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Research Regarding the Production of Eggplant Grafted Seedlings by Manual and Semi-automatic Grafting

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Abstract: The research had aimed to establish the technology for obtaining the eggplant grafted seedlings by manual grafting or mechanical with semi-automatic machine. The grafting operations were performed manually and semi-automatic by the "grafting robot" installation GR-800CS.It was used as scion "Luiza" cultivars and respectively, Aragon F1. The rootstocks used were *Torvum vigor* (Kaneko Seeds) and "Emperador" (Rijk Zwaan). The method for the obtaining of eggplant grafted seedlings - manually or mechanically - involves the following stages: sowing the graft, sowing the stock, grafting preparation, grafting and healing, transferring the grafts from the healing tunnel in the growing space. The grafting method by a grafting installation involves monitoring and execution of some relatively similar stages and operations with the ones presented within the manual method. The differences consist mainly in the preparation of the biological material for grafting and the grafting operation itself. It was determinate and established the operator's yield dynamics in a day of work, the average number of grafted plants / day / operator and the average number of grafted plants realized by a single worker / hour. In order to reflect the economic efficiency was calculated and specified the cost price for grafted seedlings of eggplant, realized by grafting method and respectively by manual or semi-automatic method. For manual grafting of a1000 eggplants are required 24.02 days /man, while for grafting of 1000 eggplants by semi-automatic methods are necessary only 9.27 days/ man. Was registered a decrease of the cost price for semi-automatic grafting over 16.3% compared with manual grafting.

Keywords: grafted, seedling, eggplants, robot, economic efficiency

INTRODUCTION

The researches have been done at Horting Institute showed that after 4 years of monoculture, the yield of vegetables had registered a reduction up to 48 %, thus making necessary the adoption of soil fumigation practices or other methods. One of the possibilities to reduce the losses of production (quantitative and qualitative) is the grafted plants method. Grafting cultivars of eggplants with high quality and productivity on rootstocks that are resistant to the soil pests and diseases is a method known for years ago, but which was improved and quickly spread in the last years. The method is based on the joining between cultivar (scion) and a wild variety, the last possessing a robust root system, a high resistance to soil pests and diseases, and in the same time, the tolerance to some of the less favorable conditions of soil types and environmental (Edelstein, 2004). The main result of the grafting process is the increase of the resistance against soil diseases such as *Fusarium, Verticillium* or nematodes (Bogoescu, 2007)**.** It is extremely important during the grafting process to ensure the vascular fusion between the scion and rootstock by using a cut that maximizes the contact surface and creating the proper conditions for close contact between those two plants (Assenza, 2004).

Over a percentage of 80% the vegetable grafting is performed manually. In the last 10 years have been developed semi-automatic and automatic devices for vegetable seedlings grafting.

The researches aim is to establish the technology for obtaining the eggplants grafted seedlings by manual grafting or mechanical with semiautomatic machine.

MATERIALS AND METHODS

The work was performed in the experimental greenhouse of the institute. This greenhouse is specialized in producing of vegetable seedlings, it has a 1450 square meters surface, it is protected against condense by a double layers cover with an under pressure air layer as thermal insulator and it is equipped with a system for shadowing, ventilation and cooling of the grafting room (Fig.1, Fig. 2).

Fig 1. Growing chamber

Fig 2. Grafting and healing chamber

It was used "Luiza" eggplant graft (Romanian variety) and respectively, "Aragon F1" (one of the most cultivated eggplant hybrids from the south of the country).

"Luiza" graft is a semi-early eggplant cultivar created at ICDLF - Vidra (Fig.3). This graft has elongated and pear-slightly curved fruits, dark purple to black color and a mean weight of 200-300g.

It is recommend the cultivation in the field or in protected area. This variety has great production potential. Powered by Hazera Genetics, "Aragon F1" is an eggplant hybrid, which reach maturity in about 67-75 days after transplanting and is used destined for cultivation in the field (Fig.4). Besides the commercial quality as black shiny fruits, elongated shape, with lengths between 20-30 cm, average weight between 0.7 and 1.1 kg, white core with few seeds, the plant shows a very useful cultural quality in the recent warmly years: performs very well at high temperatures, none aborting the flowers and tying in a remarkable proportion. The plant has low height: 60-70 cm and produce 10 to 15 fruits per plant.

The used rootstocks were *Torvum vigor* (Fig.5), accomplished by Kaneko Seeds, a Japanese company with a long tradition in the field and respectively, Emperador, produced by the Dutch company Rijk Zwaan. *Torvum vigor* is based on *Solanum torvum* species, a vigorous variety which can be used just as eggplant rootstock; have good resistance against *Ralstonia* (Pseudomonas) *solanacearum, Verticillium* spp., *Fusarium* spp. and nematodes.

Can be grown and gives good results in the extended cycle of eggplant culture and confers resistance to high temperatures.

"Emperador" (Fig.6) is a rootstock from the hybrid rootstock category, with resistance at KVP (*Pyrenochaeta lycopersici, Dydinella lycopersici, Verticilium* spp.ș *Fusarium* spp.), as result from hybridization of *Lycopersicon hirsutum* with *Lycopersicon esculentum*; "Emperador" is a generative rootstock, very vigorous, which determine the

obtaining of great dimensions fruits and the production increase. Have a good tolerance at low temperatures and a good stabile behavior in different conditions, appropriate for cultivation of tomatoes and eggplant; shows a high resistance level at nematodes.

Fig.3."Luiza" eggplant variety

Fig.4. "Aragon" F1 eggplant hybrid

Fig.5. *Torvum vigor* rootstock

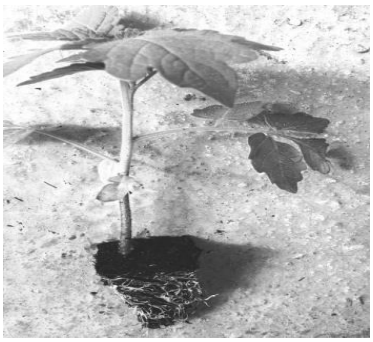

Fig.6. "Emperador" rootstock

The grafting operations was realized manually and semi-automatic on the "grafting robot" device GR-800CS, developed by Helper Robotech Co, Korea (Fig.7).

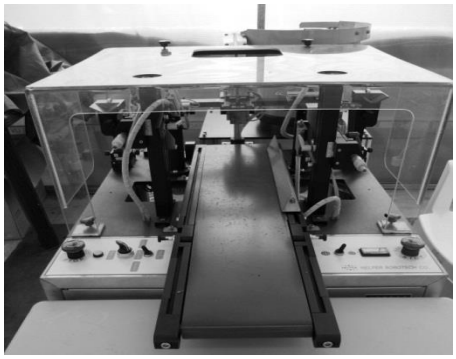

Fig. 7. Grafting robot GR-800C

The method for obtaining the grafted seedlings of eggplant - manually or mechanically - involves the stages: scion sowing, rootstock seeding, grafting preparation, grafting, healing and transferring the seedlings from the healing tunnel in the growing space. The grafting method by a grafting device involves the monitoring and execution of stages and operations relatively similar to those presented at manual method. The differences consist in biological material preparation regarding the grafting and the grafting operation practically (Kobayashi, 2005).

It was determined and established the operator's yield dynamics in a day's work, the average number of grafted plants / day / operator and the average number of grafted plants by a single worker / hour.

In order to reflect the economic efficiency was calculated the cost price for grafted seedlings of eggplant made by manual grafting method and semi-automatic method.

Tab.1

Characterization of biological material used by phenological and phenotypic indicators, during the activities in the multiplier greenhouse

Rootstock Scion	Sowing	Germinated		Grafting			Phenotypic indicators at grafting moment		
	date	date	Temperature degrees sum	date	Temperature degrees sum	No.of plants introduced at grafting	Height (mm)	Diameter (mm)	No.of rear leaf
Emperador	18.03	18.03	78	23.04	680	429	110	4	5
Luiza	13.03	20.03	196	23.04	921	40	90	4	4
AragonF1	13.03	20.03	196	23.04	921	168	80	4	3
Torvum vigor	22.02	27.02	130	30.04	767	2435	98	3	5
Luiza	13.03	20.03	196	30.04	1089	15	94	3	4
AragonF1	13.03	20.03	196	30.04	1089	15	87	3	4

RESULTS AND DISCUSSIONS

The described results in this paper refer to the researches carried out between 2012 and 2013 at the Research and Development Institute for Processing and Marketing of the Horticultural Products "Horting".

The realized activities with biologic material in the multiplier greenhouse (rootstock and scion of eggplant) led to the data presented in Tab.1. The data analysis presented in Tab.1 shows for the germination of seeds of eggplant rootstock, from KFV resistant hybrids were needed 3 days (Σ° of 78°C), while for the rootstock realized from *Torvum* species the required time was higher, respectively 5days (Σ° of 130°C). Comparing with the requirements of rootstocks, the sum of the temperature degrees required for rising the eggplant scions was 196°C in 7 days. From the rising time to the moment when the plants achieved the morphological requirements for grafting, the scions required a sum temperature degrees from 921 to 1089°C, respectively 32, up to 40 days; for the rootstock the sum of temperature degrees required to achieve the optimum parameters for grafting was much lower: 680°C at "Emperador" and respectively 767°C for *Torvum* vigor rootstock..

The grafting was done when plant's stem diameter was between 3-4mm and 3-5mm for leaves.

The data from above show that intraspecific hybrids of *Lycopersicum* rootstocks have a higher growth rate compared to "*Torvum*" rootstocks or eggplant scions and as such it is necessary to start sowing after the sowing of scions.

These results substantiate the technological recommendation to perform tests to determine seed's germination energy, the necessary duration for achieving the optimal phenophase for grafting, in order to obtain very compatible rootstocks and scions. The grafting method with a grafting device involves following and execution of stages and operations relatively similar to those described at manual method, with some exceptions. The steps regarding the scion and rootstock sowing, healing operation in healing tunnel, the

transferring of seedlings from the healing tunnel in the growing space and a great part of the preparation phase of grafting are identical. The differences appear mainly in the biological material preparation for grafting and grafting operation itself.

Grafting preparation

The biological material was fertilized with mineral fertilizer (19:19:19 + MgO) in concentration of 0.3% with 48 hours before the grafting operation and was irrigated the day before, in order to assure the turgidity of plants, but while to allow the draining the excess of water from the nutritional mixture (excess of water makes very hard the work of the robot and also can produce damages for it).

The grafting operation is performed in a shaded space at an environmental temperature which will not exceed 18 -21 ° C. Inside the grafting space as like in the multiplier greenhouse is completely banned smoking.

To obtain proper results is particularly important the sorting seedling operation, in order to ensure a high uniformity of the stem's diameter for scions and rootstocks; the optimal size of stem diameter for mechanized grafting is 2 - 3mm.

It is necessary to ensure the sufficient number of new alveolar trays for setting the grafted seedlings and the pallet trucks for evacuation alveolar trays which contain the root of scions, plastic bags for evacuation of vegetal remains and nutrient mixture resulted from the technological process.

The alveolar trays, which remain with the root part and stem remain from the used scions, can be reused for the subsequent obtaining of other non grafted seedlings of eggplant, because 90% from the plants will issue new stems from adventitious buds situated at the collar level.

Grafting

Serving a robot unit was performed by three operators, two operators supplied the robot (Fig. 8, 9) with seedlings, the third operator takes the grafted seedlings from the strip for settlement in the alveolar tray, which will be introduced into the healing tunnel.

Fig.8. Scion plants supply

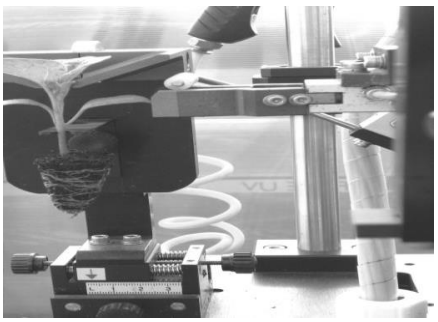

Fig.9. Rootstock plants supply

The alveolar tray designated for introducing to healing had 70 alveoli. The robot was adjusted - according the characteristics of plants - by using of the work mode "step by step". Catching the scion on rootstock is done by plastic pliers (Fig.10).

After the robot adjusting and its verification was realized the plant's grafting; the device has two modes: medium speed and high speed. Theoretical average yield in this mode is about 600 grafted plants / hour.

The quality of semiautomatic or automatic grafting is superior to the manual grafting in conditions to realize new scions and rootstocks according to the requirements of the device (Fig.12). Regarding the yield at griping for scions and rootstocks after grafting, the data presented in Tab.2 highlights the superiority of the semiautomatic method compared with

manual method. Thus, the grafted seedlings by semiautomatic method had a higher griping yield up to 4% (Torvum vigor x "Aragon") comparing with manually grafted seedlings.

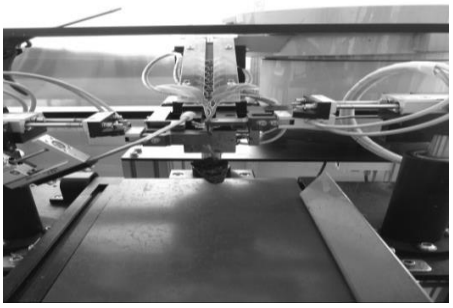

Fig.10. Sticking system for plants

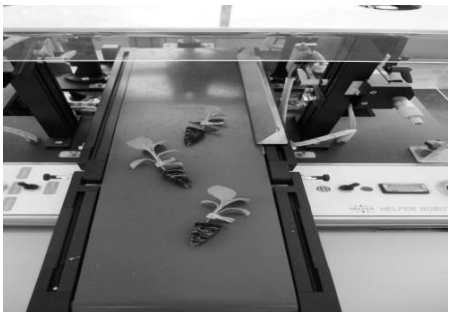

Fig.11. Carrier mechanism for seedlings

Tab. 2

The influence of grafting method on griping yield

Variety	Griping yield after grafting (%)	
	Manually	Semiautomatic
Emperador x Luiza	94.6	97.8
Emperador x Aragon	94.3	97.4
Torvum vigor x Luiza	95.1	96.9
Torvum vigor x Aragon	94.2	98.2
Average	94.55	97.55

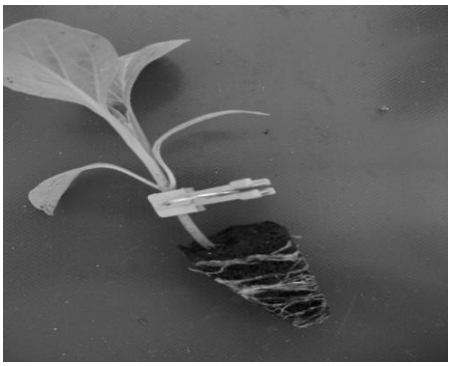

Fig.12. Eggplant seedlings semiautomatic grafted

One of the special problems appeared in using the vegetable's grafting is the necessity of a relatively high manual labor.

The experts from United States, even they have particularly intense concerns in this area of activity, are in expectancy due to this issue: necessity of a workforce relatively numerous and qualified, which involves higher costs (in Europe a worker performed between 100 and 120 grafted plants /hour).

For this reason many of this research aim to develop reliable grafting robots in order to retrieve largely the human activity. For *Solanaceae* this issue was relatively solved, particular issue remaining for the *Cucurbitaceae* crops. Upon this reason were made determinations regarding the necessary of manual labor needed to realize 1000 grafted seedlings (Tab.3).

Tab.3

Necessary of manual labor needed to realize eggplant grafted seedlings by manually grafting pieces of grafted eggplant *

Worker no.	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	TOTAL Day *
1	54	67	66	75	68	64	61	58	513
2	48	56	64	64	63	63	59	49	466
3	65	76	78	76	76	70	69	59	569
4	65	69	69	68	67	64	67	58	527
5	43	49	54	56	58	59	56	57	432
6	49	57	57	56	54	56	54	51	434
7	54	65	67	67	68	65	63	49	498
8	54	56	57	59	59	72	65	68	490
9	56	67	68	69	67	69	68	53	517
10	52	56	75	78	78	78	72	61	550
TOTAL	540	618	655	668	658	660	634	563	4996
Average/ hour/worker/day	54	61.8	65.5	66.8	65.8	66	63.4	56.3	62.45/499,6

The data analysis from Tab.3 reveals the dynamic of operator's yield during the 8 hours of work, average number of grafted plants / day / operator and the average number of grafted plants realized by a single worker / hour.

The first and last hours of activity during working time are a fractions of time with lower yield. Thus the average number of grafted plants in one hour increased from 54 grafted eggplants in the first hour of activity to 66.8 grafted eggplants during the fourth hour of work and decreased at 56.3 grafted eggplants in the last period of the day's activity. As average, an operator grafted 62.54 eggplants / hour, respectively 499.6 eggplants / working day.

It is necessary to mention that the 10 operators who have grafted was permanently served by two workers which handled the seedlings and alveolar trays, by this way for producing of the 4996 grafted eggplants worked 12 workers during 8 hours.

At a salary of 70 lei / day for operators and 50 lei / day for handler workers results a labor expense of (70 x 10) + (50 x2) = 800lei/day, respectively 800 lei: 4996 grafted eggplants / day = 0.1601lei/grafted plant The result is : for 1000 grafted eggplants are required (12 x 1000): 499.6 = 24.02 workers / day.

The data presented in Tab.4 refers to the necessary of manual labor using semi-automatic method for grafting.

The analyze per hour outlines the same curve, with lower productivity at the beginning (517 grafted eggplant / hour) and end of the working program (499.1 eggplant grafted / hour).

With the robot unit for grafting were performed in one day a average number of 4312.8 of grafted eggplant. To realize these were participated five workers (three robot operators and two handler workers). The average number of grafted eggplants performed in one day by a worker was 539.1 eggplants, respectively179.66 grafted eggplants/ person / working hour.

At a salary of 80lei/day for operators and 50 lei / day for handler workers results in labor expense (80x3) + (50 x2) = 340lei/day, respectively 340 lei: 4312.8 grafted eggplants / day = 0.0788lei/grafted plant. It follows that for 1000 grafts are required eggplant (5 x 1,000): 539.1 = 9.27 workers / day. The result is that the semi-atomatic method improves the grafting yield over 2.59 times.

Tab.4

Necessary of manual labor needed to realize eggplant grafted seedlings by semi-automatic grafting method pieces of grafted eggplant

Working days	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	TOTAL Day *
1	365	453	467	456	465	443	501	432	3582
2	410	432	476	501	498	489	456	421	3683
3	543	546	543	532	543	540	509	465	4221
4	476	543	567	569	570	570	532	501	4328
5	548	567	564	565	560	584	543	502	4433
6	570	576	564	572	584	543	534	536	4479
7	584	580	593	598	597	590	543	555	4640
8	601	579	598	589	546	576	603	543	4635
9	541	570	570	578	578	576	560	534	4507
10	532	606	603	611	599	578	589	502	4620
TOTAL	5170	5452	5545	5571	5540	5489	5370	4991	43128
Average/ hour/worker/ day	517	545.2	554.5	557.1	554	548.9	537	499.1	179,66 /539.1

Tab.5

The cost price for grafted eggplants by manual and semiautomatic methods lei/1000 eggplant seedlings

Cost element	Manual grafting	Semiautomatic grafting
Salaries	160,10	78,8
Materials	356	352.7
Clips	15	21
Alveolar trays	86	86
Nutrient mixture	75	75
Blades	5	5
Utilities	80	91
Cost Amortization	5,8	6,1
Fertigation	24	24
Fitosanitary treatments	30	30
Technological lost (seeds of scion and rootstock)	33	14.7
Other materials	8	6
Total direct costs	516.1	431.5
Indirect costs 18%	92.89	77.67
Profit 8%	48.72	40.73
TOTAL	657.71	549.9

In this case the cost price analysis (Tab. 5) for obtaining of grafted eggplants manually or by semi-automatic method requires consideration of all direct costs and indirect (common and general) care involved in the process of these seedlings realization.

The direct expenses with salary costs are given by the costs of gross salary and related tax, in accordance with the laws regarding the use of day workers and seasonal workers. As was shown previous the labor expense for realizing 1000 grafted eggplants was 160.10 lei for non grafted plants and respectively, 78.8 lei for grafted eggplants by

semiautomatic method. In light of the above, cost price for the second method as the one shown in Tab.5.

From the analyzing of the data presented in Table 5 is remarkable the lower cost price realized at semiautomatic grafting, with more than 16.3% comparing with manual grafting, respectively a lower cost price with 107.90 lei per 1.000 grafted seedlings.

CONCLUSION

- Intraspecific hybrids of *Lycopersicon* rootstocks have a higher growth rate compared to *Torvum* rootstocks or eggplant scions and as such it is necessary to start sowing after the sowing of scions.
- The results substantiate the technological recommendation to perform tests for determine seed‘s germination energy, the necessary duration for achieving the optimal phenophase for grafting, in order to obtain very compatible rootstocks and scions.
- To obtain proper results is particularly important the sorting seedling operation, in order to ensure a high uniformity of the stem’s diameter for scions and rootstocks; the optimal size of stem diameter for mechanized grafting is 2 - 3mm.
- Serving the robot unit is performed by three operators - two operators supply the grafting robot with seedlings and the third operator takes the grafted seedlings from the strip for to place it in the alveolar tray, which will be introduced into the callusing tunnel.
- The quality of semiautomatic or automatic grafting is superior to the manual grafting in conditions to realize new scions and rootstocks according to the technological requirements of the device.
- The semi-automatic method improves the yield of grafting operation over 2.59 times.
- At the semi automatic grafting have been realized a lower cost price with more than 16.3% comparing with manual grafting, respectively a lower cost price with 107.90 lei per 1.000 grafted seedlings.

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