

# Evaluate the effectiveness of grafted pepper (*piper colubrinum* l.) Production in the southeast and central highlands of vietnam

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## Abstract

Evaluating the efficiency of using grafted pepper varieties in the Southeast and Central Highlands of Vietnam from 2014-2016, on the ability to grow and develop in production, to meet the needs of pepper growers for tolerance with quick wilt and slow wilt diseases which have been destroying pepper growing areas. Applying the method of interviewing farmers with prepared questionnaires and combining field surveys for evaluation. The research results show that (i) Most grafted pepper were planted scatteredly in Southeast and Central Highlands with rootstock is wild pepper (*Piper Colubrinum* Link) origin from South America. Most grafted pepper plants had a growth period of 1-3 years until the survey time. There were also plants grown plants with 5-8 years old. Grafted pepper plants were mainly planted in diseased pepper posts in the garden and there was not much pure planting. (ii) Grafted pepper plants have a good survival rate, with 76% of households having gardens reaching a survival rate of over 90% after 12 months of planting and over 83% of grafted pepper gardens growing well. (iii) Grafted pepper plants have good resistance to quick wilt and slow wilt diseases (18-24% of gardens appear with only 1-3% of disease plants); no viral disease has been found; able to withstand waterlogged in growing areas; strong root system. Disadvantages of grafting pepper plants like scattered flowering, less panicles, low fruiting rate, poor drought tolerance so frequent watering, rootstock's shoots thrive, so required labors for removing, productivity was lower than normal pepper black pepper, low branching ability, grafting position were enlarged when pepper was developed. (iv) Yield of pepper plants grafted with scion of Indian black pepper cultivar at the age of 5 years (2014) averaged at 0.6 kg/plant, average yield of grafted scion of Vinh Linh at 3 years old were 0.3 kg/plant. For quality testing of pungency and aroma of grafted pepper was lower than regular pepper through sensory evaluation. Finally, the results of interviews on from August to September, 2019, in the surveyed areas in Southeast and Central Highlands,

at present, farmers do not accept to maintain grafted pepper in production because it is not effective.

**Keywords:** Grafted pepper, tolerant capacity, evaluation, Southeast, Central Highlands

## I. INTRODUCTION



Picture.1: Investigation of grafted pepper by IAS' scientists in BRVT province, Southeast, Vietnam (2015)

Pepper (*Piper nigrum* L.) is a spice plant with high economic value. Vietnam is a country with leading production and export pepper to many countries around the world. Pepper is one of the few strategic products of the country and has reached over 1.2 billion USD/year. However, many production areas are seriously threatened by diseases of quick wilt and slow wilt diseases, anthracnose caused by fungi such as *Phytophthora* sp., *Fusarium* sp ... and viruses causing serious damage to many growing areas of pepper in the Central Highlands and Southeast are heavily affected, even many gardens are nearly destroyed. Since then, pepper production has decreased significantly, farmers have lost their incomes and their life faced many difficulties. Therefore, to prevent the disease from damaging pepper gardens, growers have tried to apply the grafted pepper plants on the wild pepper *Piper colubrinum* Link. is one of the solutions to control the diseases. This is also one of the contents studied from 2006-2009 on grafting technique, grafting

position and evaluation in the first stage of grafted pepper. The results of this study have shown the compatibility of wild-type pepper with Vinh Linh and Indian pepper varieties, and the harmful effects of fungal pathogens have not been found (Nguyen Tang Ton *et al.*, 2010).

Several countries in the world with large pepper growing areas such as Brazil, Malaysia, and India have studied grafted pepper plants and some results have also been published and are valuable references. In Vietnam, so far no studies have been conducted basically and completely, nor has any actual model of grafted pepper been concluded. On the other hand, in the time when many pepper gardens were seriously damaged due to the quick wilt and slow wilt diseases, pepper growers wanted to have pepper seedlings to limit the harmful fungi that were devastating pepper gardens. Meanwhile, pepper breeders in the region were advertising information on the superiority of grafted pepper such as being able to withstand to quick wilt and slow wilt diseases, good growth, high yield, good quality ... and sell with prices from 22,000 to 40,000 VND/potting bag depending on the region at the period of 2013-2014. When the price of pepper grains has remained high at that time, the production efficiency is quite high. Therefore, many farmers in Dong Nai, Ba Ria - Vung Tau, Binh Thuan, Binh Phuoc, Gia Lai, and Dak Lak provinces buy grafted pepper plants to grow new plants in the gardens to replace the dead pepper plants.

Farmers growing grafted pepper plants to limit the quick wilt and slow wilt diseases is a justifiable demand in the context of the mass death of many pepper gardens that cannot be controlled. However, this issue needs to be evaluated and studied sufficiently to make convincing conclusions based on scientific and practical production to recommend for development or restriction of grafting pepper cultivation in production areas. From there, it is possible to provide an information channel to help pepper growers minimize economic losses in growing un-tested grafted pepper in Vietnam. Therefore, the study "Evaluate the effectiveness of grafted pepper (*Piper Colubrinum* L.) production in the Southeast and Central Highlands" was carried out with the aim to identify the current situation and assess the growth and development of the grafted pepper with the scion is plant pepper (*Piper nigrum*) on the rootstock of wild pepper (*Piper colubrinum* Link.) into production.

## II. METHODOLOGY OF RESEARCH

(i) Time and place of research: Conducted from March 2014 to May 2015 and verify production reality until August to September, 2019. Places: In the Southeast region (SR): Binh Phuoc, Dong Nai and Ba Ria-Vung Tau provinces; Highlands region (HR): Dak Lak and Dak Nong provinces.

(ii) Content and methodology of research

- Secondary data collection: Conducting an overview of domestic and foreign research results on grafted pepper plants on the wild pepper rootstock *Piper colubrinum* Link., relevant information in the provinces.

- Survey at farmer households who growing grafted pepper: Information needed for collection:

+ General information of farmer household (head of household, location, area of pepper, number of pillars, varieties used, time of planting ...)

+ The situation of using grafted pepper varieties (origin, type of rootstock, grafted shoots (scion), height of grafting, planting time, compatibility, agronomic characteristics ...)

+ The situation of major pests and diseases: (possibility of infection, rate of diseases)

+ Productivity and opinions of growers during surveys and current situation (2019).

- Number of households surveyed: a total of 120 households for the two regions of Southeast and Central Highlands. Among them, there are 90 households growing mixed pepper and 30 households growing pure pepper (to compare the possibility of applying farming methods). In Binh Phuoc, Dong Nai and Ba Ria-Vung Tau provinces were selected in districts with many households growing mixed pepper (60 households growing mixed pepper (grafted plus normal peppers) and 15 households growing pure pepper (only grafted peppers). In the Central Highlands region with Dak Lak and Dak Nong provinces, each province chooses the districts that have grown many grafted peppers (there are 30 households growing mixed pepper and 15 households planting pure pepper).

- Surveying methodology:

+ The survey was conducted by interviewing farmers using prepared questionnaires.

+ Sampling: because new grafted seedlings are newly planted, so the number of households planting scatteredly in the area, so the sample selection is based on the list of grafted seedlings sold by supplying units and localities. The number of households with a number of posts were more than 50 posts/garden both pure planted and gap planted.

+ The consultation on grafted pepper plants from technical staffs of the Agricultural Extension Center, the Agriculture Department, farmer associations ...

(iii) Assess the growth and development of grafted pepper in production gardens.

- Select 6 gardens with grafted pepper plants in Dong Nai and Ba Ria - Vung Tau to assess growth, disease situation and yield in the gardens planted with more than 50 posts.

- Collection of data:

- + Elements of grafted pepper productivity in the gardens have been harvested.
- + Ability to grow: the ability to give level 1 branch, plant height
- + Other agronomic criteria: ability to bear fruits and fruit formation.
- + Record the current status of pepper disease symptoms in surveyed households using different varieties to assess the prevalence of diseases on grafted pepper plants. Percentage of diseased plants (%) = (number of diseased plants/total surveyed plants) x 100.

(iv) Evaluation of grain quality in the room

- Collect fresh peppercorns and dried peppercorns to assess the sense of pungency and aroma of grafted pepper grains compared to normal pepper grains.
- The time for quality sample tasting of grafted pepper compared to normal pepper on May 27, 2015. The sample was tested on 9 people with the name of the both samples of pepper is just marked to ensure objectivity.

Methods of data processing: data are synthesized with descriptive statistical processing, frequency analysis... Apply popular software like excel, SPSS 16.1 ...



Picture 2: Investigation of grafted pepper by IAS' scientists in High Lands, (2015)

### III. RESULTS AND DISCUSSION

#### *Some previous research results on grafted pepper plants*

Research using resistant rootstocks to overcome biological and abiotic-related issues has been widely used in crops that are known such as fruit trees, tomatoes and recently in chili [1]. However, the practice of using grafted pepper to limit pathogenic fungi causing quick wilt and slow wilt diseases in pepper production is little interest for research in Vietnam. Therefore, in order to apply this technique, it is necessary to have varieties with disease resistance, species that are genetically close to pepper to use as rootstock. In particular, the wild pepper *P. colubrinum* L. is one of the species capable of researching for this goal.

*P. colubrinum* L. is native to Brazil, grows wild in swampy areas and has been found to be resistant to the quick wilt disease caused by the fungus *Phytophthora capsici.*, and at the same time withstands to burrowing nematodes (*Radopholus similis* Thorne) damages the roots of pepper plants. Therefore, the exploitation of wild-type pepper lines as rootstocks resistant to pepper pests is very important. *P. colubrinum* L. is a preferred glossy and naturally growing plant in swampy areas, with numerous stomatal roots that penetrate into the soil, forming a fairly strong root system and able to stand on these roots.

Grafting a pepper plant in production (*Piper nigrum* L.) to the rootstock is a wild pepper plant (*P. colubrinum* L.) that was first implemented in Brazil and later in Sarawak, Malaysia. Results of research on grafted pepper plants (1968) by Albuquerque [3] in Brazil have shown that this plant is highly resistant to pests caused by fungus sources in the soil, the success rate of grafted pepper plants are 98%. The vegetative growth under experimental conditions is quite good, and grafted pepper plants grow well in areas where soil moisture is maintained.

However, the survival rate of grafted pepper was quite low and died after four years follow-up. Studies of cell anatomy have shown abnormal thickening at the graft point due to overgrowth of the scion (*Piper nigrum* L.) and the appearance of stem fissures and blackening formation at the graft contiguous area between scion and rootstock. Different grafting methods were also studied in Sarawak. However, in India, the results of research on grafted pepper plants showed that grafted plants lasted for nine years under daily watering conditions and also indicated that watering is a key condition for surviving grafted pepper plants. The successful grafting results of 20 cultivars of this wild pepper showed that *P. colubrinum* L. was compatible with all experimental varieties. If grafted buds are stem vines, the plant begins to bear fruit in the first year, while grafted buds are secondary runners, plants give fruit in the third year [6].

The results of a study in Kerala, India to evaluate the effects of eight grafted pepper varieties on the *P. colubrinum* L. wild pepper rootstock showed that in February and March was the best time for grafting season [9].

In Brazil, using the wild pepper *P. colubrinum* as the rootstock, the grafted pepper plants developed well in the early stages, but after four years of planting, the grafted pepper plants grew poorly [8]. Experiments using rootstock varieties *P. chaba* grafted with many cultivars were growing in production but failed, in particular the graft point was separated after two years of planting probably due to incompatibility [7].

In India, the *P. colubrinum* wild pepper is grafted with the pepper varieties in production, showed that the grafted pepper plant grows and develops poorly for a long time [6]. According to Manohara *et al.*, [7] noted that graft between pepper varieties in production and the wild pepper *P. colubrinum*, *P. hirsutum* and *P. arifolium* were unsuccessful.

The wild-type *P. colubrinum* used as a grafted rootstock is an approach to solving the problem of tolerance to soil-borne fungi in pepper cultivation in Brazil, Malaysia, and India. The grafted pepper plant showed success at the beginning time, but then the survival rate was quite low due to incompatibility problems at the grafting point [5]. After that, the hybridization between wild pepper *P. colubrinum* and growing pepper *P. nigrum* L. cultivars has been implemented in Malaysia, but it has not been successful, the main reason is the different degree of polyploid and no correlation [5]. With the development of biotechnology, there will be much hope for the potential for transfer of the desired resistance gene from *P. colubrinum* to *P. nigrum* L.

and betel do not have a centralized ring of cambium and underdeveloped wooden circuit [2].

Research on grafted pepper plants in key agricultural ministry research project in the period 2006-2009 by Nguyen Tang Ton *et al.* [4] have shown that: (i) In the grafting technique, the wedge-type graft gives a higher survival rate than the connecting graft method and when cultivated outside the field, the wedge still gives higher survival rate. Grafting at 30-40cm site above rootstock and diameter of rootstock and scion 3-5mm is most suitable. Survival and growth rates of grafted plants during the nursery stage were not different between treatments; (ii) Compatibility of scion bud of Trung pepper variety with wild-type rootstock is low. Vinh Linh and Indian peppers are two varieties that have good compatibility with wild pepper rootstock. When planted outside the field, the grafted shoots grow and develop well, and until the time of monitoring, grafted pepper has not been recorded any case death caused by *Phytophthora capsici*, however, slow wilt disease still causes mild to moderate damage (7-10%) and grafted pepper plants have mild to moderate virus infection with main symptoms are leaf spots and light yellow spots. Results of monitoring and evaluation of grafted pepper plants to *P. colubrinum* L. wild pepper, after 18 months of growing in the field, showed that pepper yield from 450-800 kg/ha but there was no significant difference.

#### **Evaluation results on grafted pepper growing in Southeast and Highlands regions**

##### **- General information on grafted pepper**

(i) Scion varieties: In recent years, due to the quick wilt and slow wilt diseases of epidemics causing



Picture 3: Grafted pepper plants applying wedge grafting method in the investigation areas (2015).

In addition, the experiment of grafting between pepper plant on betel rootstock confirming that the ability to combine so that scion cuttings can live and develop normally is not successful because pepper

severe damage in many pepper growing areas in the Southeast and the Central Highlands regions, farmers need seedlings resistant to these harmful pests. The solution of pepper plant grafting with wild-type rootstock is one of the choices of pepper growers

while there is no pure pepper variety that shows high resistance to these diseases. This rootstock is called by many farmers as: Wild Pepper, South American Forest Pepper, or Amazon Forest Pepper. However, through a field survey, all of these names are the same kind of forest pepper rootstock with the scientific name of *Piper colubrinum* L. Most of the households used grafted shoots Vinh Linh pepper variety with 97.8% of surveyed households and only 2.2% of households used Se pepper variety.

(ii) Time of growing grafted pepper by farmers

According to the household survey in the provinces of Southeast and Central Highlands, grafted pepper was mostly planted from 2012 to 2014. In the total household surveying questionnaires, 14.3% of households (13 households) planted from 2012, increasing gradually to 29 households (32%) in 2013 and then the largest increase in 2014 with 53.1% of the surveyed households (Table 1).

**Table 1. Time of growing grafted pepper by farmers in SR and HR (N=90)**

Starting year of growing grafted pepper	Number of surveying households	Percentage (%)
2012	13	14.3
2013	29	32.6
2014	48	53.1
Total	90	100

(iii) Area and type of land to grow grafted pepper plants

Area for growing grafted pepper plants, most of farmers only gap planted in the dead pepper pits and planted for exploratory trial, so the area was not much. Some gardens planted with grafted pepper with a larger area but not significantly. The gap planting is right on the pepper plants that are infected with fungus diseases, so the cultivated area of the household is quite variable. Grafted pepper growing gardens (attributed to the popular density of 2.5 x 2.5m) were divided into 3 levels as from 0.1 ha to 0.5 ha, from 0.6 ha to 1.0 ha, and from 1.1 ha to 3.6 ha of the total surveyed households. The analysis results show that most of the planted area is less than 0.5 ha with 73.1% of households, followed by 16.1% of households planting with a higher area (0.6-1.0 ha) and 10.8% of farmers planted on an area of over 1.0 ha (1.1 ha- 3.6 ha) of the total surveyed households (Table 2).

**Table 2. Area and type of land growing grafted pepper by farmers (N=90)**

Area to grow grafted pepper	(%)	Type of land	(%)
0.01 ha - 0.5 ha	73.1	Red soil	72.6
0.6 ha – 1.0 ha	16.1	Gray soil	14.2
1.1 ha – 3.6 ha	10.8	Other soil	13.2
Total	100	Total	100

Grafted pepper plants are grown on soils corresponding to the common pepper plants usually grow in production. In particular, red soil is grown with more than 72%, followed by gray soil with 14% and the remainder is grown on other soil groups such as small gravel, black soil, hard-to-drain land, sandy soil (Table 2).

(iv) Origin of grafted pepper seedling

The source of grafted pepper seedlings of the households in the Southeast and Central Highlands regions is quite diverse. The survey results show that the majority of farmers buy from private seedling production and trading facilities with 73.7% of the households; next, farmers planted wild pepper plants and grafted themselves because they gained experience from surrounding households and observed grafted pepper seedlings so they could produce their own grafted plants at home with 18.4%. Households who bought rootstocks (because wild pepper rootstock was not available) and do grafting on their own were relatively small with 5.3% of the surveyed households (Figure 1).

(v) The reason farmers grow grafted pepper plants

Through the household survey on the reasons or causes that farmers grow grafted pepper in SR and HR showed that there are many different reasons, and have been summarized into the nine main reasons presented in Table 3. The analysis results show that the most common reason for growing grafted pepper is because pepper plants often get quick wilt disease, they should switch to growing grafted pepper with 36.7% of farmers' opinions; next, 20% of the households said that they have listened to the advertisement of good information about grafted pepper resistant to disease so they should try it out; thirdly, farmers want to try and experiment with 10% of the farmers;

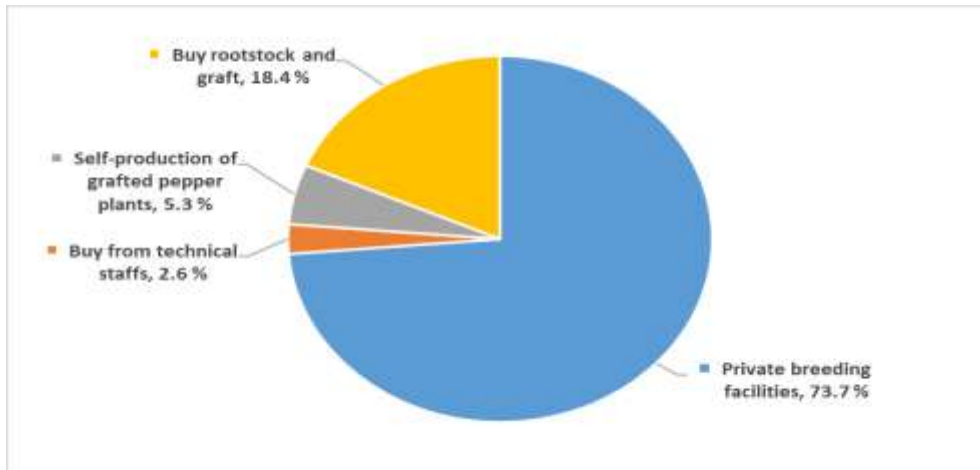


Fig 1. Origin of grafted pepper growing by farmers (N-90)

and nearly 8% of farmers think that due to the strong and abundant rooting of grafted pepper plants. In addition, there are other reasons but less common with 2-6% of households having their opinions, including: grafted pepper plants did not die from the disease compared to normal pepper; due to the flooded garden, grafted pepper was suitable; like to grow new pepper varieties with good characteristics and disease resistance; grafted pepper plants are water-resistant, high fertilizer, healthy and disease-free; and grafted pepper plants grow faster than normal pepper (Table 3).

Table 3. Farmers’ opinion on the reasons for growing grafted pepper in SR and HR

No.	Reasons for growing grafted pepper	No. of households gave opinions	(%)
1	Pepper plants often get quick wilt disease, they should switch to growing grafted pepper	33	36.7
2	Listening to ads, information on good resistance diseases of grafting pepper and should try planting	18	20.0
3	Want to try and pilot	9	10.0
4	Seeing strong growing grafted pepper plants, many roots, hoping the grafted pepper will	7	7.8

	thrive		
5	Grafted pepper plants did not die from the disease as compared to normal peppers	6	6.7
6	Because the garden was flooded, grafted pepper was suitable	6	6.7
7	Like to grow new pepper (healthy and resistant)	5	5.6
8	Water-resistant, high fertilizer, healthy, disease-free	4	4.4
9	grafted pepper develops faster than normal pepper	2	2.2
	Total	90	100

**- Evaluate on growing technology and take care grafted pepper**

In order to assess the ability to grow and care for grafted pepper that farmers can apply, planting and tending techniques have been investigated in households that grow grafted and normal pepper. The survey results showed farmers' opinions on planting and tending techniques are not really clear. 43% of households think that the techniques of planting and tending between the two types are the same, but 51% of the households think that the techniques differ between these two types. In particular, with 41% of households rated as different and about 10% said it was quite different. And the remainder is no opinion, since new planting households are unable to observe and evaluate (Figure 2).

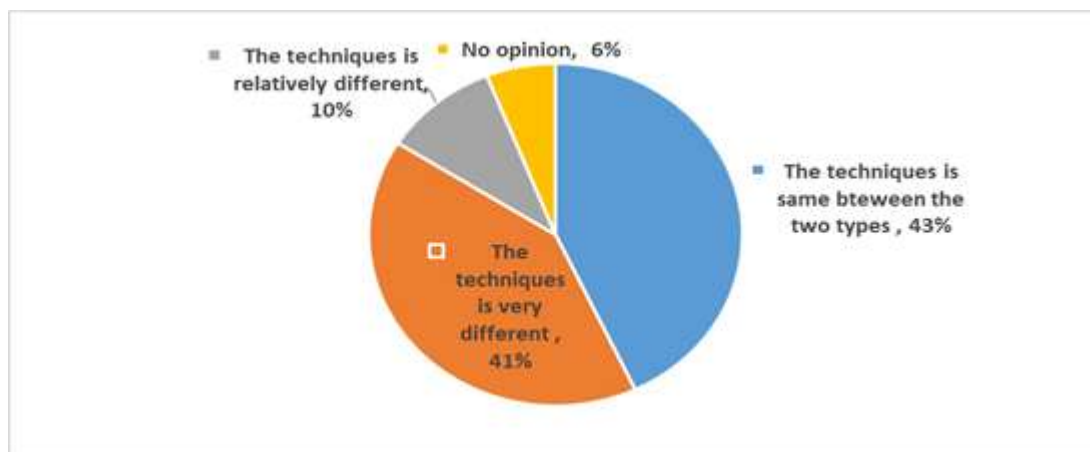


Fig. 2. Farmers' opinions on techniques of grafted pepper compared to normal pepper

Observing the grafted pepper plants in the field in the Southeast and Central Highlands and combining with interview farmers shows that there are some technical methods for cultivation grafted pepper plants and pepper plants are often different at the method of watering, fertilizing, plant protection, wiring (training by rolling the vines and buried under the ground) and tending (Table 4).

Table 4. Different methods of cultivation of grafted pepper compared to normal pepper

Cultivation methods	Grafted pepper	Normal pepper
Roll (Đôn) the pepper vines	No need	Needed (If grow by runner shoots)
Watering	More labor and fuel costs due to more watering times (2-3 days/irrigation in the dry season)	Less labor and fuel costs due to less watering (7-10 days/irrigation in the dry season)
Diseases treatment and cost	Lower due to less use of preventive pesticide	The cost of preventive pesticide is higher because of diseased plants
Fertilizer application	Apply more fertilizers	Apply less fertilizers
white bug in the root system (sùng trắng)	Easy to be harmed by a kind of white bug in the root system	Not seen
Labor for tending	Grows a lot of buds at the	No need labors to do this

	rootstock, so it needs labors to remove	
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The results of the evaluation show that it is not necessary to roll the vines and buried them under the ground in grafted pepper plants, but only to the normal pepper plants if they are used to grow by runner shoots. Regarding watering methods, grafted pepper plants need to water more and more frequently than water for normal peppers. Grafted pepper have not seen the occurrence of many diseases, so it takes less pesticides than normal pepper plants those susceptible to many diseases. In particular, grafted pepper plants with rootstocks are very vulnerable to a kind of soil bug that damaging in both the Central Highlands and the Southeast, so it needs to be treated regularly; secondly, the rootstock buds grow regularly, so it takes labor to

eradicate the buds, in order to avoid nutritional competition with grafted pepper plants.

**- Evaluate the growth situation of grafted pepper**

(i) Agronomic characteristics

The grafted pepper plants showed strong growth, possibly with more water supply, more nutrition and a stronger root system. However, the overall yield of grafted pepper is generally lower than that of normal pepper. Meanwhile, drought tolerance of grafted pepper is much lower than that of normal pepper, if in the dry season without providing irrigation water after 2-3 days, the grafted peppers will wither, while pepper plants are often able to drought tolerance. Therefore, grafted pepper plants need more water and must be supplied more often than normal peppers because the root source is living in swamps in Brazil, the roots are strong but shallow.



Picture 4: Research on compatibility of grafting position of pepper plants by IAS' scientists (2015)

Another feature is that the rootstock constantly grows young shoots due to frequent water supply so it takes a lot of labors to eradicate. The results of monitoring the second year pepper garden at BRVT province and a business pepper garden (from 5-8-year-old) in Cam My, Dong Nai province showed that grafted peppers flowering several times a year, so on one post can have many types of fruits and flowers. The grafted pepper plant has poor branching ability, small canopy, low number of 1 level branches, low rate of fruit formation and scattered. Through monitoring and field assessments in the gardens and discussion with the head of households, the quick wilt death by *Phytophthora capsici* was not present in grafted peppers.

Table 5. The different characteristics between grafted pepper and normal pepper plants

Characteristics	Grafted pepper	Normal pepper (Popular pepper cultivar)
Growth capacity	More healthy	Normal
Yield capacity	Very low	High
Dry tolerance	Poor (about 2-3 days without watering the plants will wither)	Fairly high drought tolerance
Water demand	Need water regularly and more water	No often

Root development	The roots grow shallow	The roots grow deeper and wider
Sprouting at the rootstock	Growing strongly at the rootstock	No
Flowering	Scattered	Concentrate
The ability to branch	Bad, thin canopy	Pretty good, thick canopy
Fruit/tree ratio	Low	Medium - High
Fruit formation	Scattered on the same plants with old and young fruits, young panicles and flowering	Fruiting and ripe concentration
Infection of foot rot /quick wilt dead due to <i>Phytophthora capsici</i>	Recorded at a very low rate	Easy to get infection of quick wilt death

(ii) Evaluate the growth situation of grafted pepper plants

The growing status of grafted pepper plants in the farmer's garden, was dividing into 4 level growth rates of good, fair, average, and poor growth. Through the evaluation of the farmers, up to 57% of the respondents said that the grafted pepper plants had grown well and 27% of the respondents said that the plants were fairly growth, third was average growth with 12% and the rest were poor growth with 4% (Figure 3).



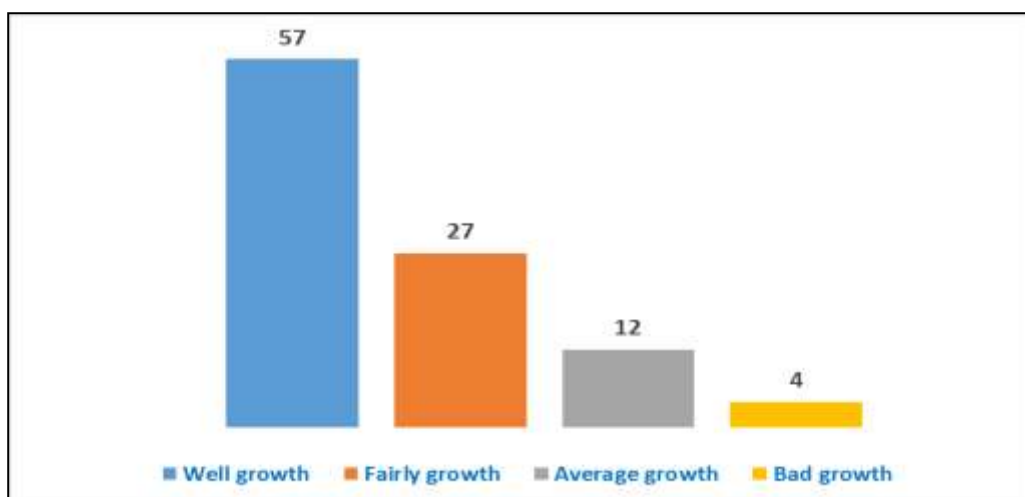


Fig 3. Farmers' assessment on the growth ability of grafted pepper plant (%)

As for the whole pepper growing gardens which are fully cared for, especially the irrigation water, the growth is quite well.

**Assess the situation of diseases harmful to grafted pepper plants**

(i) Some main diseases cause damage to grafted pepper plants

The quick wilt disease caused by *Phytophthora capsici* fungus in pepper growing gardens did not appear with nearly 82% of the opinions of farmers. Only 18.4% of farmers said that grafted pepper can be infected with *P. capsici* and died quickly, due to the prevalence of *P. capsici*, which could be infected with fungi from the grafted position or on leaves. However, at the time of the field survey at the gardens, there were no symptoms of quick wilt/death disease appeared. Opinions of pepper farmers largely reflect the reality based on garden observations after 1-3 years of planting. This can be explained that the grafted pepper plants promote disease resistance when the upper grafted bud is isolated from the ground with a safe distance and the adjacent graft site is not compromised. Because fungal pathogens in the soil can penetrate almost all parts of the pepper plant such as leaves, roots, stems, branches ... especially the part located in the soil and close to the ground. Therefore, if the grafted pepper plants have twigs and leaves from the top of the grafted close to the soil, they may also be infected, especially in the rainy season, the pathogens in the soil are splashed by the water on the upper part of the plants then infect and harm. In some surveyed areas, especially in the Central Highlands, farmers who planted grafted pepper have not learned the technique so they do not promote the disease resistance of grafted pepper; even some farmers still apply the roll vines techniques in grafting pepper, so, it is no longer

available resistance and grafting pepper has become normal pepper.

For slow wilt disease or slow death yellow leaf disease due to a combination of harmful fungi represented by *Fusarium solani*., *Phytophthora capsici* and nodular nematode *Meloidogyne incognita* and *Radopholus similis* burrowing nematode. According to the farmer's assessment, more than 75% of the farmers said that the grafted pepper plants were not infected with the slow wilt disease, and 24.5% of the farmers said that the grafted pepper plant was infected with slow wilt disease (yellow leaf disease) at a low rate of 1-3% (Table 6).

**Table 6. Farmers' assessment of the disease potential of grafted pepper plants**

Type of diseases	Farmers' assessment on the ability of grafted pepper plant reacts with serious diseases			
	No infection	Infection low rate 1-3%	Infection with rate >3%	Total
Quick wilt disease	81.6	18.4	0	100
Slow death yellow leaf disease	75.5	24.5	0	100
	No infection	Infection with low rate	Infection with rate > 80%	Total
Anthracoese	93.9	0	6.1	100

For *Collectotrichum gloeosporioides* anthracnose on grafted pepper plants, the farmer's evaluation is based on observations of grafted pepper plants in the field. Fungal pathogens invade leaves, buds, branches and pepper. The typical symptom of the disease is angular yellow spots surrounded by yellow halos. The lesions

are irregularly shaped and have a yellow halo outside the lesions. The lesions spread, drying leaves and falling. For this disease, nearly 94% of the farmers' opinions said that the grafted pepper plants were not infected, but about 6% of the farmers assessed that the grafted pepper could be infected with anthracnose disease with the disease rate as high as 80 % (Table 6).

(ii) Viral diseases

The pepper is easy infected with virus (often called mad pepper disease) with easily recognizable symptoms because it is characterized by stunted plants, small leaves, thick leaves, floating mosaic marks, pale green yellow, and edges leaves curl, not growing, pepper leaves are curly. Due to many reasons such as: infected seeds from mother plants, cuttings are not disinfected, lack of water, micronutrients and disease vectors such as aphids, red spiders, thrips ... sting sucks and spreads from diseased plants to healthy plants. Virus infected pepper plants rarely die but their productivity decreases rapidly. The virus has now been identified as a strain of the cucumber mosaic virus CMV (*Cucumber Mosaic Virus*) and the Pepper yellow mottle virus PYMV (*Pepper yellow mottle virus*) based on ELSA techniques. For mad pepper disease, 100% of farmers' opinions said that so far, the grafted pepper were completely free from virus infection not like normal pepper plants.

**Assess the compatibility of grafted pepper plants**

Interoperability between rootstock and scion is one of the important criteria affecting the ability to live after grafting and the ability to grow later of the grafted plant. Observations and assessments of grafted pepper plants growing in the field about compatibility of plants at grafting points show that the number of gardens under 30% of grafted pepper plants has a smoothing level at grafting points with more than 20% of households; the number of grafted pepper gardens with over 30-60% seamless at the grafting point has more than 24% of households; nearly 14% of households have recorded that the grafted pepper gardens have reached a smooth level at 60-90%; And nearly 38% of the households (accounting for the highest) pepper gardens recorded the smoothing level at the grafting position reaching over 90%. In addition, 3.4% of households recorded newly planted grafted pepper gardens so they could not evaluate this indicator (Table 7). The grafted pepper gardens with smoothing level of 90% or more are growing and developing normally.

Observations of grafting points with abnormal hypertrophy indicate that the majority of grafted pepper gardens have normal grafting positions, ie without abnormal hypertrophy with 81.6% of surveyed gardens. However, there are still 6.2% of the gardens with grafted pepper plants having 100% hypertrophy at the grafting position and about 12% of the gardens having grafted pepper plants with the level of 5-30% of the plants in the garden (Table 7). It is possible that new gardens were planted in year 1 and year 2 so the degree of hypertrophy at the junction point is unknown.



Picture 5. Investigation of grafted pepper over 8 years old in Cam My district, Dong Nai province (2015)

**Table 7. Assessment of the compatibility at the grafted position**

Items	Assessing the compatibility at the grafting position of the grafted pepper plant						
	Level	<30%	30-60%	>60-90%	>90%	Other	Total
Smooth		20,7	24,1	13,8	37,9	3,4	100
Abnormal hypertrophy	Level	<5%	5-15%	>15-30%	100%	Normal	
		6,2	4,0	2,0	6,2	81,6	100

pepper gave yield in the business period (05 years old) varied from 0.2-1.2 kg/plant, reaching an average of 0.6kg/plant, 3-year-old Vinh Linh grafted pepper ranges from 0.2-0.4 kg/plant, averagely reaches 0.3 kg/plant; and Vinh Linh pepper (normal pepper) yield of three years old varies from 0.3 to 0.5 kg/plant, averaging 0.4 kg/plant (Table 8).

However, through field survey at 5 and 6 year old grafted pepper gardens in Cam My, Dong Nai province, most of the grafting position of the plants is not smooth and hypertrophy. In particular, the graft shoots grow stronger than the rootstock, the stem circumference above the graft position can double the circumference of the rootstock. It is



Picture 5. Researchers studied some wild pepper varieties in the mountain regions of Quang Tri and Quang Nam provinces (Vietnam) in the hope of finding a more suitable rootstock than the Amazon pepper rootstock. (2016)

possible that grafted pepper plants at the stage of basic growth did not show clearly about hypertrophy due to not yet completely growth, but the later when it has developed, the hypertrophy at location of grafting increased very clearly.

**Possibility for yield of grafted pepper plant**

Most of the households surveyed on grafting pepper were in the period of basic growth and gap planting, so the yield indicator only monitored at some households in Lang Me hamlet, Xuan Dong commune, Cam My district, Dong Nai province in period of 3 - 5 years old. Then, this data yield is for reference only because there are not many more gardens to verify. Sampling results of these gardens in the 2014-2015 season show that the Indian grafted

**Table 8. Preliminary assessment yield of grafted pepper**

Pepper variety	Unit	Lowest	Highest	Average
Grafted pepper with Indian variety	Kg/plant	0.2	1.2	0.6
Grafted pepper with Vinh Linh variety	Kg/plant	0.2	0.4	0.3
Normal pepper (Vinh Linh variety)	Kg/plant	0.3	0.5	0.4

Note: N=10 plants/pepper variety

Based on a survey of two grafted pepper gardens in Kim Long commune, Chau Duc district, BRVT province, at the time the gardens were 15 months to 24 months old and preparing for fruit formation. It showed that the number of panicle/pillars of grafted pepper plants was less than that of conventional pillars. And the number of seeds/panicle is only 30-40% compared to normal pepper, meaning that the fruit rate of grafted pepper is lower than 30-40% compared normal pepper. Therefore, according to the evaluation of grafted pepper farmers, the yield of grafted pepper can be 30% lower than that of normal pepper in the same farming conditions.

### Quality evaluation - the pungency and aroma of grafted pepper

The pungency and aroma of pepper (right after grinding) were assessed sensitively by fresh and dry seed samples using symbols of normal pepper and grafted pepper to ensure objectivity when evaluating. This is also an important indicator in evaluating the quality of grafted pepper. The results of pepper in-room tasting and scoring based on a 10-point scale of grafted and normal peppers for the above two indicators showed that the pungency of fresh (freshly harvested) pepper averaged 7.78/10 points and dry pepper (12% moisture content) is 7.85/10 points compared to normal pepper. The scores are similar to the criteria for the aroma evaluation of fresh and dried pepper, respectively, 7.05/10 and 7.02/10 points (Table 9).

**Table 9. Results of quality evaluation of grafted pepper compared to normal pepper**

Grafted peppercorn samples	Pungency	Aroma
Fresh peppercorn (freshly harvested)	7,78 ± 0,37	7,85 ± 0,41
Dry peppercorn (12% moisture content)	7,05 ± 0,45	7,02 ± 0,44

Note: N=9 people; 10 points scale.

Thus, the peppercorn of grafted pepper has a pungency and aroma have about 20-30% of quality scale lower than normal pepper according to the sensory evaluation in this research.

### Assess the possibility of stable development over time of grafting pepper in the survey areas

Results of online interviews in surveyed areas on August to September, 2019 on the efficiency and stability of grafted pepper production with people who understand grafted pepper in DARDs, agricultural and agricultural extension workers, The Sub-departments of Plant Protection Department in the provinces of BRVT, Dong Nai, Binh Phuoc (Southeast region) and Dak Nong, Dak Lak (Central Highlands) showed that grafted pepper plants were not accepted by farmers in production because of the ability to develop in the following years (2016-2019) are not effective, so almost farmers in the former surveying areas break down the gardens or do not plant new plants of grafted pepper.

## IV. CONCLUSION AND SUGGESTION

### Conclusion

- From 2012-2016, grafted pepper plants were mainly planted scatteredly in many Southeast and Highlands provinces. The rootstock is wild pepper or forest pepper (*Piper Colubrinum* link.) originating in South America. In the beginning grafted pepper plants to be planted in the Southeast region, and then spread to some Highlands provinces, the common surveying planting area is less than 0.5 ha/household. Grafted plants were mainly purchased from private seed dealers.

- Most of grafted pepper plants in the survey time have 1-2 years of growth, and small number of 5-6 years old gardens. At the time of the survey, most of the grafted pepper plants were grown for gap filling in death pepper pillars due to diseases in the garden and a few were planted purely all the gardens. The grafted pepper plants has a good survival rate after 12 months of planting and most grafted pepper gardens have good growth ability.

- Grafted pepper plants have some advantages such as being able to resist diseases of fast death and slow death; no viral diseases has been found; able to withstand waterlogged in growing areas; plants with strong root development. However, grafted pepper also have some disadvantages including: scattered flowering, little fruiting, little sprouts, low fruiting rate, poor drought tolerance, require frequent watering, rootstock buds thrive and use more labors to remove, the grafted pepper yield lower than the normal pepper, low ability to branch, the grafting position is hypertrophy when the grafted pepper is developed.

- Results of online interviews in former surveyed areas form August to September, 2019 on the efficiency and stability of grafted pepper production with people who understand grafted pepper in DARDs, agricultural and agricultural extension officers. In the provinces of BRVT, Dong Nai, Binh Phuoc (Southeast region) and Dak Nong, Dak Lak (Highlands region), showed that grafted pepper were not accepted by farmers in production because the development ability in the years after 2016-2017 has

no effect. As a result, farmers destroyed the grafted peppers or did not plant new plants of grafted pepper.



Picture 7. Researchers collected wild forest pepper vines in Vietnam for proper rootstock research (2016)

### Suggestion

- Grafted black pepper plants should be further studied, evaluated and monitored for productivity, economic efficiency, growth ability and resistance to pests and diseases of grafted pepper for years.
- Do not encourage farmers to grow grafted pepper plants under difficult farming conditions, areas with scarce water resources, and farmers are not equipped with knowledge of caring techniques for this plant.
- In addition, it is necessary to continue researching on different types of rootstocks and shoots, giving priority to exploiting indigenous rootstocks (wild forest pepper available in Vietnam) on good genetic characteristics, and continuing to assess the quality of grafted peppercorns through chemical composition analysis.

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