Annual Progress Report
August 2018- July 2019

Progress report of Doubling Farmer Incomes through Grafted Vegetable Seedlings

Submitted to
Department of Horticulture
Government of Andhra Pradesh

ICRISAT DEVELOPMENT CENTER

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Background

Andhra Pradesh is one of the fastest growing states in India. It produces about 19.88 m MT of horticultural produce from 1.4 m ha, accounting for 6.74% of the country's horticultural produce. Total vegetable production in the state is 5.35 m MT from an area of 0.2 m Ha. The state stands fourth in the production of loose flowers (1.40 m MT), which is about 8.49% of the total production. (Horticultural Statistics At A Glance 2017: GoI and MoAFE)

Andhra Pradesh is home to one of the largest vegetable cluster in the world, called the Madanapalle cluster in Rayalaseema. Vegetable cultivation in this region is afflicted with soil-borne diseases along with issues pertaining to salinity and high temperatures. This leads to increase in cost of cultivation coupled with reduction in crop yield. Most of the small and marginal farmers in the region are hardworking and open to use modern practices like drip irrigation. However, for some time now, they have been plagued by increasing input costs and stagnating yields, rendering cultivation non-remunerative.

The Department of Horticulture is focused on transforming the highly drought-prone Rayalaseema region into the horticulture hub of the country, for which it leverages the Centre of Excellence (CoE) facility and infrastructure in Kuppam to benefit small and marginal farmers in the region. The state's Horticulture Department views the introduction of grafted vegetable seedlings of high value crops as a way to counter above factors to improve the livelihoods and incomes of farmers. The new global trend of grafting vegetable seedlings enables intensive and, continuous production, higher yields and boosts farm productivity.

Scope for grafting technology

Since the 1920s, Japan and Korea have been using grafting as an alternative approach in vegetable production to fight soil borne diseases such as Fusarium wilt, bacterial wilt and nematodes. The method was later used for commercial production and then adopted by many countries in Europe, the Middle East, Northern Africa, Central America and parts of Asia. Grafted seedlings can be used to produce fruit-bearing vegetables like watermelon, cucumber, melon, tomato, eggplant and pepper. Apart from providing resistance against biotic/abiotic stresses, the seedlings increase yields of cultivars.

The project on "Doubling Farmer Incomes through Grafted Vegetable Seedlings" is being implemented in Public Private Partnership approach. Since January 2017, ICRISAT in collaboration with the private partner Heirloom Seedlings and Plants Pvt. Ltd. (HSPL) is working at State of Art facility, available for protected cultivation in ICRISAT. The team worked on feasibility of vegetable grafting with a major focus on *Solanaceous and Cucurbitaceous* crops. During the extensive work, rootstocks of different vegetables like tomato, brinjal, chilli, capsicum, bitter gourd, cucumber and snake gourd were evaluated and research was conducted on screening of rootstock- scion combinations. These trials were aimed at identifying crop-wise best graft combinations in terms of increasing yield potential besides reducing overall cost of cultivation, for the benefit of small and marginal farmers.

As the results of this technology are encouraging in terms of increasing farm productivity as compared to the yield from non- grafted vegetable cultivation, there exists a good scope to scale it further with the help of NARS partners or state government (s). Looking into this opportunity, ICRISAT and HSPL agreed to work at CoE Kuppam in Chittoor district, with the financial support from Department of Horticulture (DoH), Government of Andhra Pradesh and

take the grafting technology forward to benefit the large number of vegetable growers in Rayalseema region of Andhra Pradesh.

Objectives

The overall goal of this initiative is to double the farmers net income through grafted vegetable seedlings in the Rayalseema region of Andhra Pradesh. The specific objectives are as follows

1. To establish a hi-tech grafted seedlings nursery for solanaceous and cucurbitaceous vegetables through the Centre of Excellence facility at Kuppam.
2. To establish a cluster of 400 ha to grow grafted vegetable seedlings in the Rayalaseema region during three cropping seasons.
3. To provide technical support and guidance with documentation to the cluster farmers to increase productivity.
4. Build awareness and capacity to train 1200 farmers in seedling grafting cultivation and conduct six farmer exposure visits-cum-field days.

Consortium partners and institutional arrangement

To implement this project in mission mode, a Public Private Partnership consortium approach is followed comprising of the following together with partners:

- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) leading the project and facilitating towards scaling up the improved technologies to all stakeholders
- Department of Horticulture, Andhra Pradesh for support in technical backstopping
- Heirloom Seedlings and Plants Pvt. Ltd. as a private partner for working on grafted seedling production at COE Kuppam

1. Activities at Center of excellence, Kuppam

ICRISAT along with HSPL decided to use 10 protected structures for producing grafted seedlings and demonstrate new crops and cultivars in few of those structures. As agredd in the meeting with Commissioner on 1st August 2018, the plan for utilization of 10 structures were shared with Department of horticulture (DoH).

1.1 Quality concerns at CoE Kuppam

As per the shared plan, seedling production were initiated from August 2018. However, there were some serious constraints faced in terms of quality of irrigation water, growing media available at CoE and unavailability of healing chamber, which is pre-requisite for producing quality grafted seedlings.

Even though the production started as per the plan, the saline irrigation water and poor media resulted in large scale seedling mortality. More than 8 lakh seedlings of both rootstocks and scions were sown, but a large quantity of the seedlings died (Fig 1) due to high electrical conductivity (EC) and total dissolved salts (TDS) of the coco peat and irrigation water available at the CoE (Table 1). To address this issue, water tankers were out sourced for irrigating seedlings. The results of the water and coco peat analysis done on 27th September 2018 at the ICRISAT laboratory are given in Table 1. As the grafted seedling are performing well in farmers field, other farmers are interested to grow grafted vegetable seedlings but they are facing problems in purchasing it due to higher price. So department need to come up with

suitable subsidy plan (i.e.@50 per cent rate), so that many more farmers will come forward to adopt this technology.

Table 1. Results of the water and coco peat analysis				
Sl. No.	Sample	pH	EC (mS)	TDS (ppm)
1	Irrigation water (IW)	7.63	0.79	722
2	Coco peat	6.83	1.73	1574
3	IW + Coco peat	6.97	2.70	2455

Note: Permissible limits to raise a nursery: EC = 0.7- 1.5 mS and TDS = 500- 1400 ppm.

Figure 1. Mortality due to high EC and TDS of irrigation water and coco peat.

1.2 Construction of healing chambers

The unavailability healing chamber was major concern as post-grafting, the seedlings need to be placed in specialized chambers to ensure high percentage of grafting success. To address this, we have built four healing chambers (low tunnels) that stand on benches to enable the graft union to heal. These healing chambers have low light and high humidity that enable less loss of water from the plant body resulting in callus formation and success of graft union. These structures are permanent and are being used for grafting activities in this project.

Figure 2. Healing chamber (Low tunnels)

1.3 Mass production of grafted seedlings

After resolving all these issues, grafted seedlings production of tomato, chilli, bitter gourd etc. were started from November 2018 at CoE facility. As per agreed MoA, seedling production is the responsibility of ICRISAT led consortium whereas creating demand, identification of the beneficiary farmers and the sale of the seedlings needs to be taken care by DoH, Andhra Pradesh. Accordingly, plan for developing these seedlings were shared on 10th August 2018 and the seedlings were being produced at CoE Kuppam.

Table 2. Grafted seedling production plan at CoE Kuppam

Grafted Seedlings	Timelines for seedling availability (in Thousands)													Total target of seedlings (in Thousands)
	15-Sep	30-Sep	15-Oct	31-Oct	15-Nov	30-Nov	15-Dec	31-Dec	15-Jan	31-Jan	15-Feb	28-Feb	15-Mar	
Tomato	30	30	30	30	30	30	30	30	30	30	30	30	30	390
Brinjal	25	25	25	25	25	25	25	25	30	30	30	30	30	350
Bitter gourd	5	10	10	10	10	10	20	20-	20	30	30	30	30	215
Snake gourd	2.5	2.5	2.5	2.5	2.5	10	10	10	10	10	10	10	10	93
Capsicum	30	30	30	30	30	30	30	30	30	30	30	30	30	390
Chilly	10	10	20	10	20	20	20	30	30	30	30	30	30	290
Cucumber (summer)							5	5	5	5	5	5	5	35
Watermelon (Summer)							5	5	5	5	5	5	5	35
Muskmelon (Summer)							5	5	5	5	5	5	5	35
Total no of seedlings														**1,833**

1.3.1 Grafted vegetable seedlings production

This activity is pertaining to objective one wherein focus was on to establishing a hi-tech grafted seedlings nursery of solanaceous and cucurbitaceous vegetables at the Centre of Excellence facility at Kuppam.

a. Sowing of rootstocks & scion

Rootstocks and scion varieties of tomato, brinjal, capsicum and pumpkin were re-sown in the second week of August in a hi-tech polyhouse. Crop wise rootstock and scion varieties used for grafting are mentioned in below table

Table 3. Rootstock scion combinations used for grafting at CoE Kuppam

Sr. No.	Crop	Rootstock	Scion
1	Tomato	KKBW/ KKKFL	PHS 448/ Sahoo
2	Brinjal	KKST/KKBL	Shyamala/ Super Gulabi
3	Capsicum	HPP	Bachata Inspiration
4	Pumpkin	GVML/KKEW/ FT	Hou Pmpkin
5	Bitter gourd	GVML	Palee/ Pragathi/ VNR22
6	Snake gourd	GVML/KKEW/ FT	EW Kovai

All most in all the crops, two rootstocks were used to graft the scion varieties. Depending upon the germination time of rootstock and scion varieties, seeds were sown so that both rootstock and scion will be ready for grafting within 20-25 days after sowing.

b. Sharing seedlings with farmers

The seedlings of tomato, capsicum, bitter gourd, brinjal and pumpkin were produced and with the help of DoH, the seedlings were shared to farmers from nearby village clusters. Altogether, ~73000 seedlings were sold to the farmers (figure 8). To demonstrate the effectiveness of the grafting technology, DoH facilitated the sale by giving subsidy on seedling cost which really helped the farmers to come forward and try t in their fields. However many of the seedling were unsold as there was not much demand and accordingly, DoH has informed ICRISAT led consortium partner to restrict the seedling production.

Figure 3. Brinjal rootstock.

Figure 4. Capsicum rootstock.

Figure 5. Pumpkin rootstock

Figure 6. Chilli rootstock.

Figure 7. Tomato scion varieties.

1.3.2 On-Farm demonstration

In order to establish a cluster of grafted vegetable seedlings growers in the Rayalaseema region, the on-farm trails were conducted in the nearby village during three cropping seasons. ICRISAT with the help of DoH identified villages in Kuppam block of Chittoor district. In some of the villages, grafted seedlings were given to the farmers to demonstrate the advantage of the grafting over non-grafted seedlings. These villages include Kuppam, Ramakuppam, Vasanadu, Gundupalle, Daseganuru etc. Farmers who cultivated grafted seedlings realised the benefits in terms of increase in crop duration, disease & pest resistance and yield thereby considerable increase in net income. The details of the seedlings distributed to farmers is given below in Table 3 and depicted in Figure 8.

Table 3: Crop wise sale of grafted vegetable seedlings

Sl no.	Crop	No. of seedlings
1	Tomato	14614
2	Capsicum	9870
3	Pumpkin	5000
4	Bitter Gourd	157
5	Brinjal	282
6	Snake Gourd	873

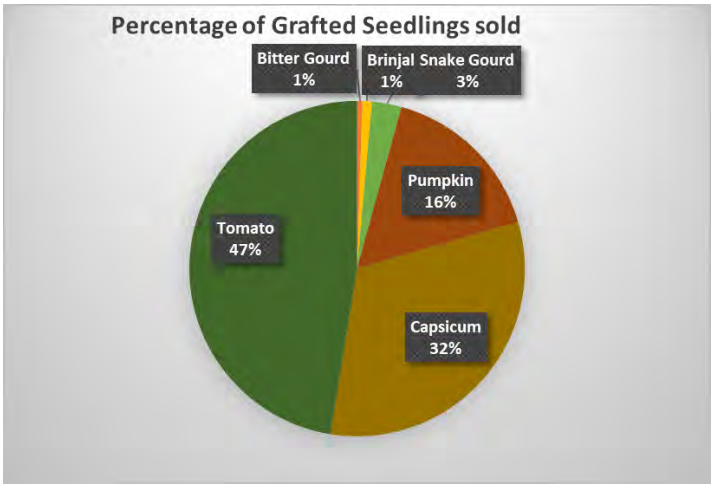


Figure 8. Crop wise seedling sale

Success stories

There were some case studies pertaining to net accrued benefits due to use of vegetable grafted seedlings by the farmers. Few of the farmers were monitored for yield benefits throughout the crop duration.

i) Grafting Tomato Seedlings for Disease Resistance

Sri. Chandrappa is an auto rickshaw driver and small farmer owning about 1 acre of land. He has been cultivating various varieties of tomato crop for years. Learning about doubling the farmers through the grafted vegetables program through horticulture department officials. He decided to try the new grafted variety of tomato developed in Center of Excellence for Vegetables and Flowers for improving yield and income. Sri. Chandrappa decided to try and harness the performance of tomato as advised by concerned staff and farm facilitators and compared with non-grafted variety. Sri Chandrappa received 7500 seedlings 90% subsidized rate from the department of horticulture. He has grown PHS 448 X R1 improved grafted tomato. Regular visit of farm facilitators and other departmental staff, ICRISAT staff for technical guidance was very much useful in timely monitoring the crop and training was availed regarding crop cultivation, agronomical practices. Sri. Chandrappa noticed significant disease resistance in grafted tomato over non Grafted varieties. As per his crop pickings, he generated overall income of Rs.170, 000 per acre. His input cost for the pesticides has been significantly reduced. Sri Chandrappa is happy for adopting to Grafted tomato Seedlings. He sincerely thanks the department of horticulture staff, ICRISAT and farm facilitators for all the required help to achieve the impact. The department has used his field for conducting field day and field visits to demonstrate to other farmers.

Figure 9. Tomato in Mr. Chandrappa's field

ii) **Grafting for Soil Nematodes resistance**

Sri. Joseph is a Tamil farmer who migrated to Bandasettipalle Village in Kuppam Mandal. He hired an abandoned Polyhouse for capsicum cultivation, it has been noticed that the polyhouse has been abandoned as a cause of soil nematode problem. Department of horticulture officials have approached Sri. Joseph and was advised him to adopt the Grafted vegetable in order to tackle nematode problem. He bought 1200 Grafted Capsicum Seedlings from the COE, Kuppam and observed significant difference in the plant health-vigour and less mortality compared to a non-grafted seedlings. He described the size of capsicum fruit is larger, significant difference in the color of the fruit. On a recent Visit by ICRISAT officials along with the Department Officials, he explained his agronomical practices and thanked the officials on advises and frequent visits for the field monitoring. Sri. Joseph expressed that he is interested to shift his entire cropping to grafted vegetable cultivation for the next season.

Figure 10. Capsicum in Mr. Joseph's field

1.3.3 Introducing new crop varieties for the farmers in the region

Considering the scope of this project and discussion with commissioner in the review meeting, the project private partner viz, HSPL focused on demonstrating the yield potential of new crops as well as the varieties of different high value crops under polyhouse and open field conditions for the benefit of the farmers in Rayalaseema region (Table 3). These demsonatrtions were also conducted in the CoE facility to explore the venue as a training option for nearby farmers and educate them on different production approach for doubling their income. The crops include high value pumpkin, small pumpkins, vegetable soybean, purple corn, etc (Table 4).

Table 4. Structure-wise utilization at COE.

Sr. no	Structure and area	Area (sq.m.)	Crop cultivated
1	Shadenet-1	1000	Butternut pumpkin
2	Walk in tunnel 5	500	Cucumber
3	Insectnet	2000	Cucumber
4	Walk in tunnel 1	500	Hot pepper
5	Walk in tunnel 7	500	Hot pepper
6	Shadenet-2	1000	Pumpkin
7	Nvph 3 (naturally ventilated polyhouse)	1000	Rijkzwaan capsicum
8	Walk in tunnel 6	500	Golden cherry tomato
9	Walk in tunnel 4	500	Yahudha brinjal
10	Walk in tunnel 5	500	Broccoli
11	Shadenet-2	1000	Purple corn
12	Walk in - 3 tunnel	500	Vegetable soybean
13	Walk in tunnel1	500	Tomato
14	Insectnet	2000	Marigold
15	Nvph 3 (naturally ventilated polyhouse)	1000	Marigold
16	Walk in tunnel 6	500	Marigold
17	Nvph 1 (naturally ventilated polyhouse)	1000	Chrysanthemum
18	Shadenet-3	1000	Chrysanthemum
19	Shadenet-1	1000	Purple corn/musk melon
20	Walk in tunnel 3	500	Lalith and blackgem brinjal
21	Nvph-2 (naturally ventilated polyhouse)	2000	Chrysanthemum
22	Hitech 3	2000	Soil preparation
23	Hitech 4	2000	Soil preparation

Figure 11. High value pumpkin in a shed net.

Figure 12. Three varieties of vegetable soybean.

Figure 13. Pinched marigold.

Figure 14. Purple corn trial in fruiting stage.

Figure 15. High value small pumpkin.

1.3.4 Capacity building and documentation

The consortium partners were actively engaged to provide technical support, and guidance to fellow farmers on best bet management practices for vegetable grafted seedling cultivation to increase their farm productivity. The training programs were carried out on best management practices in crops like tomato, chilli, brinjal, capsicum and bitter gourd.

1.3.4.1 Sharing of resource material

ICRISAT with the help of DoH prepared the pamphlets in local language i.e. Telugu. These pamphlets include detailed information on grafting technology, soil and bed preparation, crop spacing, fertigation scheduling, pest and disease management etc. Pamphlets were distributed to the farmers during the training programs conducted and also made available at CoE facility so that farmers can avail it during their visit to CoE.

Figure 16. Tomato pamphlet in telugu

Figure 17. Capsicum pamphlet in telugu

Figure 18. Chilli pamphlet in telugu

Figure 18. Bitter gourd pamphlet in telugu

Figure 18. Brinjal pamphlet in telugu

1.3.4.2 Training and awareness building

ICRISAT in association with Department of Horticulture, AP has facilitated a training during 6th-12th March, 2019 and 17th to 19th July, 2019 for small and marginal farmers aiming to transfer the knowledge on advanced grafting technology of vegetables to the farmers in order to enhance their income.

The activities of capacity building had been carried out in six villages *viz.* Cheldinganipalle, Daseganuru, Gundupalle, Chandam, Gadduru, Kenchanaballa of Kuppam block of Andhra Pradesh to nurture the interest of local farmers towards cultivation grafted vegetables and to pave the way for doubling the farmer's income. These training programs were conducted with objectives to create awareness on efforts put by DoH, GoAP to establish Centre of Excellence at Kuppam which can cater the need of vegetable growers; demonstrate benefits of grafting technology; educating them on best bet practices on grafted vegetable cultivation with a major focus on soil preparation, spacing, fertigation and pest- disease management practices etc. Similarly, farmers fields were regularly monitored to give handholding support by experts from DoH, ICRISAT and other partners to beneficiary farmers.

During the trainings, about 400 farmers were trained for cultivating vegetables in the different village clusters in Kuppam block. These training sessions were carried out in two phases wherein efforts were put on practical knowledge sharing. Several farmers participatory organizations actively participated in these trainings which has led to create considerable awareness and interest amongst the farmers thereby created good demand for grafted seedling cultivation.

Figure 19.Training program in Chandam village

Figure 20.Training program in Gadduru village

1.3.4.3 Training rural youth for grafting

A week-long hands-on training was given to 15 local village youth on selection of rootstock-scion, different methods of grafting, hands on practice in grafting etc. They were also trained for healing process of the grafted seedlings and hardening of the seedlings *i.e.* gradual exposure of the grafted seedlings from *in-vitro* to *ex-vitro* conditions.

Figure 21. Training on grafting process.

2. Strategic research at ICRISAT

In order to expand the usage of grafted seedlings amongst the farmers, strategic research is being conducted at ICRISAT's facility of protected cultivation structures at ICRISAT campus, Patancheru Hyderabad. The primary objective of this research is to screening of different rootstock –scion combinations and evaluate their performance under controlled condition. Apart from this, the findings will be shared with project farmers on economic viability of this technology and best bet technological aspects of grafted vegetable cultivation.

Apart from this, efforts were concentrated towards addressing crop specific problems like bacterial wilt of solanaceous crops, *fusarium* wilt of cucurbits, nematode in capsicum and restricting heavy metal uptake in plants. These crops specific problems are being addressed during three years of project period through process involving screening, evaluation and

identifying best rootstock- scion combinations for further recommending to farmers for large scale cultivation. Similarly, this strategic research at ICRISAT campus will be carried out to address biotic and abiotic stress and act as back up research to support production of quality grafted seedlings at CoE Kuppam.

Table 5: Approved strategic research component for first year at ICRISAT campus

Crops	Year I	Remark
Tomato	Screening	Research for bacterial wilt resistance
Tomato & Chilli	Evaluation	Research for restricting heavy metals uptake
Capsicum	Screening	Research for resistance against root knot nematode
Bitter gourd	Screening	Research for Fusarium wilt resistance

2.1 Screening

2.1.1 Screening for bacterial wilt resistance in tomato

In an experiment conducted for testing the bacterial wilt resistance in tomato, five scion varieties of tomato i.e. Heem Sohna, PHS 448, US 440, DS 810 and Nirupama were grafted on three rootstocks *i.e.* EG 195, EG 203 and A 108. Microbial culture of *Ralstonia solanacearum* was applied to these fifteen combinations of tomato. The results revealed that the graft combination of **EG 203 and PHS 448** found most resistant to the bacterial wilt of tomato as compared to other graft combinations.

2.1.2 Screening for nematode resistance in capsicum

A pot culture experiment on screening of graft combinations in capsicum was conducted for analysing resistance against root-knot nematode. In this experiment, four grafting combinations *i.e.* two varieties of capsicum (Orobelle and Bomby) were grafted on two rootstocks HPP and Bulky Bob. Inoculum containing nematode species *Meloidogyne incognita* was added to the soil in the pots. It was observed that graft combination of rootstock HOU Pepper and Bomby variety was resistant to nematode damage as compared to the rest of the combinations. During second year, the screened combination will be evaluated for resistance to nematode infestation.

2.1.3 Screening for *fusarium* wilt in bitter gourd

A study on screening of rootstock- scion combinations was conducted on bitter gourd using two rootstocks i.e. GVM luffa (Interspecific Hybrid) and one scion variety i.e. VNR 22. Microbial inoculum of *Fusarium oxysporum f. sp. momordicae* was applied to the pots in order to evaluate the resistance by the rootstocks. In this study, we observed that both the rootstocks grafted with VNR 22 variety of bitter gourd didn't perform well when inoculated with *F. oxysporum f. momordicae i.e* both the rootstocks found susceptible to the *fusarium* wilt. This has forced us to further screen new rootstock-scion combinations during second year for *fusarium* resistance.

2.2 Evaluation

2.2.1 Evaluation of rootstock- scion combination for restricting heavy metal uptake in capsicum

Based on results from previous study on "An investigation of chromium uptake in grafted and non-grafted tomato plants irrigated with treated wastewater" at ICRISAT, three varieties of tomato *i.e*. Heem Sohna, DS 810 and Nirupama were selected and grafted on two rootstocks i.e. EG 195 and EG 203. Chromium (VI) was added to the overhead tank as K_2CrO_7 to achieve a concentration of 0.02 mg/L of Cr (VI) in the irrigation water. The study found that plant growth, yield and heavy-metal uptake in plant tissue (terminal leaf or fruit) varies among different grafted combinations. The present study found that the grafted Combination (R1V2) **EG 203 X DutchAgri-810** resulted in highest yield and showed minimal or zero concentration level in the terminal leaf tissue and fruits respectively. This clearly elaborate scope for grafting in restricting heavy metal uptake by using suitable root stocks. The results will be validate during second year for its consistency and based on the second years results, best rootstock will be recommended for grafted seedling production, particularly in the areas affected with heavy metals.

2.3 Assessing production potential of grafted seedlings

In order to assess the impact of grafted vegetable cultivation, systematic research was conducted on different vegetable crops. The results of these studies under protected and open field condition is presented below.

2.3.1 Tomato

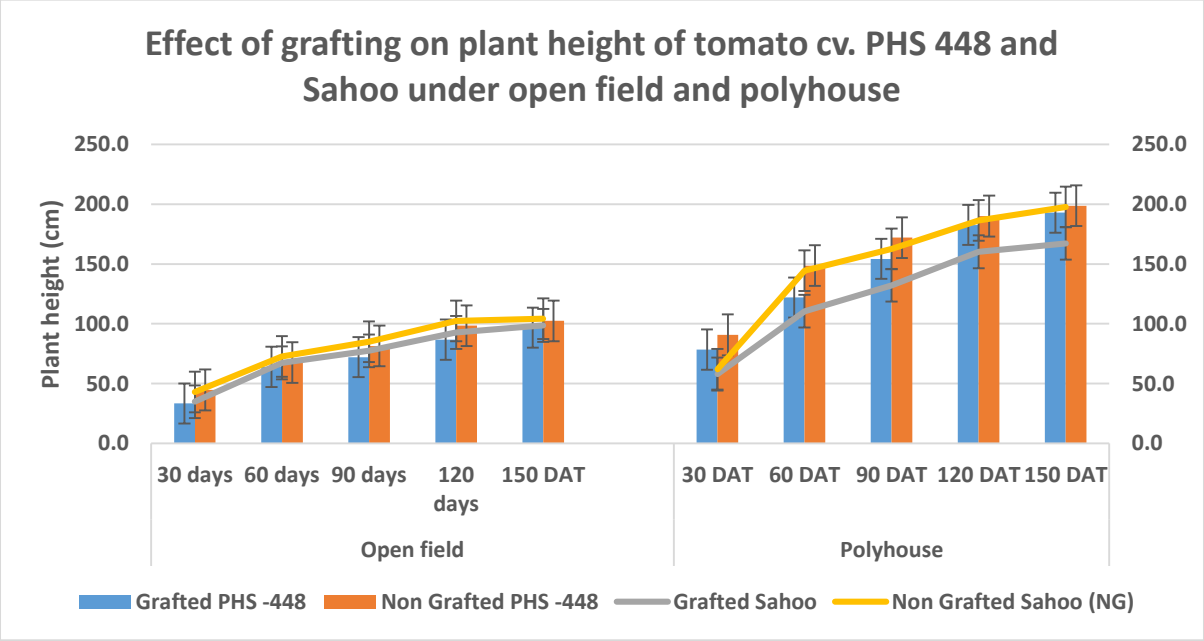
In this experiment, two varieties of tomato (PHS 448 and Sahoo- TO 3251) which is preferred by the farmers in rayalaseema region were grafted on rootstock EG 195. These grafted plants were transplanted in open field as well as in poly house to study its performance under both the conditions. Monthly observations on plant growth like plant height, leaf area, chlorophyll content of leaves, nutrient uptake pattern growth observation like no. of fruits/plant, yield per plant and yield per ha were recorded. Results of this study are mentioned as below

2.3.1.1 Growth characterization

a. Plant height was measured at monthly interval and data in below table represents the average height of the sampled plants from the experiment. From the data depicted in below table, it is revealed that plant height was maximum in non-grafted plants as compared to grafted plants at 30, 60, 90, 120 and 150 days after transplanting in both the varieties of tomato in open and polyhouse conditions. This might be due to initial slow growth pertaining to controlled apical growth in grafted seedlings compared to non-grafted.

Table 6: Effect of grafting on height of the tomato plants

Combination	Open field					Polyhouse				
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
Grafted PHS -448	33.5	64.0	72.1	86.8	96.8	78.4	121.95	154.25	182.6	192.8
Non Grafted PHS -448	44.8	67.7	81.5	98.4	102.4	90.8	148.6	172	190	198.6
Grafted Sahoo	34.9	67.3	77.5	92.7	98.6	58	110.5	132.2	160.1	167.2
Non Grafted Sahoo	43.0	72.8	85.0	102.4	104.3	61.9	144.5	162.5	186.4	197.5

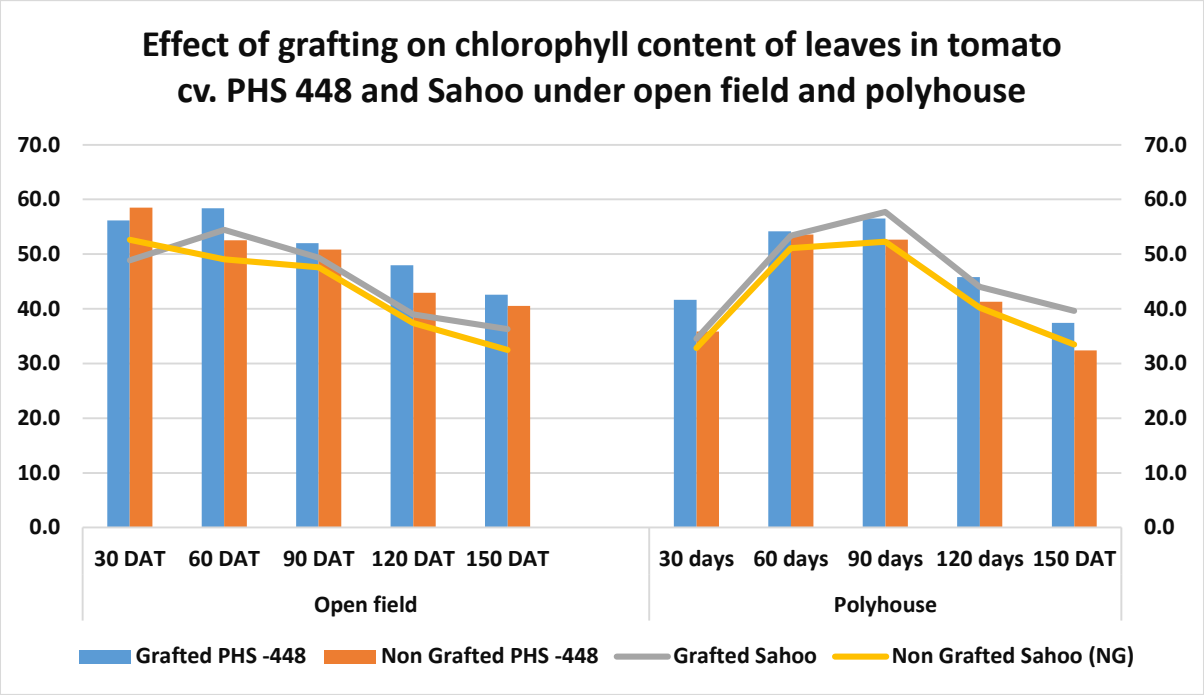


b. Effect on chlorophyll content of the leaves

Chlorophyll content of the leaves was measured using SPAD meter at 30, 60, 90, 120 and 150 days after transplanting. The data shown in table 7 is average of the data recorded from top, middle and bottom leaves of the plants. The data reveled that chlorophyll content of the leaves was maximum in grafted tomato plants at 30, 60, 90, 120 and 150 days after transplanting in both the varieties. However, initial good growth in case of non-grafted plants resulted in higher chlorophyll content at 30 days after transplanting in both the varieties and in open as well as polyhouse conditions.

Table 7: Effect of Grafting on Chlorophyll content of the tomato leaves

Combination	Open field					Polyhouse				
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
Grafted PHS -448	56.2	58.4	52.0	48.0	42.6	41.6	54.2	56.5	45.8	37.4
Non Grafted PHS -448	58.5	52.5	50.9	43.0	40.5	35.8	53.6	52.6	41.3	32.4
Grafted Sahoo	48.9	54.4	49.4	39.0	36.3	34.5	53.4	57.7	44.0	39.6
Non Grafted Sahoo	52.6	49.1	47.6	37.4	32.5	32.8	51.1	52.3	40.2	33.5

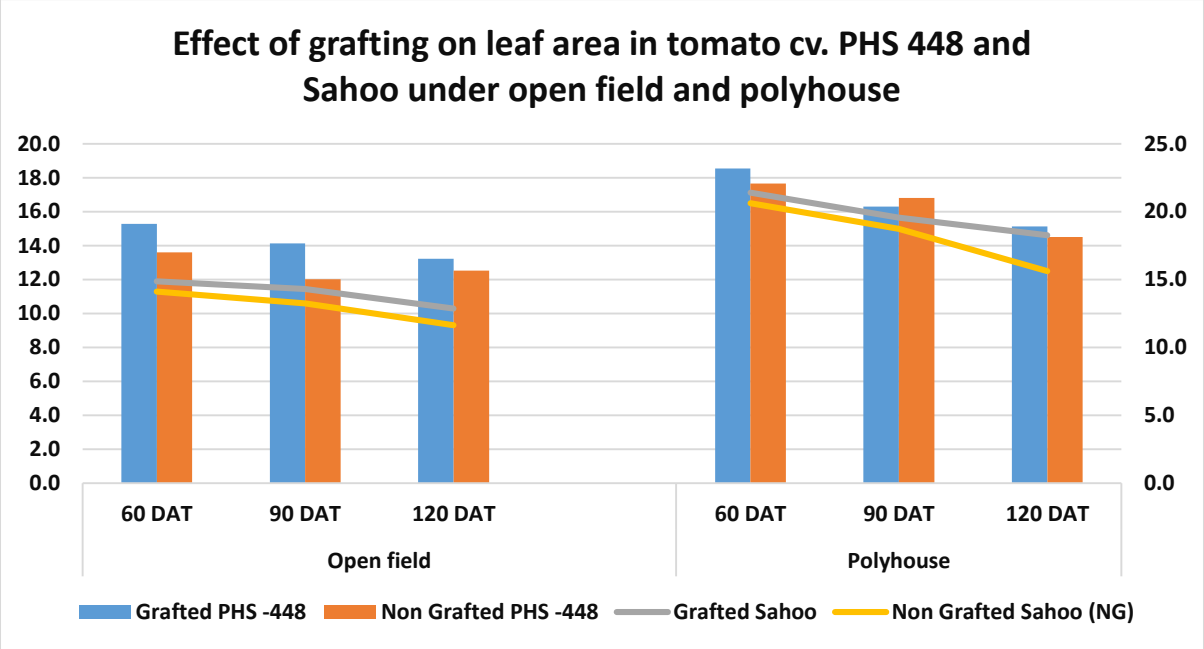


c. Effect on leaf area

Leaf samples collected from the plant were measured for leaf area using automatic leaf area measuring machine at the interval of 30 days starting from 60 days till 120 days after transplanting. Results revealed that at 60, 90 and 120 days after transplanting, leaf area was found maximum in grafted plants during all the growth stages in PHS 448 and Sahoo varieties, except at 90 DAT in non- grafted plants of PHS 448. This gives us clear signal for higher dry matter accumulation in grafted plants than non-grafted thereby expressing its yield potentiality, under both open and polyhouse conditions.

Table 8: Effect of Grafting on tomato plant leaf area (cm^2)

Combination	Open field			Polyhouse		
	60 DAT	90 DAT	120 DAT	60 DAT	90 DAT	120 DAT
Grafted PHS -448	15.3	14.1	13.2	18.5	16.3	15.1
Non Grafted PHS -448	13.6	12.0	12.5	17.7	16.8	14.5
Grafted Sahoo	14.9	14.3	12.9	21.4	19.6	18.3
Non Grafted Sahoo	14.1	13.2	11.6	20.6	18.7	15.6

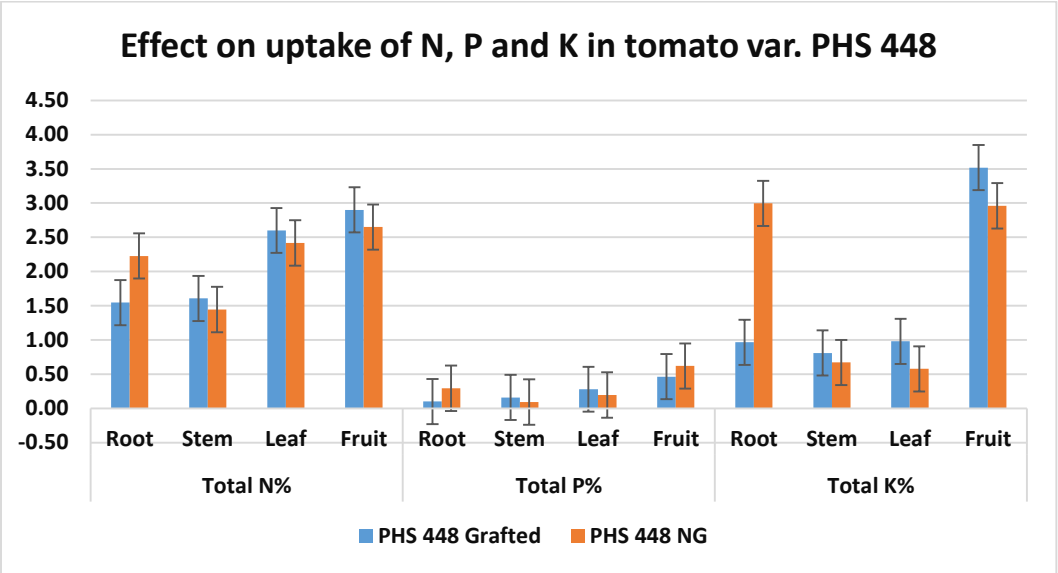


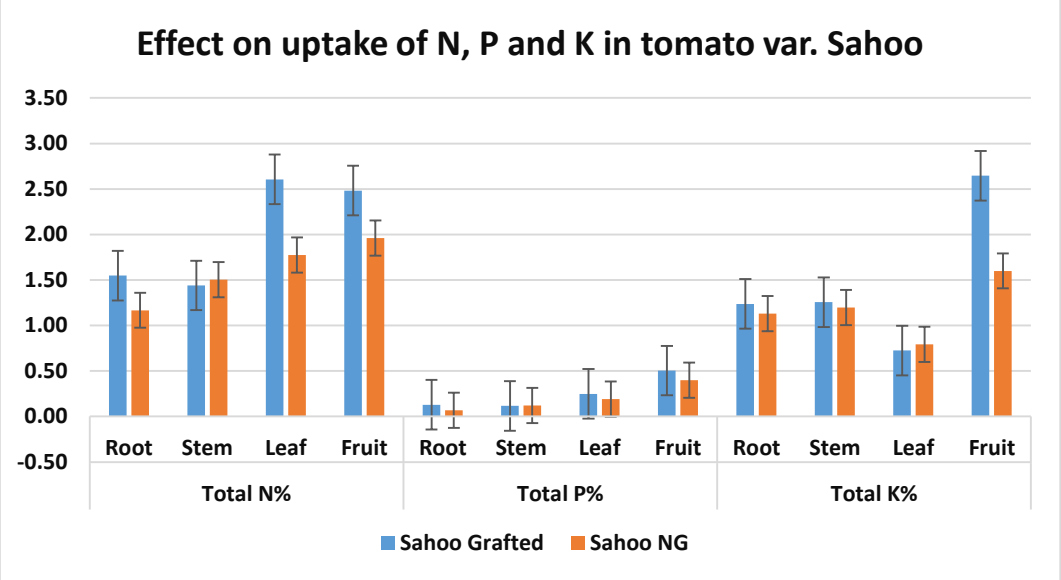
d. Major nutrient uptake pattern in tomato under open field conditions

The efforts were directed to study the effect of method of seedling production on uptake of major nutrients in different plant parts of tomato var. PHS 448. In this study, plant samples like root, stem, leaf and fruits were analyzed for N, P and K contents. From the results it is concluded that maximum concentrations of N, P and K was observed in roots of non-grafted plants as compared to grafted plants of tomato var. PHS 448, whereas, total N, P, K was maximum in stem, leaf and fruits of the grafted tomato plants. This has clearly indicated that grafted plants translocate more nutrients to sink (fruits) compared to non-grafted plants.

Table 8: Effect of Grafting on the major nutrients uptake in Tomato plants.

Combination	Total N%				Total P%				Total K%			
	Root	Stem	Leaf	Fruit	Root	Stem	Leaf	Fruit	Root	Stem	Leaf	Fruit
Grafted PHS 448	1.55	1.61	2.60	2.90	0.10	0.16	0.28	0.46	0.97	0.81	0.98	3.52
PHS 448 NG	2.23	1.45	2.42	2.65	0.29	0.09	0.19	0.62	3.00	0.67	0.58	2.96
Grafted Sahoo	1.55	1.44	2.60	2.48	0.13	0.12	0.25	0.50	1.24	1.26	0.73	2.65
Non Grafted Sahoo	1.17	1.50	1.77	1.96	0.07	0.12	0.19	0.40	1.13	1.20	0.79	1.60





e. Micro nutrients uptake

Analysis of plant parts for both the varieties var. PHS 448 and Sahoo was carried out for studying micronutrient uptake pattern. The trend shows that micronutrients like Fe, Zn, Cu and Mn had more concentration in the roots of non-grafted tomato and it is maximum in other plant parts like stem, leaves and fruits of both the varieties of grafted tomato.

Table 9: Effect of Grafting on the Fe uptake in Tomato plants.

Combination	Fe (ppm)			
	Root	Stem	Leaf	Fruit
PHS 448 Grafted	874.81	839.33	3962.90	302.84
PHS 448 NG	1710.40	542.90	2299.07	240.65
Sahoo Grafted	1129.15	378.35	1579.60	163.75
Sahoo NG	710.92	618.61	673.74	140.78

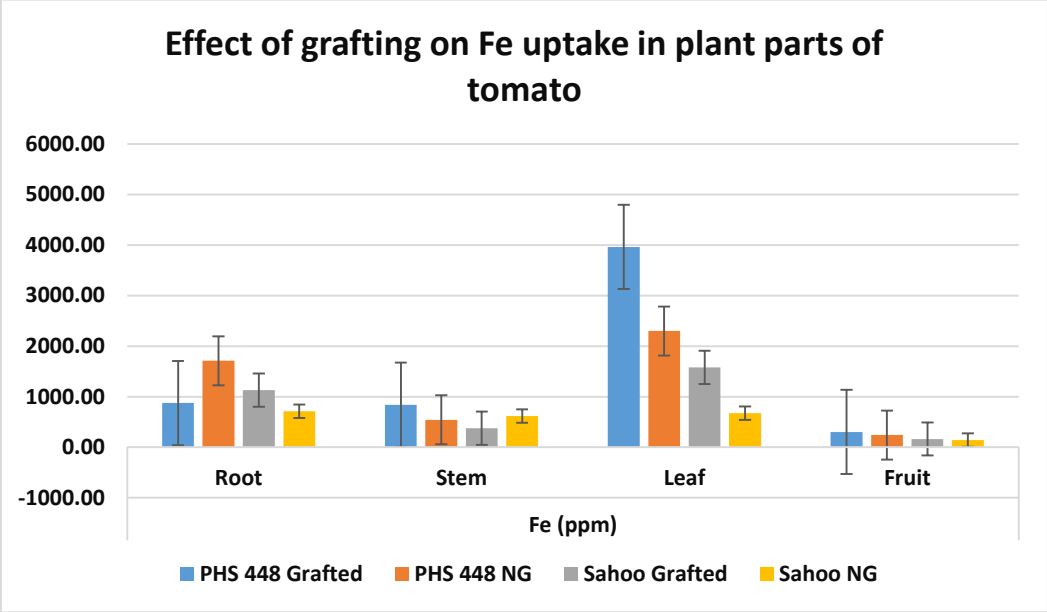
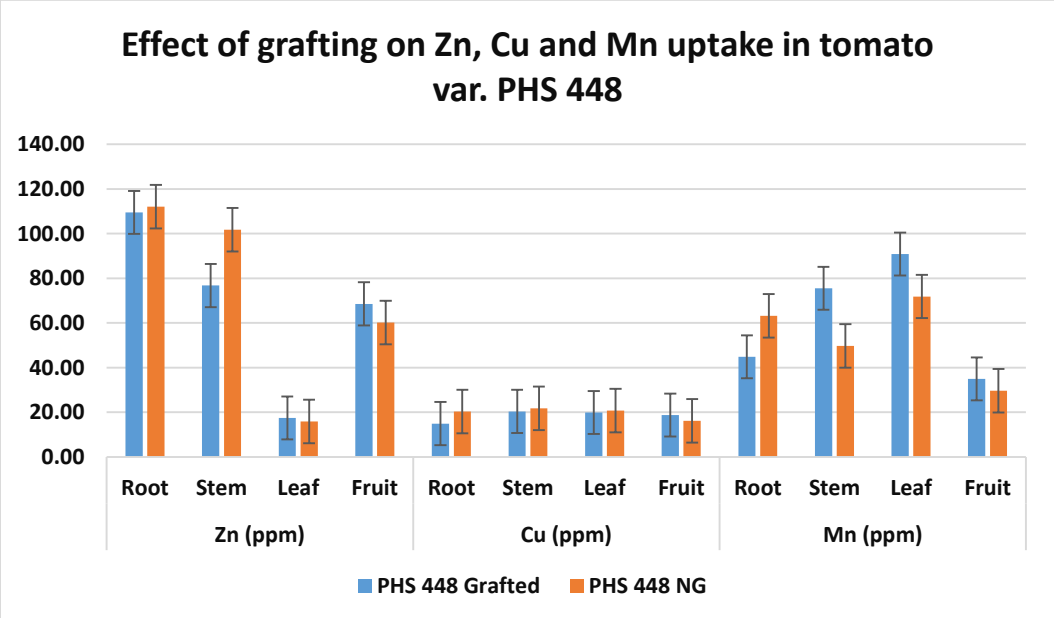
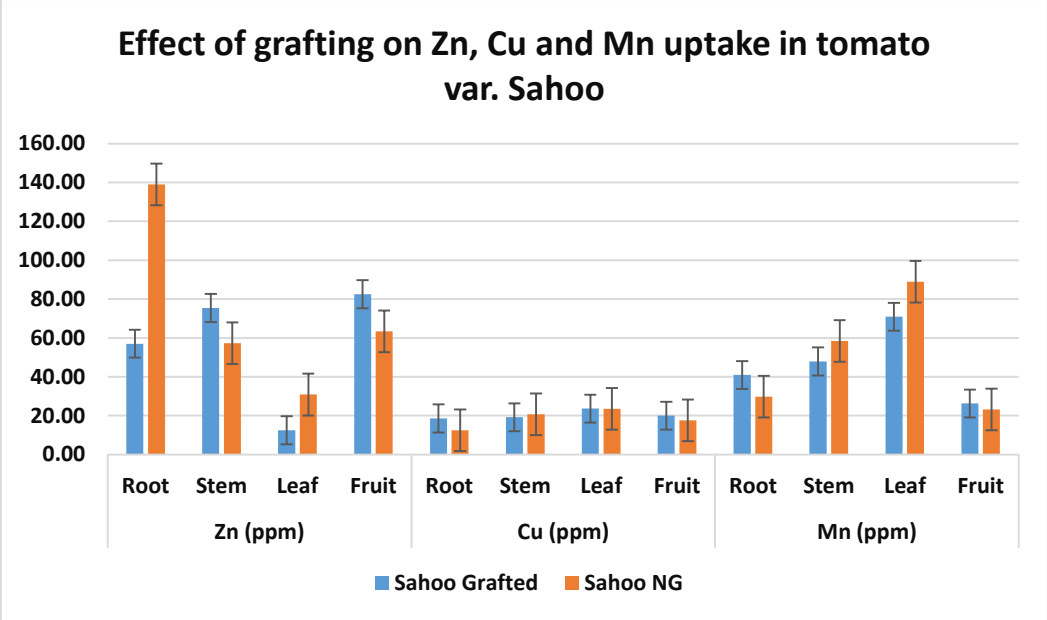


Table 10: Effect of Grafting on the Zn, Cu and Mn uptake in Tomato plants.

	Zn (ppm)				Cu (ppm)				Mn (ppm)			
	Root	Stem	Leaf	Fruit	Root	Stem	Leaf	Fruit	Root	Stem	Leaf	Fruit
PHS 448 Grafted	109.51	76.74	17.43	68.54	14.93	20.38	19.92	18.69	44.80	75.54	90.89	34.90
PHS 448 NG	112.12	101.79	15.83	60.10	20.28	21.81	20.70	16.20	63.22	49.68	71.85	29.60
Sahoo Grafted	57.02	75.43	12.44	82.50	18.59	19.16	23.63	20.00	40.90	47.89	70.90	26.25
Sahoo NG	138.96	57.23	30.85	63.45	12.41	20.70	23.45	17.55	29.78	58.45	88.85	23.14





2.3.1.2 Yield characterization

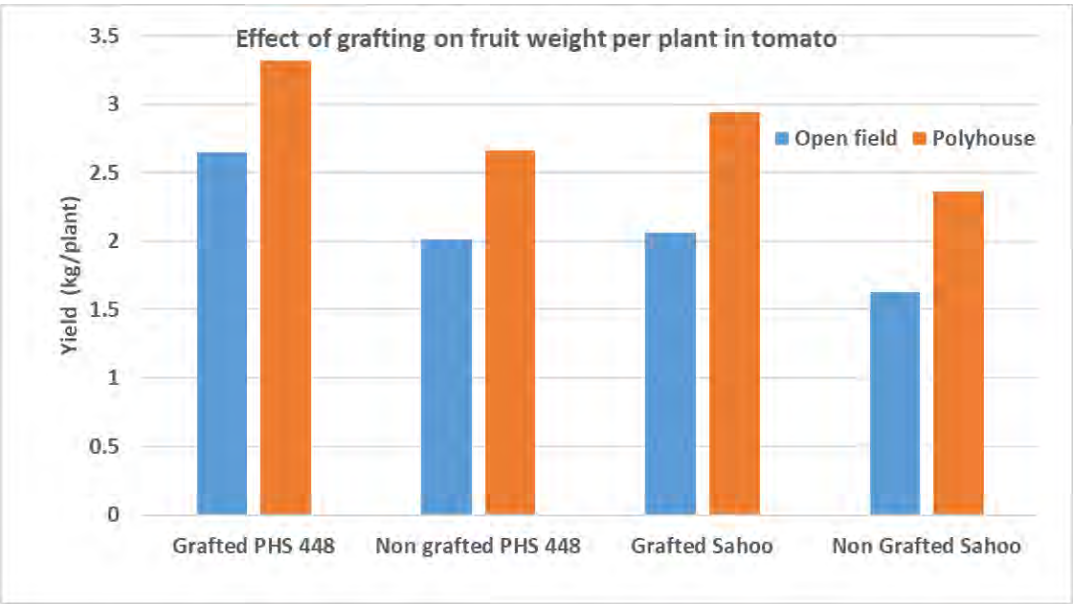
Observations on fruit yield parameters were recorded at every picking, which is summarized and converted into hectare unit in below table. Similarly, data on no. of fruits/ plant, average weight of fruit and total fruit weight per plant were recorded.

a. Fruit weight per plant (kg/plant)

Observations on average fruit weight are summarized in below table. From the data, it can be concluded that average fruit weight/plant was maximum in grafted plants of tomato cv. PHS 448 and Sahoo under open as well as polyhouse conditions.

Table 11: Effect of grafting on fruit weight per plant in tomato

Combinations	Open field	Polyhouse
Grafted PHS 448	2.65	3.32
Non grafted PHS 448	2.01	2.66
Grafted Sahoo	2.06	2.94
Non Grafted Sahoo	1.63	2.36

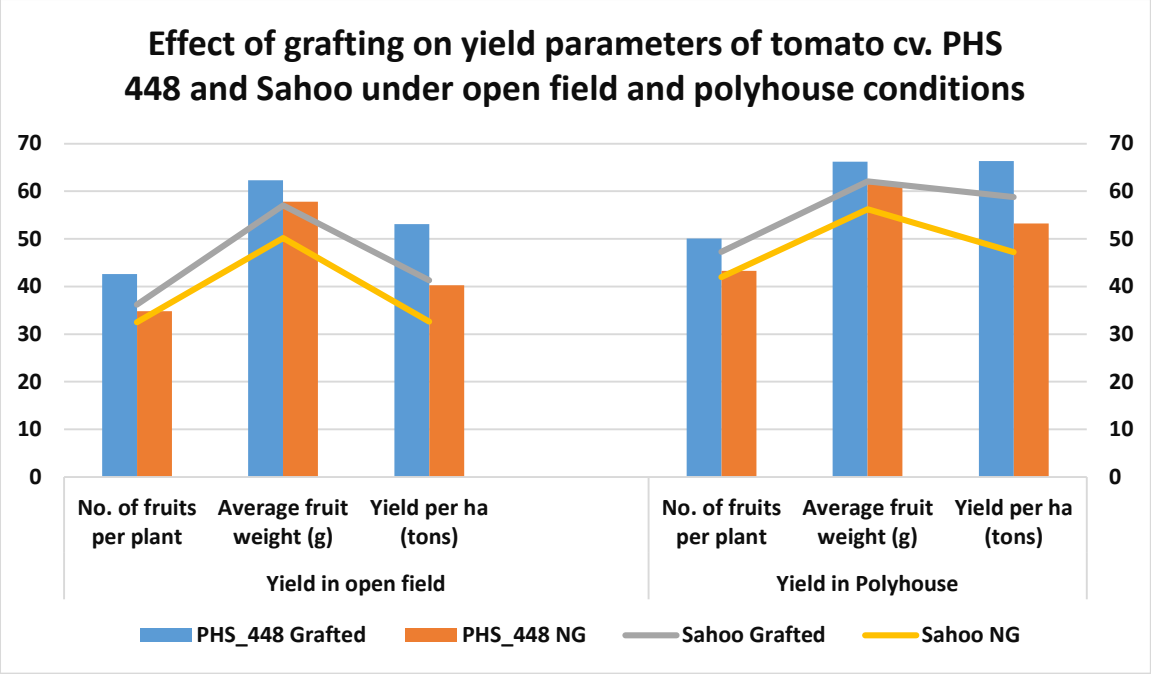


b. Other yield attributing parameters

Data on no. of fruits per plant, average fruit weight per plant and yield per hectare as mentioned in below revealed that good quality of fruits were harvested from grafted plants and yield of grafted tomato was also maximum in grafted plants of PHS 448 and Sahoo under open field and polyhouse conditions.

Table 12: Effect of grafting on yield parameters in tomato

Combination	Yield in open field			Yield in Polyhouse		
	No. of fruits per plant	Average fruit weight (g)	Yield per ha (tons)	No. of fruits per plant	Average fruit weight (g)	Yield per ha (tons)
Grafted PHS 448	42.6	62.3	53.1	50.1	66.2	66.3
Non grafted PHS 448	34.8	57.8	40.2	43.3	61.5	53.3
Grafted Sahoo	36.2	57.0	41.3	47.3	62.1	58.7
Non Grafted Sahoo	32.5	50.2	32.6	42	56.2	47.2



Summary

During first year, focus was given to produce grafted seedlings of tomato, capsicum, brinjal, bitter gourd etc through the facility available at CoE Kuppam. Similarly, awareness building programs were conducted in convergence with Department of horticulture and private partner, which has resulted in creating interest amongst the framers about this technology. The strategic research at ICRISAT campus has shown promising results which need to be evaluated/validated further. However, during second year, we expect more sustenance from DoH, in terms of extending 50 per cent subsidy to all the farmers and in encouraging farmers for large scale adoption of grafted technology so as to help them to enhance their income.

Annexure I

List of beneficiary farmers cultivating grafted seedling technology

No	Name	Place	Crop	Number
1	Agrorythm Research Centre	Nellore	Capsicum	99
2	Prathap Chandra Reddy	Aragonda	Capsicum	396
3	Prathap Chandra Reddy	Aragonda	Bitter Gourd	10
4	Prathap Chandra Reddy	Aragonda	Snake Gourd	10
5	Prathap Chandra Reddy	Aragonda	Tomato	6
6	N Ramu	Mulbagai	Tomato	1000
7	K C Sampangi	Kuppam	Capsicum	1980
8	M Mahadevan	Santhipuram	Tomato	40
9	M Mahadevan	Santhipuram	Capsicum	54
10	M Mahadevan	Santhipuram	Bitter Gourd	38
11	K Upendran	Jampumuru	Tomato	50
12	K Upendran	Jampumuru	Capsicum	208
13	Kaveri Chinnappa	Vasanadu	Capsicum	1203
14	Tummala Sivarama Krishna Prasad	Guntur	Capsicum	30
15	Tummala Sivarama Krishna Prasad	Guntur	Snake Gourd	10
16	Tummala Sivarama Krishna Prasad	Guntur	Bitter Gourd	10
17	Tummala Sivarama Krishna Prasad	Guntur	Tomato	20
18	E Rajeswari	Prakasam	Tomato	120
19	E Rajeswari	Prakasam	Bitter Gourd	40
20	E Rajeswari	Prakasam	Snake Gourd	20
21	P Dinakar	Prakasam	Tomato	4
22	P Dinakar	Prakasam	Bitter Gourd	3
23	P Dinakar	Prakasam	Snake Gourd	3
24	Adiraju Subrahmanyam	East Godavari	Capsicum	3300
25	Sarojamma	Kuppam	Tomato Demo	2800

26	J Simhadri Rao	Guntur	Tomato Demo	2800
27	J Gangadhar Rao	Guntur	Snake Gourd	800
28	R Bhogeswar Rao	Krishna	Tomato Demo	2800
29	Chandana Kedaresh	Guntur	Capsicum	5
30	O N Subbareddy	Ramakuppam	Tomato Demo	2800
31	O N Subbareddy	Ramakuppam	Bitter Gourd	20
32	O N Subbareddy	Ramakuppam	Snake Gourd	20
33	Yashodamma	Kuppam	Tomato Demo	2800
34	Lailamma	Kuppam	Tomato Demo	2800
35	P G Venkatesh	Kuppam	Tomato Demo	2800
36	G Krishna Murthy	Kuppam	Tomato Demo	2800
37	G Krishna Murthy	Kuppam	Bitter Gourd	10
38	G Krishna Murthy	Kuppam	Snake Gourd	10
39	G Krishna Murthy	Kuppam	Tomato	26
40	Viswanatha Reddy	B Kothakota	Tomato	100
41	Y Peddula Ramana Reddy	Prakasam	Tomato Demo	2800
42	Y Peddula Ramana Reddy	Prakasam	Tomato	720
43	Kanth Reddy	Bangalore	Pumpkin	1000
44	Dastagiri	Santhipuram	Tomato Demo	2800
45	Ashok Reddy	Kolar	Tomato	20
46	Padmamma	Santhipuram	Tomato Demo	2800
47	Balachandra Babu	Santhipuram	Tomato Demo	2800
48	Rama Reddy	Bangalore	Tomato	98
49	R Sreedhar Babu	Prakasam	Tomato Demo	2800
50	P Masthan Rao	Maruthuru	Tomato Demo	2800
51	A Sambi Reddy	Tadepalligudem	Tomato Demo	2800
52	K Murugan	Mile	Tomato	98
53	Madusudhan	Kuppam	Tomato	15

54	Madusudhan	Kuppam	Brinjal	15
55	Subramanyam	Santhipuram	Tomato	100
56	A Lakshmanna	Madanapalli	Tomato	10
57	A Lakshmanna	Madanapalli	Brinjal	10
58	K V Raghupathi	Kuppam	Tomato	10
59	K V Raghupathi	Kuppam	Brinjal	10
60	P Siva Rama Krishna	Kadapa	Tomato	11
61	P Siva Rama Krishna	Kadapa	Bitter Gourd	3
62	P Siva Rama Krishna	Kadapa	Brinjal	10
63	Reddappa Reddy	Madanapalli	Brinjal	3
64	Reddappa Reddy	Madanapalli	Tomato	6
65	Reddappa Reddy	Madanapalli	Bitter Gourd	2
66	Gollapalli Jaggaraju	East Godavari	Tomato	20
67	Pollacherla Veera Raju	East Godavari	Capsicum	700
68	Ar Kalai Selvi	Kangundi	Tomato	2800
69	Pm Yamini	Kangundi	Tomato	2800
70	C Ashok Kumar	Daseganuru	Tomato	2800
71	A Sujatha	Daseganuru	Tomato	2800
72	Arumugam	Animiganipalli	Tomato	5
73	Arumugam	Animiganipalli	Brinjal	5
74	Arumugam	Animiganipalli	Bitter Gourd	5
75	M Koteswara Rao	Santhipuram	Tomato	711
76	T Narayana Swamy	Kolar	Brinjal	5
77	T Narayana Swamy	Kolar	Bitter Gourd	5
78	Rammohan Rao	Guntur	Tomato	6
79	Rammohan Rao	Guntur	Bitter Gourd	6
80	Rammohan Rao	Guntur	Brinjal	6
81	Venkatadri	East Godavari	Tomato	20

82	Venkatadri	East Godavari	Brinjal	20
83	Venkatadri	East Godavari	Bitter Gourd	5
84	N Venkatesh	Ramakuppam	Capsicum	1780
85	Hemanth	Srinivasapuram	Tomato	99
86	Hemanth	Srinivasapuram	Brinjal	99
87	Hemanth	Srinivasapuram	Capsicum	15
88	Reddy Sridevi	East Godavari	Capsicum	100
89	Reddy Nikitha	East Godavari	Pumpkin	4000
90	G Murthy Rajulu	Guntur	Brinjal	99
91	G Murthy Rajulu	Guntur	Tomato	99
				72796