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Economics Analysis of Tomato Hybrid Seeds Produced through Soilless Systems

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ABSTRACT

Background: The agricultural sector is highly dependent on the availability and quality of seeds for a productive harvest. The global demand for food and water is expected to increase due to population outgrowth, urbanization and climate change. Soilless farming may change the face of agriculture by providing a more sustainable and productive alternative to traditional cultivation and is being largely exploited for vegetable cultivation.

Methods: The experiment consisted of 12 treatments. Two parental lines (P_1: TAG 1 and P_2: TAG 2) were subjected to seed treatment (S_1: Untreated and S_2: Thiram @ 2g kg^{-1} and chlorpyrifos @ 3g kg^{-1}) and twenty-eight days old seedlings were transplanted to soil (M_1: Conventional) and soilless systems (M_2: Hydroponics and M_3: Aeroponics). Hybrid seeds were produced in all the system were analysed for the quality and economics of seed production in soilless system was worked out.

Result: The results revealed that there was a significant increase in test weight (0.39 g), average seed length (0.52 cm) in the soilless system due to the continuous availability of nutrients at controlled condition. Although the cost incurred was comparatively higher in the soilless method, the gross return was 94.68 per cent higher under aeroponics and 79.22 per cent higher under hydroponics compared to the conventional method. The benefit to cost ratio was found higher in aeroponics (2.08) followed by hydroponics (1.97) and lower under the conventional method (1.87). It is inferred that soilless agriculture could be a promising tool for quality and healthy hybrid tomato seed production throughout the year within protected cultivation.

Key words: Aeroponics, B:C ratio, Hydroponics, Hybrid seed production.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) being an important vegetable crop with the largest coverage area among the vegetables in the world after potato. It belongs to the family Solanaceae. The total global area under tomato is 5.03 Million ha with production to the tune of 180.76 Million (FAOSTAT, 2019). India contributes 7.3% share of world production and it occupies 789 thousand ha. But the productivity in India (24.6 t ha^{-1}) is much lower compared to other countries *viz*., USA (96.8 t ha^{-1}), Brazil (71.9 t ha^{-1}) and China (59.3 t ha^{-1}). Quality seeds one of the important components contributing to productivity to the tune of 15-20 per cent. In developing countries like India, it is being a tedious task to supply quality seed at the proper time in the conventional production system as it is prone to abiotic/biotic stress, foreign pollen contamination, weeding, rouging and achieving isolation distance.

Soilless culture is the technique of growing plants with roots immersed in the nutrient solution. These systems can be classified according to the techniques employed as hydroponics, aeroponics and aquaponics. The word hydroponics first appeared in a scientific magazine article (Science, Feb 178:1 by Gericke). Hydroponics is a technology for growing plants in nutrient solutions with or without the use of an artificial medium. Aeroponics is the cultivation of plants in an air or mist environment without the use of soil or aggregate media. It consists of enclosing the roots in a dark chamber and supplying a nutrient solution using a mister. Aquaponics is an integrated fish and plant production technology, essentially comprising of two sub-systems, such as, Aquaculture and Hydroponics.

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Currently, about 3.5% of the worldwide area for vegetable production adopts soilless agriculture (Hickman). The advantage of these systems is plant nutrition and biotic stress can be controlled much more efficiently. Increasingly greenhouse farming and urban agriculture are being looked at as a more efficient and cost-effective way to produce vegetables (Kinoshita *et al.,* 2016). Since the earlier experimental results revealed that the soilless system has wide potential for vegetable production. These efficient systems can be exploited for hybrid seed production as they share a common principle of production. The quality, cost and return analysis play a significant role in farm economics as it supports decision making at various levels for the farmers, researchers, policy makers, bankers and administrators.

Thus, the research questions were, to analyse the seed quality produced through the soilless system if it meets the quality standards is the system economical for hybrid seed production.

MATERIALS AND METHODS

The present investigation was carried out through hydroponics and aeroponics for hybrid seed production of tomato (*Solanum lycopersicum* L), during 2017-19 at National Seed Project, University of Agricultural Sciences, GKVK, Bangalore. The experiment consisted of 12 treatments.

Treatment details of the experiment

Parental lines and seed treatment

Two female lines *viz.,* TAG 1F and TAG 2F with their respective pollen parents (TAG 1M and TAG 2M) were collected from the BASF Nunhems Pvt Ltd and stored at -20°C for further usage. Seeds were subjected to seed treatment and dived into untreated control and treated (thiram @ 2g kg^{-1} and chlorpyrifos @ 3g kg^{-1} and dried in shade).

Methods of hybrid seed production

Conventional method

The field experimental plot contains 12 blocks with the net plot size of 5.4 × 3.6 m and the gross plot size is 6.4 × 4.5 m. Tomato plants were at a row spacing of 0.9 m and 0.6 m between plants within a row. At the time of transplanting, urea, single super phosphate and muriate of potash were applied as the basal dose of nitrogenous, phosphorus and potassium fertilizer as per the recommended package of practices of the University of Agricultural Sciences, Bangalore (100:100:100 NPK/ha) for open field cultivation. Nitrogen was supplied as urea in three splits such as 50 per cent basal (during transplanting), 25 per cent each at 30 and 60 DAT (Days After Transplanting) respectively. The entire quantity of P and K were applied basally during transplanting.

P- Parental line	S- Seed treatment	M- Hybrid seed production method
P_1: TAG 1F (Female) TAG 1M (Male)	S_1: Untreated	M_1: Conventional method
P_2: TAG 2F (Female) TAG 2M (Male)	S_2: Treated (thiram @ 2g/kg + chlorpyrifos @ 3g/kg)	M_2: Hydroponic method M_3: Aeroponic method

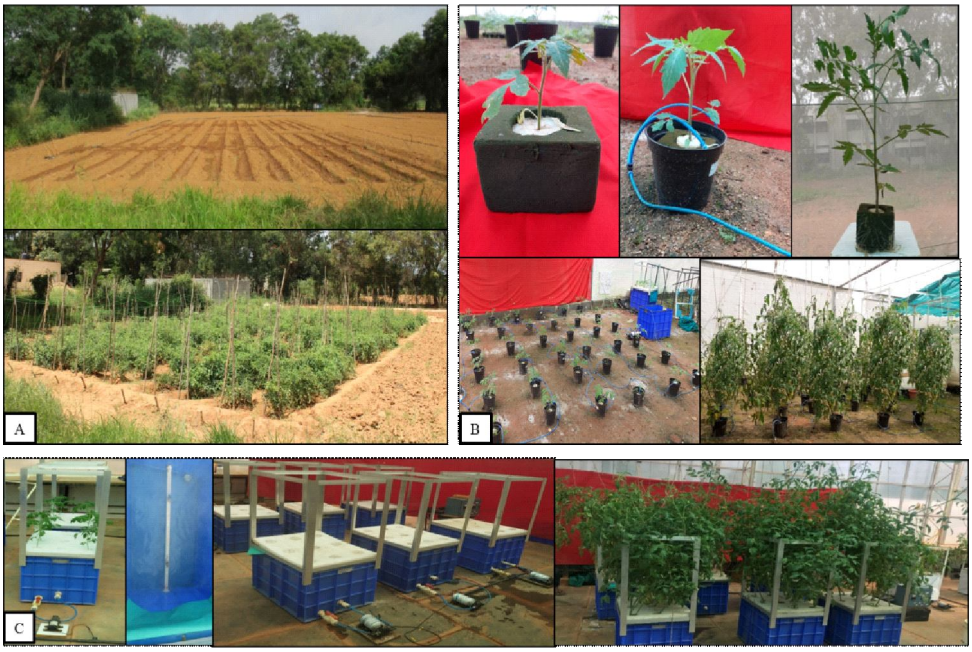


Fig 1: A) Layout of conventional method; Prototype and layout of B) Hydroponics System; C) Aeroponics System.

Hydroponics method

In the drip system, pots were fitted with sponges. Twenty-eight days old seedlings were transplanted into each pot, connected with drip along with the timer for delivering Hoagland's nutrient solution for 3 hours per day (Morning-45 min, afternoon-90 min and night-45 min).

Aeroponics method

The experiment in aeroponics contains six chambers with the individual timer and motor. Twenty-eight days old seedlings were placed on the foam sheet. Six plants were accommodated per chamber, Hoagland nutrient solution was sprayed to root zone at an interval of 30:360 sec and 30:180 sec on and off-cycle in morning and night respectively (Fig 1).

Seed quality parameters

Test weight (g), seed size were analysed under BIOVIS PSM Seed Image Analyser for average seed length and seed width of 100 seeds for each replication, seed germination (%) (Anonymous, 2017) seedling vigour index I (Abdul Baki and Anderson, 1973).

Cost and benefit analysis

Cost of cultivation was calculated based on 1) Variable cost which varies with the level of production like labour cost, land preparation, pollination labour cost, seedling/seeds, fertilizers, nutrient solution, plant protection chemicals, staking materials, pruning and miscellaneous. 2) Fixed cost is the cost that does not vary with the level of production *viz.,* land revenue, managerial cost, risk premium, amortized establishment cost. Amortization is an accounting technique that reduces cumulative establishment cost at a discount rate over the economic life of the plantation. Net house (15 years), staking iron roads (20 years), sponge for hydroponics (3 years) and others (10 years) with the 4 % discount and annual maintenance cost.

$$A = P \frac{i\,(1+i)^t}{(1+i)^t - 1}$$

Where,

A - Amortized establishment cost; P - Establishment cost; *i* - Discount rate; t - Economic life.

The number of labours was calculated based on the number of plants and operation involved in the particular method of hybrid seed production. The average salary was 280 Rs Day^{-1} except for pollination where skilled labours were employed with an average salary of 300 Rs Day^{-1}. The cost of fertilizers used for the soilless system was calculated based on the average amount of nutrients consumed.

The benefit was analyzed and gross returns, net returns, returns per rupee of variable cost, returns per rupee of cost of cultivation, incremental cost, incremental benefit and incremental benefit-cost were computed.

Statistical analyses

The experimental data were statistically analysed by adopting Completely Randomized Design with Factorial concept (FCRD) as per Gomez and Gomez adopting "Fisher Analysis of Variance Technique" with the Critical difference values were computed at 5% level wherever F test was significant.

RESULTS AND DISCUSSION

The quality of hybrid seed produced in hydroponics and aeroponics was compared with the conventional system and the results revealed that the soilless system performed better than the soil system. Test weight was significantly influenced by parental lines and method of seed production. TAG 1 (0.39 g) parental line had the higher test weight compared to TAG 2 (0.35 g). Among the methods of seed production, aeroponics (0.39 g) recorded higher test weight which was on par with hydroponics (0.38 g) and lower in the conventional system (0.34 g). The average seed size analysed in the biovis image analyser showed a significant difference among the methods of hybrid seed production. The data obtained revealed among the method of hybrid seed production, higher seed length as recorded in aeroponics and hydroponics (0.52 cm) and lower was recorded in the conventional system (0.47 cm). Seed width varied significantly for parental lines, higher width was recorded in TAG 1 (0.36 cm) (Table 1). Seed germination of hybrids did not significantly vary among the parental lines, seed treatment and method of hybrid seed production. SVI-I varied significantly among seed treatment, treated seeds (S_2) recorded higher SVI-I (2749) compared to untreated S_1 (2672), among the methods of hybrid seed production hydroponics (2821) recorded higher SVI-I and lower was recorded in conventional (2577) (Table 2).

The differences in test weight and seed width among the parental lines are genetically controlled. The difference in test weight and seed size among the methods of hybrid seed production may be due to controlled nutrient feeding as the nutrients are present in ionic forms with the precise nutrition, pH and temperature, compared to the complexities of mineralization, mobilization and uptake by the plant in the conventional system. This is likely due to soilless system provides more favourable sink/source balance which enhanced the better root-shoot growth (Gruda; 2009, Liu *et al.,*2016) (Fig 2 and Fig 3). The seeds were viable among all the treatments thus, the results were non-significant for seed germination and field emergence as it in turn indicates liveness and quality of seeds. It is inferred that soilless agriculture could be a promising tool for quality healthy tomato seed production under protected cultivation (Kaddi *et al.*, 2014).

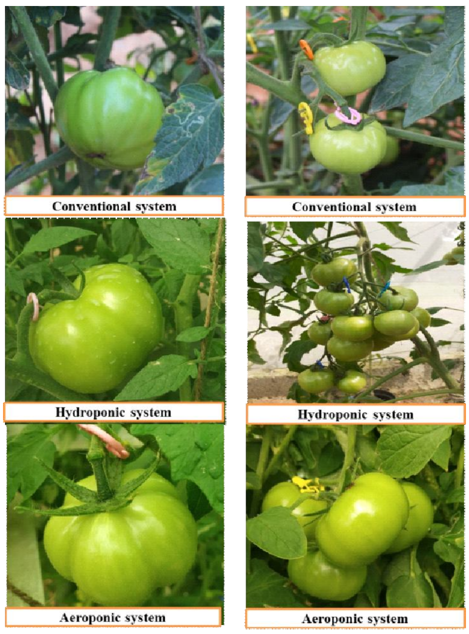
The cost and return structure of hybrid seed production of tomato in conventional, hydroponics and aeroponics were calculated and presented in Table 3. Based on the economic calculation, the variable cost involved the working capital cost and it was comparatively lower for the conventional

Table 1: Seed quality parameters as influenced by different methods of hybrid seed production, seed parent and seed treatment in tomato.

Treatment		Test weight (g)			Seed length (cm)			Seed width (cm)		
		P1: TAG 1	P2: TAG 2	Mean	P1: TAG 1	P2: TAG 2	Mean	P1: TAG 1	P2: TAG 2	Mean
S1: Untreated	M1: Conventional	0.38	0.31	0.34	0.45	0.49	0.45	0.33	0.32	0.32
	M2: Hydroponics	0.40	0.37	0.39	0.52	0.52	0.52	0.37	0.37	0.37
	M3: Aeroponics	0.40	0.36	0.38	0.52	0.54	0.52	0.39	0.37	0.38
S2: Thiram @ 2 g kg-1 and chlorpyrifos @ 3g kg-1	M1: Conventional	0.38	0.30	0.34	0.46	0.47	0.46	0.34	0.32	0.33
	M2: Hydroponics	0.40	0.37	0.38	0.53	0.52	0.53	0.37	0.37	0.37
	M3: Aeroponics	0.43	0.38	0.41	0.52	0.52	0.52	0.38	0.37	0.37
	Mean	0.39	0.35		0.50	0.51	0.50	0.36	0.35	
P × S	S1	0.39	0.35	0.37	0.49	0.51	0.49	0.36	0.35	0.36
	S2	0.39	0.35	0.38	0.50	0.50	0.50	0.36	0.35	0.36
P × M	M1	0.38	0.30	0.34	0.45	0.48	0.45	0.33	0.32	0.33
	M2	0.40	0.37	0.38	0.52	0.52	0.52	0.37	0.37	0.37
	M3	0.41	0.37	0.39	0.52	0.53	0.52	0.38	0.37	0.38
		S.Em.±	CD (P=0.05)	CV(%)	S.Em.±	CD (P=0.05)	CV(%)	S.Em.±	CD (P=0.05)	CV(%)
	P	0.003	0.008	3.00	0.005	NS	4.11	0.004	0.010	4.20
	S	0.003	NS		0.005	NS		0.004	NS	
	M	0.003	0.010		0.006	0.017		0.004	0.013	
	PS	0.004	NS		0.007	NS		0.005	NS	
	PM	0.005	0.014		0.008	NS		0.006	NS	
	SM	0.005	0.014		0.008	NS		0.006	NS	
	PSM	0.007	NS		0.012	NS		0.009	NS	

Table 2: Germination per cent and SVI-I as influenced by different methods of hybrid seed production, seed parent and seed treatment in tomato.

Treatment		Germination (%)			SVI-I		
		P_1: TAG 1	P_2: TAG 2	Mean	P_1: TAG 1	P_2: TAG 2	Mean
S_1: Untreated	M_1: Conventional	89.67	91.00	90.33	2549	2517	2533
	M_2: Hydroponics	89.67	89.67	89.67	2863	2714	2788
	M_3: Aeroponics	89.00	90.00	89.50	2801	2590	2695
S2: Thiram @ 2 g kg^{-1}	M_1: Conventional	89.00	89.00	89.00	2646	2595	2620
and chlorpyrifos	M_2: Hydroponics	90.00	90.00	90.00	2831	2874	2853
@ 3g kg^{-1}	M_3: Aeroponics	89.67	90.00	89.83	2717	2832	2774
Mean		89.50	89.94		2734	2687	
P × S	S_1	89.44	90.22	89.83	2738	2607	2672
	S_2	89.56	89.67	89.61	2731	2767	2749
P × M	M_1	89.33	90.00	89.67	2597	2556	2577
	M_2	89.83	89.83	89.83	2847	2794	2821
	M_3	89.33	90.00	89.67	2759	2711	2735
		S.Em.±	CD (P=0.05)	CV (%)	S.Em.±	CD (P=0.05)	CV (%)
	P	0.24	NS	1.13	31.57	NS	4.94
	S	0.24	NS		31.57	NS	
	M	0.29	NS		38.67	112.87	
	PS	0.34	NS		44.65	NS	
	PM	0.41	NS		54.69	NS	
	SM	0.41	NS		54.69	NS	
	PSM	0.59	NS		77.34	NS	



TAG 1F TAG 2F

Fig 2: Effect of conventional, hydroponic and aeroponics systems on fruit growth of TAG 1 and TAG 2 tomato plants.

method (Rs. 592503/-) followed by aeroponics (Rs. 626883/-) and it was found higher in hydroponics (Rs. 720944/-). Due to the cost incurred for nutrients was higher in the hydroponics method (Rs. 243424/-), followed by aeroponics (Rs. 90789/-) and lower in conventional (Rs. 22000/-) (Appendix-I). The fixed cost was higher for aeroponics (Rs. 920360/-) followed by hydroponics (Rs. 786276/-) and lower was for conventional system (Rs. 295304/-). This is due to higher establishment cost in the soilless based method of hybrid seed production.

The returns were calculated based on the yield obtained in the individual method of hybrid seed production and the procurement cost of hybrid seeds. Higher returns over total cost were noticed in aeroponics method (Rs. 1672637/-), followed by hydroponics (Rs. 1456380/-) and lower in the conventional method (Rs. 748586/-) (Table 4).

The return per rupee (B:C ratio) was higher in aeroponics (2.08), followed by hydroponics (1.97) and lower in conventional method (1.87). The incremental cost and benefit ratio was calculated to understand the benefit ratio over the other methods. IB:C ratio for aeroponics over conventional method recorded the higher ratio (2.38) than hydroponics over conventional method (2.12). Thus, based on the cost and return analysis it was found that higher cost was incurred for the soilless method of hybrid seed production compared to soil-based seed production as it involved the aeroponics and hydroponics chamber, net-house for protected cultivation since the nutrients were supplied at regular interval basis which took the major share for a fixed cost. Even with higher investment cost, returns were also higher in the soilless agriculture method of hybrid seed production due to high density under hydroponics (2.8 plant/m^2), aeroponics (3.1 plant/m^2) compared to a soil-based method of hybrid seed production (1.7 plant/m^2).

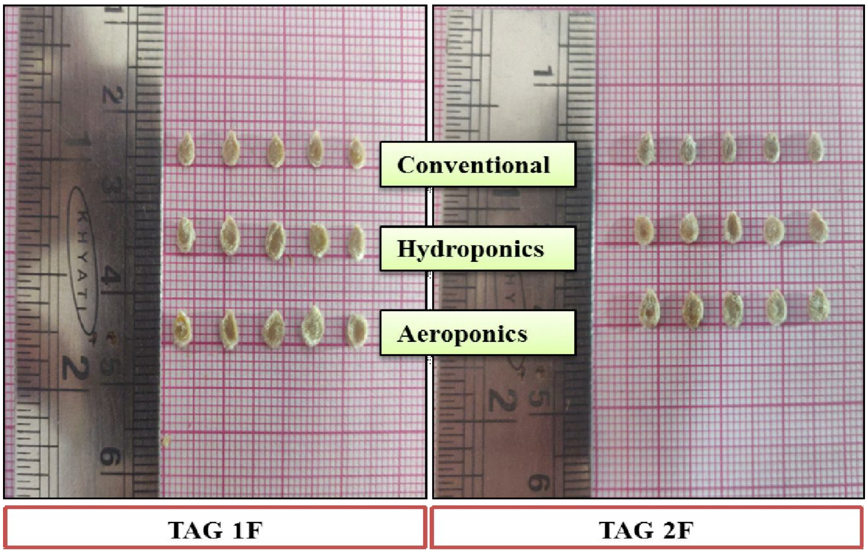


Fig 3: Effect of different methods of seed production on seed size of tomato.

Table 3: Variable and fixed cost for hybrid seed production in conventional, hydroponics and aeroponics method in tomato (Per hectare/crop).

Variable cost/ working capital (Rs)	Conventional	Hydroponics	Aeroponics
Land preparation	19967	0	0
Farm yard manure	92625	0	0
Seed material cost	17290	27444	30707
Plant preparation	17290	27444	30707
Staking (sticks and threads)	69229	29689	32555
Labour			
Pollination	168750	225000	281250
General labour cost	49400	49400	49400
Earthling up weeding +Debris cleaning	29640	3088	3088
Fruit harvesting (labour)	19760	29640	29640
Roughing and fruit elimination	3339	3339	3339
Fertilizers	22000	243424	90789
Pesticides	31616	15808	15808
Electricity	835	7503	6583
Seed extraction	12000	12000	12000
Interest on variable cost @7%	38762	47165	41017
Total variable cost	592503	720944	626883
Fixed cost			
Land rent @ 10% of gross return	165600	296800	322400
Land revenue	86	86	86
Motor	1849	0	0
Drip	15226	0	0
Pots	0	81207	0
Motors plus timer	0	3699	3699
Pipes	0	18272	18272
Foam/sponge	0	51624	12181
Net house structure	0	88862	88862
Staking iron rods	0	72699	72699
Managerial cost @ 10% of the WC	61211	72534	63100
Risk premium @ 5 of 80% of WC	24484	29014	25240
Chambers plus sprinklers	0	0	230152
Interest on fixed cost @10%	26846	71480	83669
Total Fixed cost	295304	786276	920360
Total	887807	1507220	1547243

Table 4: Cost and return structure for hybrid seed production in conventional, hydroponics and aeroponics method in tomato.

Particulars	Conventional method		Hydroponic method		Aeroponics method	
	Per hectare	Per Kg	Per hectare	Per Kg	Per hectare	Per Kg
IFixed cost (Rs)	295304	1427	786276	2119	920360	2284
Variable cost (Rs)	592503	2862	720944	1943	626883	1556
Total cost (Rs)	887807	4289	1507220	4063	1547243	3839
Yield (Kg)	207		371		403	
Price per Kg (Rs)	8000		8000		8000	
Gross returns (Rs)	1656000	8000	2968000	8000	3224000	8000
Returns over variable cost (Rs)	1063497	5138	2247056	6057	2597117	6444
Returns over total cost (Rs)	768193	3711	1460780	3937	1676757	4161
Returns per rupee of variable cost	2.79		4.12		5.14	
Returns per rupee of total cost	1.87		1.97		2.08	
	Hydroponics/conventional		**Aeroponics/conventional**			
IC	619413.13		659436.13			
IB	1312000		1568000			
IC:B ratio	2.12		2.38			

IC: Incremental cost ratio, IB: Incremental benefit ratio, IC:B: Incremental cost benefit ratio.

There was an increased seed yield of 1g plant^{-1} in the soilless method, which in turn increased the B:C ratio (Julian *et al.,* Treftz and Omaye,). Seed quality is a critical aspect of agriculture to ensure food security. It is affected by a number of complex genetic, environmental factors. Phenotype is not just based on the interaction of genotype and environment but also on the management, by providing better environment condition with proper nutrients. The complete potentiality of the plant could be harvested, which also ensures the seed quality. These models can be exploited for hybrid seed production especially where one pollination would yield many seeds and for high-value low volume crops.

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