acquisition, which in turn provides sources of income for the citizens for expansion of businesses and production capacities, in a revolving cycle that sees an increase in job creations and reduction in unemployment and poverty.
g. It gradually increases the confidence in the country's market for its exportable commodities, thereby increasing spending from foreigners in the country's economy and therefore generating income, boosting investment in the country's market and setting up standards for the country, which all lead to generation of income to boost the country's GDP.
h. It leads to discovery and use of more raw materials in the search for ways to improve products by the reverse engineering process and this in turn creates further export and innovation opportunities for the country.
i. The increase in income generation, leads to increased wages and salaries which in turn provides better labour productivity and reduces emigration of working class citizens as a result of general satisfaction derived from working conditions.
j. On the other hand it increases immigration of labour into the country, leading to increased productivity and therefore income generation.

All these pointers eventually lead to economic growth of the country and as seen with the case in China, are all traceable to the propagation and promotion of technological development via reverse engineering. Nigeria can fully tap into this amazing wealth creator, only by ensuring that it focuses on the use of reverse engineering to achieve innovation.

VI. Summary/Conclusion

In this paper, we argue that reverse engineering is the next best step the government of Nigeria can take, as was done in China, in order to uplift the economy and give Nigeria more competitive advantage in the world economy.

Nigeria must therefore give reverse engineering sufficient focus and attention to allow it to grow into a huge income generating sector of its economy, as it is public knowledge now that reverse engineering was the platform used to achieve what China has achieved.

We might say we are just beginning and therefore just require monitoring, diligence and more focus to thrive in this aspect of the economy. If that be the case, then government must be reassured that they

[75] Aginam, E. (2014). Op. Cit.
[76] Ibid.
[77] Ibid.
[78] PLATT, J.R. (2010). Ibid.

are on the right path and encouraged to do more, as the benefits of persistence on this path cannot be over-emphasized. This is what is evident in the system and process used by China in its amazing transformation from a developing economy to the second largest economy in the world.

The Nigerian government must therefore in like manner, commit itself to innovation creation through support for reverse engineering as well as developing polices to boost same thereby, bolstering and diversifying the economy to enable economic growth and an enviable economy, for the resource, culture, and people rich nation, that is Nigeria.

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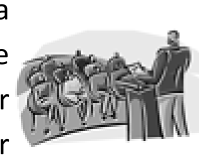

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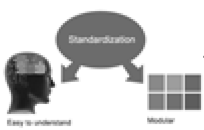

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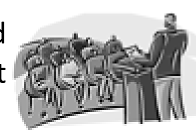

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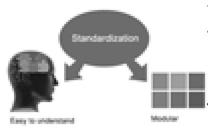

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- Two Column with Equal Column with of 3.38 and Gaping of .2
- First Character must be three lines Drop capped.
- Paragraph before Spacing of 1 pt and After of 0 pt.
- Line Spacing of 1 pt
- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
- Numbering of Second Main Headings (Heading 2) must be in Alphabets, Italic, and Font Size of 10.

You can use your own standard format also.
Author Guidelines:

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

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(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

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- Please note the criterion for grading the final paper by peer-reviewers.

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- To the point depiction of the research
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- Describe the method entirely
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- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
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- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
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Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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