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An Agro-economic Comparison between Dwarf and Long Green Beans Production with Soilless Production System under Greenhouse Condition in UAE

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***Abstract* – Green bean is an important vegetable crop grown in open field and under greenhouse condition in the Arabian Peninsula (AP) Region. ICARDA previous studies show that the yield and water productivity of the green beans in the region in the cooled greenhouse are 6 kg/m^2 and 10 kg/m^3 per year respectively. In UAE, total annual consumption of green beans calculated at about 5,122 tons of which only 1543 tons are local products. To cover the deficit UAE imports about 3579 tons of green beans with the estimated value of 3,141,000US$. Soilless production systems provide a good alternative solution for producing the high-value vegetable crop in the region while addressing the general region constraints against agricultural development which includes harsh environment, lack of suitable soil and the shortage of water resources. Different green beans varieties required different production systems. This study aims to compare the yield and income of dwarf and long beans in hydroponics system in UAE. For dwarf beans, the vertical soil-less system used while long beans planted at a flat soilless production system. After assessing the production records and partial income analysis, it seems that dwarf beans produce higher yield and revenue than long beans. Although the vertical system requires extra 2.03 AED costs per square meter of the greenhouse (0.55AED running and 1.48AED investment cost), generates 2.98 surpluses in gross income. The increase of revenue is as a result of higher yield, although the price for dwarf beans is lower in the market. Dwarf beans yield reached to the pick of 1.98kg/m^2 with compared to long beans yield of 0.98kg/m^2 is higher by two folds. Dwarf beans not only produce more but also start production earlier and continue production one week longer compared to long beans. This first and longer production period helps to catch-up with the higher price at the beginning and end of seasons at the market.**

***Keywords* – Cost of Production, Green Beans, Hydroponics, Partial Analysis, Soilless Production System, Soilless Vertical System.**

I. Introduction

Green bean is an important vegetable crop grown in open field and under greenhouse condition in the Arabian Peninsula (AP) Region. The International Center for Agricultural Research in the Dry Areas (ICARDA) previous studies show that the yield and water productivity of the green beans in the region in cooled GH are 6 kg/m2 and 10 kg/m3 per year respectively. These figures calculated for three growing seasons per year, therefore, the average yield would be around 2kg/m^2 per season [1].

In UAE, total annual consumption of green beans calculated at about 5122 tons of which only 1543 tons are local products. The calculations based on 11 years average between 2003 and 2013 (Table 1). To cover the deficit UAE imports about 3579 tons of green beans with the estimated value of 3,141,000US$.

Figure 1 also presents the gap between annual production and consumption of green beans in UAE.

Table 1. Green beans Import, Export and Production records in UAE for 11 years period between 2003 and 2013 [2]

Year	Import (Ton)	Export (Ton)	Production (Ton)	Estimated Consumption (Ton)
2003	2266	925	1064	2405
2004	4183	210	1200	5173
2005	1511	723	3118	3906
2006	8326	333	2205	10198
2007	2226	720	1219	2725
2008	6982	441	1234	7775
2009	6982	234	895	7643
2010	2853	234	1484	4103
2011	1268	248	1510	2530
2012	1574	262	1500	2812
2013	5740	212	1539	7067
Average	3992	413	1543	5122

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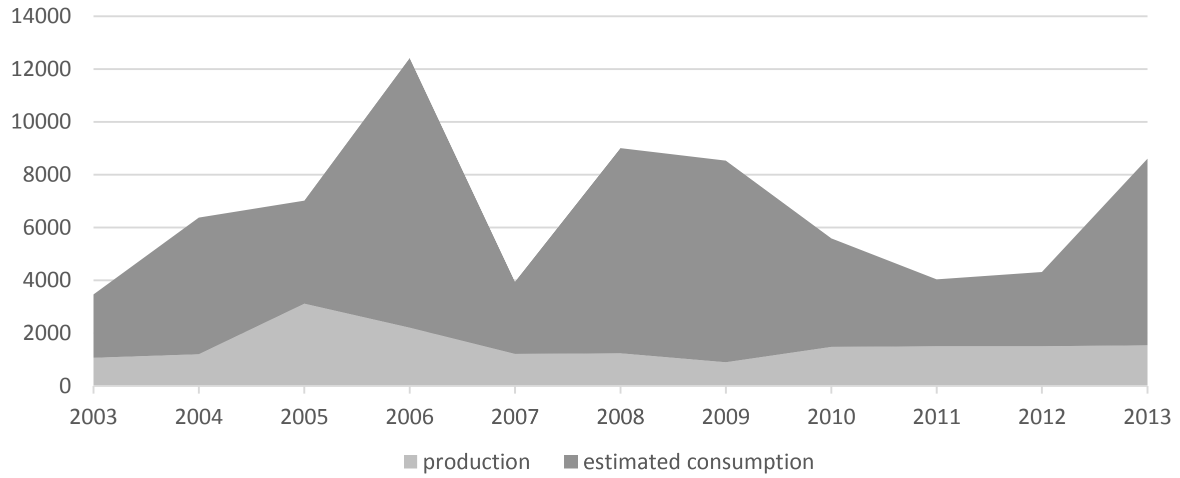

Fig. 1. Green beans production and consumption (Ton) between 2003 and 2013 in UAE

To increase the production and to answer local market increasing requirements for green beans, there is a need to overcome the general challenges which face agricultural development in AP and then of course UAE.

The AP is a water-limited region with extreme aridity and limited renewable water resources. In most areas, the annual precipitation is far below the potential crop water requirements. Hence, except a few areas in Yemen, all arable crop production requires irrigation. Another shortcoming of the region is that the renewable supply of water per capita is amongst the lowest in the world [3].

Of the 3 million-km^2 land area of the AP, about 50% is rangeland, mostly in Saudi Arabia. Pasture condition is deplorable and in some areas well below the production potential. Vast parts classified as empty lands and others have few species at very low densities. There are signs of deterioration of both the soil and plant components of the rangeland ecosystem. Overgrazing is the primary cause of rangeland degradation, which reflected in livestock, feed shortages. In attempts to alleviate feed shortages, farmers have relied on growing exotic forages with high water requirements. Excessive use of groundwater has lowered water tables, increased salinity, and in severe cases lead to croplands abandoned. In 2003, the AP's arable and irrigated area was < 8 million ha (FAO, 2004).

The AP is facing significant challenges in developing more sustainable land use and efficient water usage while preserving its environment and heritage with the current rate of population growth [3].

The issues of water management, productivity, sustainability, and environment are closely interconnected. If current inefficient practices continue, there will be rapid depletion of water resources, extinction of native species and knowledge of them, and quick environmental destruction. Soil-less techniques can improve water use efficiency, and water and fertilizer management in crop production. Also, it can also answer the low soil fertility, inadequate quality, and high rate of soil borne pathogens, which are also present significant problems in the region. Soilless production systems would increase yield quality and quantity per unit of water, area, and workforce [4]. The soil-less growing techniques developed and adapted by ICARDA are being adopted in AP countries.

High-density cropping or vertical soil-less cultivation is an excellent system for high-value production, such as herbs, green vegetables, dwarf beans, and fruit [5]. The system uses a tower of interlocking stackable Styrofoam pots [6] , which have drainage holes and are filled with soil-less media. The nutrient solution is collected in catchment channels under the lowest pot and re-circulated. The system was introduced by ICARDA to the region adapted for strawberry production in marginal and nonproductive lands in Kuwait, Oman, Saudi Arabia, and Bahrain. The vertical expansion increases the productivity per unit area. Planting and harvesting are much easier, and capital outlay per plant will progressively decrease.

Strawberry production using the vertical hydroponics system was highly successful, with several advantages over traditional soil-beds. In Kuwait the benefits were [7]:

- 463% increase in yield
- 700% increase in crop density
- 98% reduction in water consumption
- 63% reduction in fertilizer consumption
- 59% reduction in production costs.

Beans are one of the most productive and low-maintenance vegetable plants that can be grown in a hydroponic system [8]. There are many different types of beans to select from, some of the most popular types are the pole bean, the string bean (also known as the green bean), the lima bean (also known as the butter bean), and the pinto bean. However, selection of green beans varieties also depends on the production system. Long beans cannot grow in the vertical system where only dwarf varieties can develop. From another hand market requirement also is necessary for selection of beans varies.

The present study aims to compare the productivity and cost/benefit ratio of long and dwarf green beans varieties under soilless production system in UAE. Each variety planted in its suitable production systems where dwarf beans transplanted into a vertical system.

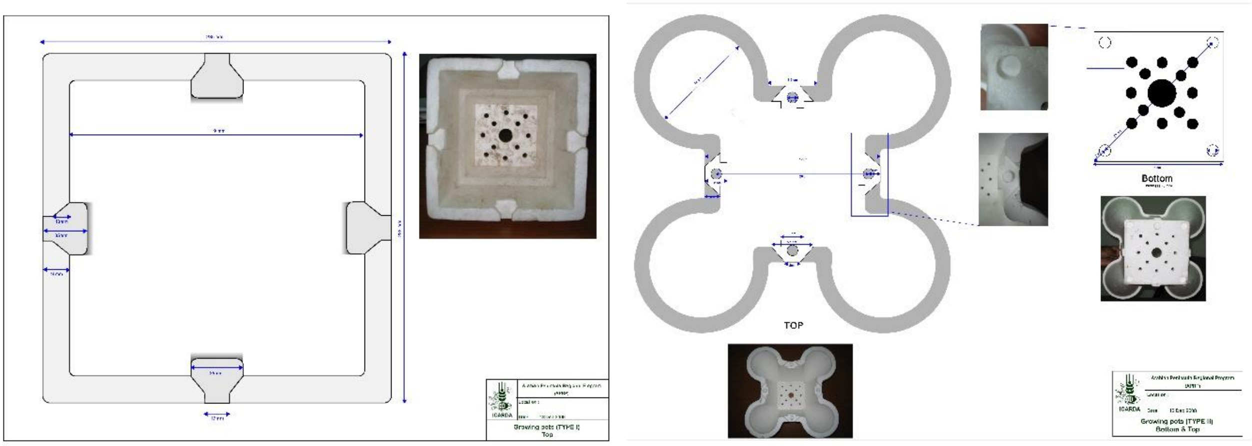

Fig. 2. Profile of polystyrene pots. Vertical system pots right with adjusted corners for four plants

II. Materials and Methods

A greenhouse structure (8x30m) with cooling system (Pad and Fan) and polyethylene cover at Al Dhaid research station (Agricultural Innovation Center) selected for this study. The greenhouse also equipped with soil-less production system with the irrigation tank buried in the middle of the greenhouse.

The vertical system installed in an area of 60m^2 while the area allocated for extended beans was about 120m^2. Both systems used polystyrene pots. However, the pots for vertical system adjusted for accommodating four plants in each corner. The smaller containers accommodate 2 two plants each with V pattern for plantation of long beans (Fig. 2).

The vertical system consisted of 17 columns in each row. Each column builds up with eight pots seating on top of each other (a total of 272 pots). A ½" high-pressure PVC pipe passed through the pots core and provided columns with more stability. The pipes were connected to each other from the bottom with one meter PVC pipe and fixed to the greenhouse ceiling by wire from the top.

For the long beans, 200 pots were lined on top of collection canals. Two seedlings planted in each pot. For both systems, a closed production technique utilized where the irrigation water which also contained nutrition and fertilizer were pumped from the tank to the pots. Excess water was collected through the canals and returned to the reservoir. Containers filled with perlite as media.

The beans varieties which used in this study include 1) Short beans Variety: SHADE and 2) Long beans Variety: Pole Bean Saphiros. A total of 1054 dwarf and 400 long beans seed planted for the study. Vertical and flat Systems planted on 12 and 18 January respectively. Both system harvest in same days with the same treatments. The used one tank with similar fertilizer compounds.

To calculate the cost-benefit ratio, besides all cost of production, after each harvest the local market price for long and dwarf beans were collected from different markets to calculate the income for each harvest.

III. Results

A. Production

Long beans were in production in 13 weeks while dwarf produces one more week. The last harvest of long beans and dwarf was 9 and 13 April respectively. Dwarf beans not only produce longer but also start production one week earlier compared to long beans (Fig. 3).

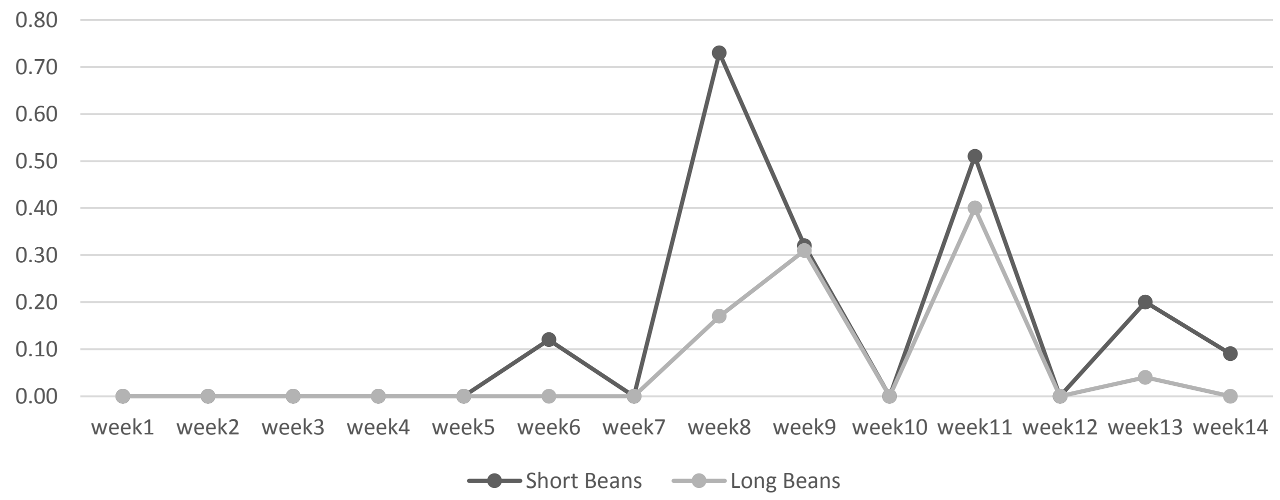

Fig. 3. Production records (kg/m2) at each harvest

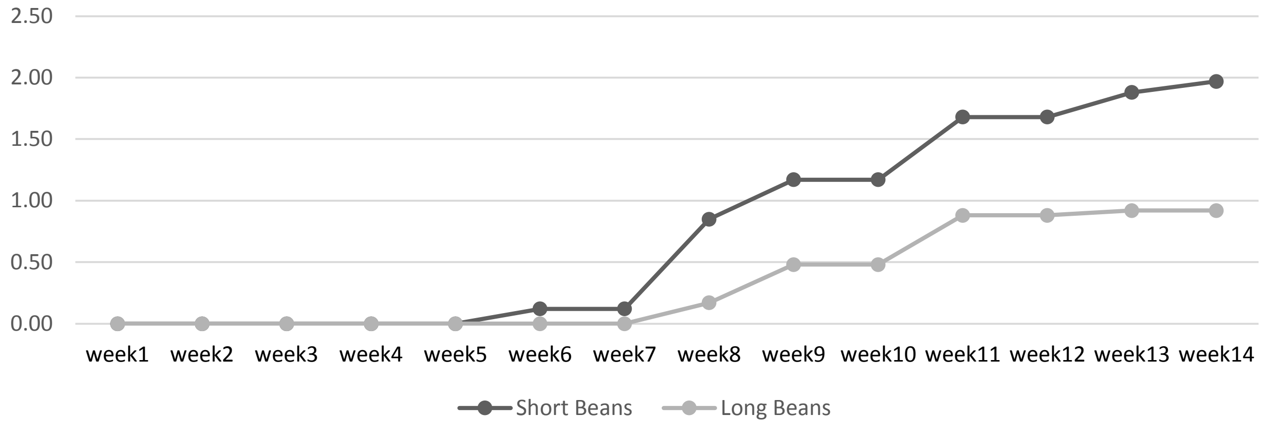

Fig. 4. A cumulative production records (kg/m2) during the production period

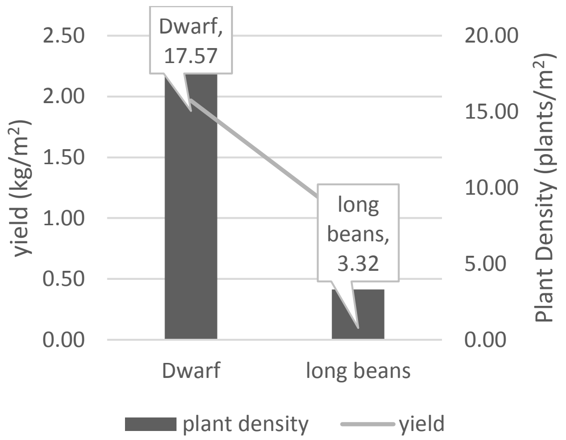

Fig. 5. Comparing plant density (plant/m^2) and yield (kg/m^2) between dwarf and long beans

Fig. 4 illustrates the accumulation production during the crop year. The dwarf beans production was more than double of what produced by long beans. Dwarf made 1.97 kg/m^2 of greenhouse while long beans produced 0.92 kg/m^2. Plant density (plants/m^2) with the vertical system also increased by more than five times. The extra plant density also has a positive impact on yield (kg/m^2) where the dwarf beans also produce five timed more crop than long beans (Figure 5).

Table 2 shows the total income per square meter of greenhouse for each varies in each harvest. The dwarf generated more income than long beans by 1.5 folds. However, the differences between production and income between the two varieties are not significant. Microsoft Excel Data Analysis pack have been used to test the equality of variance and t-student test to compare the mean production of two varieties.

Table 2. Production (kg/m^2), market price and income (AED/m^2) for each harvest.

Date	yield/m^2 (short)	yield/m^2 (long)	Market price/kg (short)	Market Price/kg (long)	income/m^2 (Short)	Income/m^2 (long)
19-Feb-17	0.12	0.00	3.95	0	0.46	0.00
6-Mar-17	0.73	0.17	3.85	6.95	2.82	1.21
13-Mar-17	0.32	0.31	3.25	5.95	1.03	1.82
29-Mar-17	0.51	0.40	4.45	6.45	2.25	2.61
9-Apr-17	0.20	0.04	7.95	7.5	1.62	0.28
13-Apr-17	0.09	0.00	7.95	9.5	0.73	0.00
Total	1.97	0.92			8.91	5.92

Table 3. F-Test Two-Sample for Variances

	income m^2 (long)	income/m^2 (Short)
Mean	0.99	1.48
Variance	1.16	0.84
Observations	6.00	6.00
df	5.00	5.00
F	1.38	
P(F<=f) one-tail	0.37	
F Critical one-tail	5.05	

Table 3 shows the F-test for two-sample analysis for variances. As F< F Critical one-tail, we accept the null hypothesis. This is the case 1.38<5.0. Therefore, it can be stated that the variances of the two population are equal.

Table 4. t-Test: Two-Sample Assuming Equal Variances

	income m^2 (long)	income/m^2 (Short)
Mean	0.99	1.48
Variance	1.16	0.84
Observations	6.00	6.00
Pooled Variance	1.00	
Hypothesized Mean Difference	0.00	
df	10.00	
t Stat	-0.86	
P(T<=t) one-tail	0.21	
t Critical one-tail	1.81	
P(T<=t) two-tail	0.41	
t Critical two-tail	2.23	

Table 4 presents t-students test for comparing the two group means of income (assuming equal variances). We do a two-tail test. If the t-value is graeter than the t-critical value, you can reject the null hypothesis [9]. This is not the case,-0.86<2.23. Therefore, we do not reject the null hypothesis. The observed difference between the two varieties means income/m^2 (1.48 – 0.99) is not persuasive enough to say that the average income between two varieties differs significantly.

B. Cost-benefit Ratio

Nevertheless, calculating the net benefit of the production of the two beans varieties reveals that the dwarf generates more net profit by more than four folds. Although the market price for long beans is higher (table 2), the upper yield of dwarf returns better.

A partial budget helps to evaluate the financial effect of different technologies. The partial budget will be considered only variables that will be changed. It does not consider the variables that are left unchanged. Only the change under consideration is evaluated for its ability to increase or decrease income in the farm business [10].

All data, especially those related to capital and investment cost converted to AED/m^2/season where three growing seasons for both systems is considered. For calculating the budget, the market price of production and agricultural inputs are used without calculating the variables such as environmental issues and subsidies paid by the government.

Therefore, this is financial rather than economic analysis. While some of the actual tools are the same, financial analysis focus on private profitability and financial flows related to some indicators such as market price, depreciation, interest rate, credit, etc. The economic analysis in addition to the financial analysis looks at the some of the socio-economic and sustainability issues such as tax and subsidies, natural resource management, labor opportunity, price control and rationing, etc. [11].

Table 5 shows the total income, current and investment cost of production as well as net profit per seasons per m^2 of the greenhouse. For the calculation of capital costs and their depredations, three growing seasons per year have been considered. For the cost of seeds, seed germination rate also considered calculating the total cost of seeds required.

C. Capital and Investment Costs

Adopting of the vertical system needed to increase the capital cost by 1.48 AED/m2/year, which is to cover the costs associated with additional to irrigation systems, bigger pots, and extra growing media. The return irrigation systems, tanks, and pump in both cases are the same. The estimated costs and economic life of each component are considered as 1) pots four years, 2) Media 3 years and irrigation system five years. The salvage value considered as zero.

D. Cost of Production and Materials

Adopting the vertical production system increased the running cost of production by 0.55 AED/m^2/year m^2 of the greenhouse:

1. Reduce the cost of seeds, although the vertical system increased the crop density by five times (Fig. 5) and required more seeds. However, the cost of dwarf seeds was significantly lower than long beans seeds where the market price for 100 seeds of long and dwarf was 38AED and 8AED respectively. For calculation of required seeds, losses due to germination rate also considered.
2. There were no separate tanks for each system; therefore measuring actual fertilizer consumption for each variety was not possible. However, the total fertilizer consumption is used for estimating the fertilizer utilization in each system[1]based on their yield. The vertical system produced more yield than the long bean, therefore required more fertilizer. Overall, adoption of the vertical system increased 1.74 AED/m^2/seson of the greenhouse.

Other costs associated with irrigation water and agrochemical considered the same for both production system as biomass was the same.

E. Yield and Gross Income

In general, vertical systems produced more beans per unit of area by more than two folds. Although the price for short beans was lower in the market, higher production resulted in a better income.

Overall, vertical system generate extra 3AED/season/m^2 gross income. Figure 6 illustrates, and better highlights the total income, current, and investment cost of production as well as net profit per seasons per m^2 of the greenhouse.

[1] Based on the interview with specialists

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Table 5. Net profit/season/m2 of greenhouse for production of the beans varieties

	Dwarf (Short)	Long	Difference
Total income m^2	8.91	5.92	2.98
Current Cost of production			
Seeds	1.71	2.90	-1.19
Fertilizer	3.27	1.54	1.74
Current Cost of production/m^2/season)	4.98	4.43	0.55
investment cost			
Pots	0.88	0.28	0.60
Media	1.11	0.39	0.72
irrigation system	0.66	0.50	0.16
Total investment cost/m^2/season	2.64	1.17	1.48
Net profit/season/m^2	1.29	0.32	0.96

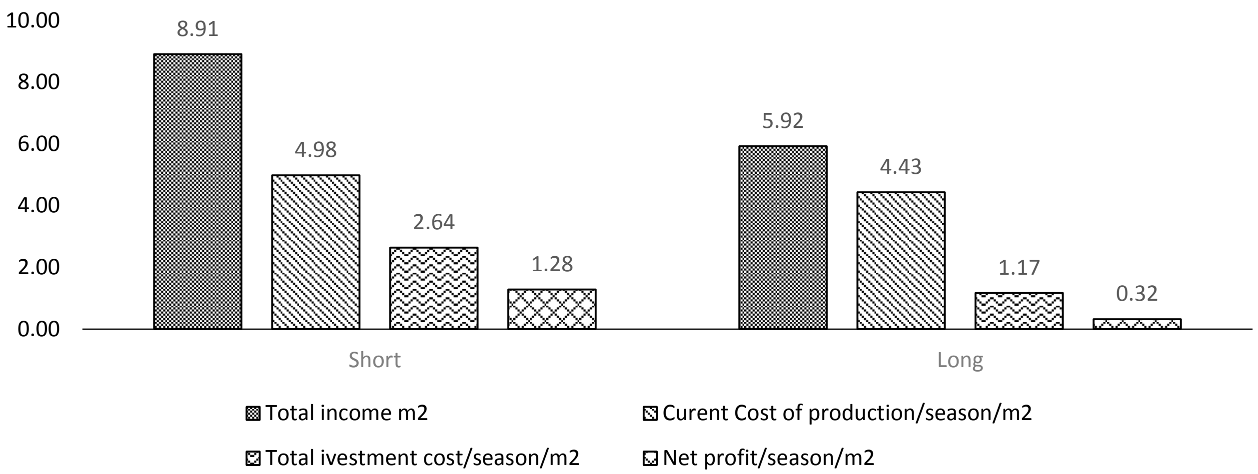

Fig. 6. Comparison between the cost of production and net income /m^2/season for two beans varieties

IV. Discussions and Recommendations

The observed difference between the two varieties means income/m^2 (1.48 – 0.99) is not convincing adequate to say that the average income between two varieties differs significantly.

Nevertheless, assessing the production records and partial income analysis, showed that dwarf beans produce higher net income than long beans. Calculating the net benefit of the production of the two beans varieties reveals that the dwarf generates more net profit by about four folds per square meter of the greenhouse. Although the vertical system requires extra 2.03 AED costs per square meter of the greenhouse (0.55AED running and 1.48AED investment cost), generates 2.98AED surpluses in gross income.

The increase of revenue is as a result of higher yield, although the price for dwarf beans is lower in the market. Dwarf beans yield reached to the pick of 1.98kg/m^2 with compared to long beans yield of 0.98kg/m^2 is higher by two folds.

Dwarf beans not only produce more but also start production earlier and continue production one week longer compared to long beans. This early and longer production period helps to catch-up with the higher price at the beginning and end of seasons at the market.

Overall, it can be stated that production of dwarf beans with vertical hydroponics system generate better income and higher yields compared to long beans with normal flat hydroponics systems.

The following activities are recommended to enhance and complete the outcomes of this study:

- Continue the study within two different greenhouses or one greenhouse with two irrigation tanks. This will provide suitable information on fertilizer and water use efficiency of each system.
- The crop production cycle to be completed for one year (3 to 4 seasons) to increase the internal and external validity of the study.
- Considering a study on post-harvest and enhance the market value of the product. Looking at the market price for imported and locally produced beans reveals that the imported beans have higher prices and market.

V. Conclusion

Vertical column-based soilless production system presented a viable alternative to conventional horizontal growth systems by optimizing growing space in greenhouse more efficient, thereby producing more crop

It can be seen then that that dwarf beans produce higher yield and income than long beans under soilless production system in UAE. Although the vertical system requires extra 2.03 AED costs per square meter of the greenhouse (0.55AED running and 1.48AED investment cost), generates 2.98 surpluses in gross income. The increase in income is as a result of higher yield, although the price for short beans is lower in the market. Dwarf beans yield reached to the pick of 1.98kg/m^2 with compared to long beans yield of 0.98kg/m^2 is higher by two folds. Dwarf beans not only produce more but also start production earlier and continue production one week longer compared to long beans. This early and longer production period helps to catch-up with the higher price at the beginning and end of seasons at the market.

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