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Assessment of existing fertigation protocols in protected culture of vegetable crops in relation to marketable yield

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Abstract

Fertigation in soilless culture is a major determinant of the quality and quantity of the greenhouse crop yields. Sri Lankan growers are facing several problems of using hydroponic fertilizers. Thus, the over use and misuse of fertilizer have become a common problem in protected culture with subsequent increase in cost of production. Hence, this survey was conducted to find out the demographic profile of the greenhouse growers, most effective fertilizer schedule and growing medium for main greenhouse crops. On-farm data collection was done to confirm the data on fertigation collected from the farmer survey. Different fertigation schedules and growing media were evaluated for marketable yield. The more suitable and effective fertigation schedule was selected for different growth stages in each crop. According to the results obtained, the lower level of fertigation schedules that produce significantly higher marketable yield were selected as the most effective fertilizer schedules. For salad cucumber, it was 0.5, 1, 1.2 g/plant/day of Albert's fertilizer solution while for bell-pepper and tomato, it was 0.5, 1, 1.5 g/plant/day during 1-4, 5-8 and 9 week onwards after transplanting, respectively. Further, A significant yield difference could not be identified among different growing media used for hydroponic culture.

Key words: Albert's solution, Coir medium, Hydroponic, Poly-tunnel, Soluble fertilizer, Vegetables

Introduction

Growing perishable crops in environment-controlled greenhouses is a prominent feature of global horticulture last for many decades. Since its introduction to Sri Lanka in 1997 protected agriculture techniques are being practiced for the cultivation of high-value vegetables to meet the growing local and export market demands.

Department of Agriculture plays a major role in providing technical guidance for constructing protected houses and agronomic practices to farmers. However, there is no proper fertigation schedule developed so far for greenhouse crops. Therefore, growers are facing numerous problems in selecting hydroponic fertilizers and using them for fertigation. Thus, the overuse and misuse of fertilizer have been occurring while constantly increasing the cost of production. Difficulties in facing the export market competition are due to the high cost of production which is around 60-70% of the running cost for fertilizer.

Fertigation in soilless culture is a major determinant of the quality and quantity of the greenhouse crop yields. While optimizing fertigation for maximizing the yield potential, limitation of the fertilizer dosage and composition of major (macro) plant nutrients is highly considered for maintaining the economic and environmental sustainability of this industry in the new millennium (Wijesekara, 2013). The latter has received thorough attention in recent times due to new food quality standards applied on international value-chains and local supermarkets such as Good Agricultural Practices (GAP) and Sri Lanka Standards (SLS).

Hydroponics or soilless culture is a method of cultivating crops in any growing medium other than soil or in a pure water culture where all the nutrients are added to the irrigation water (Raviv and Lieth, 2008). A wide variety of crops can be grown in soilless systems including vegetables such as bell pepper, tomatoes, lettuce and cucumber. Hydroponically grown vegetables are fed by balanced soluble fertilizer to supply daily nutrients requirement. Pre-mixed fertilizer materials are very popular with many greenhouse operators because they are easy to use (Hochmuth and Geoge, 2012) 'Albert's Solution' is a pre-mixed balanced soluble fertilizer which contained all the essential nutrients even with trace elements and commonly used in protected cultivation

in Sri Lanka (Wijesekara, 2013). Albert's fertilizer is formulated and sold by different sector input suppliers. Sri Lankan hydroponics growers mainly use Albert's fertilizer without specific recommendation on crops, growth stages and seasonal weather patterns. However, research done on the drip-fertigated coco-peat culture has made significant efforts on intensifying the use efficiency of N, P and K for tomato and bell pepper crops under semi-intensive greenhouse conditions in mid elevations (Mayakaduwa *et al*., 2008 and Mawalagedara *et al*., 2011).

Therefore, this survey was conducted to find out the demographic profile of the farmers, most effective fertilizer schedule and growing medium for main greenhouse vegetable crops (Tomato, Bell Pepper, and Salad Cucumber) and to optimize their use in hydroponics for economically feasible and environmentally sound greenhouse crop production.

Materials and methods

Study-I: Farmer Survey

Information were collected from farmers of their demographic profile, fertigation and crop output of greenhouses.

The study was carried out during 2017-2018 in 3 different districts of Sri Lanka (Kandy, Nuwara Eliya and Matara). The farmer survey was conducted to collect information related to framers general background, practical aspects of fertigation scheduling, marketable yield and commonly practiced growing media for major greenhouse crops (Bell Pepper, Tomato and Salad Cucumber). In addition to this basic information, in and out temperature, humidity, Electrical Conductivity (EC) and pH levels of media and light measurements data also were collected. The Likert scale test was used to evaluate the respondent's perception and attitudes towards different fertigation methods.

Data were collected using a pre-tested questionnaire, following stratified random sampling methods while taking around 30 farmer samples in each district. Selected districts are in the predominant regions for greenhouse vegetable cultivation in Sri Lanka.

Study-II: On-farm Survey

On-farm data collection on yield and quality responses of selected greenhouse crops was done to confirm the data collected from the farmer survey in study-1. Selected fertigation schedules from the farmer survey were practiced in known farms with close supervision. Based on the study-I survey results, growers were categorized into several groups based on their fertigation method used for each crop. The selected crops (Tomato and Salad Cucumber) were subjected to farmer specific fertigation methods and schedules for two consecutive seasons without changing the growing medium between seasons at two farmer's poly-tunnels in Peradeniya (Tomato) and Gampola (Salad Cucumber) area (Table 1). Plants were grown in sterilized coir medium in standard grow bags under usual agronomic practices of farmers. Data recording and frequent observations were continued until the end of the season.

Table 1. Selected fertigation schedules for salad cucumber and tomato

	Fertigation No.	Albert's Solution (g/plant/day)			Calcium Nitrate and Potassium Chlorite (g/plant/week.)
		1-4 wks	5-8 wks	9-16 wks	4-16 wks
Salad Cucumber / Tomato	4	0.5	1	1.2	5
	5	0.5	1	1.5	5

Data were gathered on the quantitative and qualitative use of fertilizers under prevailing environmental conditions. Based on the yield and major quality parameters (original shape, size and absence of deficiency symptoms), the efficiency of fertigation was assessed. The output of the study II was compared with farmer practices and perceptions from the study-I.

Data Analysis

Data were analyzed using descriptive statistical analysis methods, analysis of variance (ANOVA), t-test and mean separation at $p < 0.05$ using the Tukey test (Honestly Significant Differences Test, $[T = q_{a\,(c,n-c)} \sqrt{(MSE/n_i)}]$, Specially this test was selected because the sample sizes were not equal for each treatment.

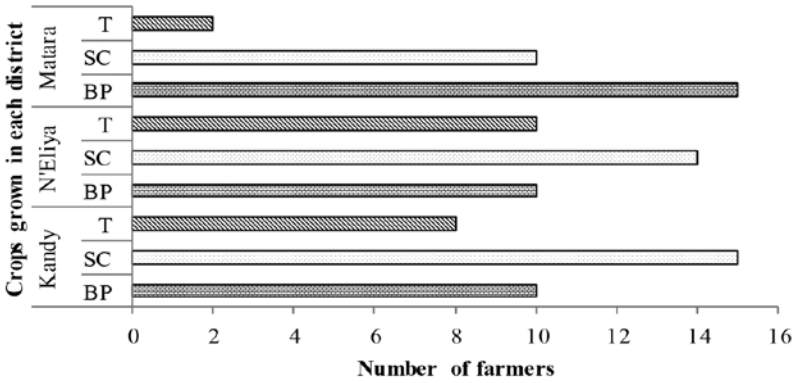
Results and discussion

Study I: Farmer Survey

The demographic profile of the farmers from all three districts (Kandy, Nuwara Eliya and Matara) showed that most of the protected culture farmers have comparatively higher education level where 100% of the farmers were educated above the G.C.E. Ordinary Level (O/L) while 9.8% were having bachelors degree (university) level education. Ninety percent of the farmers were male, showing inadequate female participation in protected agriculture entrepreneurship, agreeing with the situation reported five years ago (Wijerathne *et al*., 2014). Both fulltime and part time farmers were involving in protected culture sector (Table 2).

Table 2. Percentage of farmers in each factor of the demographic profile

Factors		Kandy	Matara	Nuwara Eliya	Average farmers
Gender	Male	80.0	100	89.5	90.0
	Female	20.0	0	10.5	10.0
Education level	O/L	28.6	37.0	37.8	34.8
	A/L	42.9	51.9	59.5	52.2
	Diploma	10.7	0	0	03.3
	Degree	17.9	11.1	02.7	09.8
Other income sources	Employment	14.3	23.1	23.7	20.7
	Business	57.1	30.8	34.2	40.2
	Other	28.6	46.2	42.1	39.1



T-Tomato, SC - Salad Cucumber, BP-Bell Pepper

Figure 1. Number of farmers growing 3 vegetables in each district.

Composition of the farmers represented in the survey showed that inequality of number for each of the crop grown in three different districts (Figure 1). It was obsereved that tomato growing farmers cultivated different varieties; Lariza, Cerus and Thilina.

This study revealed that farmers used different materials as growing media with different ratios of composition for greenhouse vegetable cultivation (Table 3). The type of growing medium appropriate for different growing conditions is determined by several factors and crop performance is usually the primary factor in developing a growing medium (Olle *et al*., 2012). According to Zaller (2007), the addition of compost did not change the yield of vegetable grown on organic media. Results of this study also showed that there was no significant difference of yield among the growing media of greenhouse vegetables (Table 3) since the required fertilizer were applied daily through the fertigation.

Mostly Greenhouse farmers used grow bags specially with inner black and outer-white for vegetable cultivation (55.2%) due to durability, and other advantages (reflect sunlight by white-colored outer layer, then reduce the temperature of the growing media and also reduce weed and algae growth due to inner black color). After using a growing medium for one or two seasons, those were added to the open field or dumping outside (92.6%), while polluting soil and water sources nearby if the media remaining high amount of chemicals (Table 4).

Table 3. Average marketable yield of the three different crops under different growing media

Types of Growing Media	Average marketable yield (kg)		
	Bell Pepper	**Salad Cucumber**	**Tomato**
Soil			3.6[a]
Compost			4.5[a]
Coir dust	3.5[a]	5.2[a]	
Coir dust: paddy husk	2.1[a]	4.8[a]	
Coir dust: paddy husk: compost	2.8[a]	6.0[a]	4.1[a]
Coir dust: paddy husk: sand		4.0[a]	
Coir dust: paddy husk: topsoil	3.0[a]		
Paddy husk: topsoil	2.6[a]		

The means denoted by the same letters within each column are not significantly different ($p<0.05$)

Table 4. The percentage of farmers doing different cultivation practices in each district.

Factors		Percentage of farmers in each district			
		Kandy	**Matara**	**Nuwara Eliya**	**Total**
Cultivated on	Bags	83.3	100.0	68.4	82.1
	Soil	16.7	0.0	31.6	17.9
	Other	0.0	0.0	0.0	0.0
Bag type	Black	22.6	29.6	28.9	27.1
	Black & White	61.3	70.4	39.5	55.2
	Other (on soil)	16.1	0.0	31.6	17.7
After using the media	Destroy	3.2	16.0	5.3	7.4
	Add to open field	80.6	12.0	57.9	53.2
	Other	16.1	72.0	36.8	39.4

Most of the farmers (81%) practiced hydroponic cultivation/ soilless culture which can be defined as a method of growing plants in a water base, nutrient rich solution with or without growing medium as an inert medium to support the root system. The survey results showed that different types of fertigation schedules were used by the farmers since there is no recommended fertigation schedule for greenhouse vegetable by the Department of Agriculture. Majority of the farmers (96%) were taken necessary advice on fertigation from private companies/ shops and the neighboring farmers.

This study showed that 100% of the farmers used Albert's Solution as the main soluble fertilizer in their fertigation. Water soluble fertilizers are easy to use in fertigation and Albert's fertilizer is the most commonly used fertilizer in Sri Lankan greenhouse farmers (Wijesekara, 2013). In addition to Albert's solution, Calcium Nitrate, Potassium Chloride and Magnesium Sulphate fertilizer were used to supply nutrients additionally. Some farmers applied foliar applications of liquid fertilizer and slow release fertilizers including trace elements without having any recommendation or deficiencies. The amount of fertilizer added also vary among farmers (Table 5). Increasing yield per plant is one way to increase the profit. Therefore, farmers added fertilizer in order to increase the yield.

Table 5. Different fertigation schedules used by the farmers

Fertigation No.	Crops	Albert's-solution (g/plant/day)			Calcium Nitrate	Potassium chlorite	Other Fertilizer
		2 wks	4 wks	8 wks	4-8 wks	4-8 wks	
1	T, SC	0.2	0.5	1.0	√	√	
2	T	0.5	0.8	1.0	√	√	
3	BP, SC	0.5	1.0	1.0	√	√	
4	SC	0.5	1.0	1.2	√	√	
5	T, SC, BP	0.5	1.0	1.5	√	√	
6	SC, BP	0.5	1.0	1.0	√	√	√
7	SC, BP,T	0.5	1.0	1.5	√	√	√
8	T, SC, BP	Lower than No.1					
9	T, SC, BP	Higher than No.7					

T=Tomato, SC=Salad Cucumber, BP=Bell Pepper √-added in a different amount

For salad cucumber, fertigation number 3-9 (Table 5) of fertigation schedules were used and according to the yield data, Fertigation No. 4 and 5 were the higher yielding fertigation schedules and commonly used by the farmers (Figure 2). Consistent with the ANOVA test there was no significant difference among them and according to the Tukey test, there was no significant difference between each fertigation method while yield differences among the districts also could not be found. Therefore, fertigation No. 4 can be selected as the most suitable fertigation schedule for salad cucumber which has a lower rate of fertilizer than the other. For tomato fertigation schedule of No. 2, 5, 6-9 were commonly used and No.5 was showed the significantly higher yield and within the selected fertigation schedule different varieties performs different yielding habits (Figure 3).

Fertigation schedules used by the farmers varied from No. 1, 3, 5-9 for bell pepper crop and the yield data also vary according to the fertigation schedule. No. 5 was given the significantly higher yield in Nuwara Eliya and Kandy districts (Table 6).

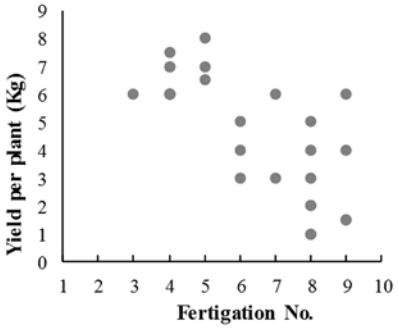


Figure 2. Yield variation among different fertigation schedules of salad cucumber

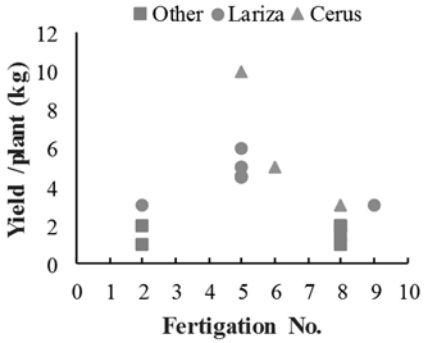


Figure 3. Average yield among different varieties of tomato under different fertigation schedules.

In Matara district, farmers used to practice only fertigation schedules of number 6 and 9 fertigation schedules which add more fertilizer to the plant but the yield was stagnated at 2 kg per plant. Excess fertigation resulting in high EC and low pH levels in growing media and it leads to poor absorption of most of the essential nutrients to the plant (Hochmoth and Geoge, 2012).

Farmer's perception for selecting crops is an important point when introducing new fertigation schedule as a trial. According to the survey results, 45.6% farmers in favor of testing new fertigation schedule for tomato crop since it is comparatively low-value crop and less risk to grow. Farmers' perception for selecting bell pepper and salad cucumber crop as test crops were 21.1% and 33.3%, respectively.

Table 6. Yield variation of bell pepper among different fertigation schedules in each district

Fertigation No.	Marketable yield (kg/plant)		
	Matara	Kandy	Nuwara Eliya
5		4.0[a]	4.5[a]
6	2.0[a]	2.56[b]	2.0[b]
7			2.0[a]
9	2.0[a]	2.50[b]	
8			1.8[a]
3	2.0[a]	1.75[c]	
1		1.56[c]	

The means denoted by the same letters within each column are not significantly different ($p<0.05$)

Perception of the farmers on fertigation

Fertilizer application is the most critical and challenging activity in greenhouse crop cultivation since the optimum amount of fertilizer should be supplied to achieve maximum yield while the cost of production is keeping at a lower rate. Perception of the farmers on fertilizer application activities was studied in this study. Nearly 50% of farmers perceived that increasing fertilizer dosage than the recommended level can increase the yield while the majority of farmers (86%) were agreed and strongly agreed with that overuse of fertilizer can affect the environment. Most of the farmers (63%) did not have adequate knowledge on fertilizer application and 82% farmers did not receive proper agricultural extension service on fertigation aspect in protected culture. The majority (94%) of the farmers more liked to apply Albert's Solution than the other fertilizers while 48% of farmers do not have good knowledge of applying Albert's Solution. Only 16 % of farmers agreed with the fact that they have known the proper concentration of Albert's Solution which should be applied (Table 7).

Table 7. Percentage of farmers according to their perception on fertigation

Questions	Agree/ Strongly Agree	Neutral	Disagree/ Strongly disagree
Applying higher fertilizer increase the yield	48	05	47
Use of Albert's fertilizer effective and economical	76	16	08
Overuse of fertilizer affect the environment	86	09	05
Have lack of knowledge on fertilizer application	63	19	19
No proper extension service received on fertigation	82	05	13
Albert's fertilizer is preferred than other fertilizer	94	04	02
Application of higher Albert's fertilizer increase the yield	50	22	28
Have problems in application of Albert's fertilizer	57	19	24
Have good knowledge on correct dosage of Albert's fertilizer	16	36	48
Prefer to test new fertilizer schedule	100	0	0

Study-II: On-Farm Survey

The selected fertigation schedule from study-1 is subjected to the on-farm survey in study-II. Though the average yield of the cucumber in these fields was higher than the farmers' field in study-I, similar results were observed in study-II. Average yield and the marketable yield were almost similar in this On-farm survey due to proper management of the poly-tunnel to have fewer pests and diseases.

The average yield of salad cucumber under the No. 4 and 5 fertigation schedules was not significantly different (Table 8). Therefore, the fertigation No.4 can be selected as the most suitable fertigation schedule for salad cucumber since it contents lower fertilizer amount than No.5. The nitrogen dosage of Albert's solution in No.4 at last stage was 0.148 g/plant/day which was similar to the Haifa greenhouse crop guide, 2014 (0.145 g/plant/day).

Table 8. Comparison of average yield obtained by salad cucumber under two different fertigation schedules.

Crop	Variety	Fertigation No.	Average total yield /plant (kg)	Average marketable yield/plant (kg)
Salad Cucumber	F-dhal	4	7	7[a]
		5	6.67	6.67[a]

The means denoted by the same letters within the column indicates statistical similarity among treatments ($p<0.05$)

Average marketable tomato yield given by same fertigation schedules (No. 4 and 5) were showed the significant difference and No. 5 was significantly higher than the No. 4 yield. Therefore, the No.5 fertigation schedule can be selected as the most suitable fertigation schedule for tomato crop (Table 9).

Table 9. Comparison of average yield obtained by tomato under two different fertigation schedules.

Crop	Variety	Fertigation No.	Average yield / plant (kg)	Total marketable yield/ plant (kg)
Tomato	Lariza (F1)	4	4	4[a]
		5	4.8	4.6[b]

The means denoted by the same letters within the column indicates statistical similarity among treatments ($p<0.05$)

Conclusion

The most effective fertilizer schedules for salad cucumber was 0.5, 1, 1.2 g/ plant/day of Albert's fertilizer while that for bell pepper and tomato were 0.5, 1, 1.5 g/plant/day during 1-4, 5-8 and 9 week onwards after transplanting, respectively. At the same time Calcium Nitrate and Potassium Chloride fertilizer were applied at the rate of 5 g/plant/week in reproductive stages (4-16 weeks). Those selected fertigation schedules can be recommended to the greenhouse farmers, subjected to further testing by the research division of the Department of Agriculture. Hence the research output on fertigation protocols (with proper media, EC and pH management) can be used to benefit greenhouse vegetable farmers in many ways such as minimizing overuse of fertilizer, cost of fertilizer, high nutrient absorption by plants, and qualifying them towards certifications in "Good Agriculture Practices". This information will help to continue this research up to the finding of critical nutrient levels for selected greenhouse crops and the project output will enhance both economic and environmental sustainability of protected culture in Sri Lanka.

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