

PARTICIPATORY F₁ HYBRID SEED PRODUCTION OF TOMATO AND ITS ECONOMIC BENEFIT

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ABSTRACT

Quality seeds play significant role in the agriculture production. This study was aimed to produce quality F₁ seed of tomato by involving farmers at reasonable price and increase the availability of F₁ hybrid 'Srijana' in commercial tomato growing areas of Nepal. The activities were carried out during three consecutive years from September 2009 to August 2012 in three sites i.e. Dhikurpokhari and Armala of Kaski district, and Mattikhan of Syangja district. Altogether 12 plastic houses were constructed for F₁ seed production. Twelve female farmers and technicians from Agricultural Research Station (ARS), Malepatan; District Agricultural Development Offices from Kaski and Syangja districts and I/NGO personnel and seed entrepreneurs participated in different seed production activities. Parental lines of Srijana tomato hybrid were maintained in ARS, Malepatan. Training was provided to farmers on F₁ hybrid seed production focusing on emasculation and pollination of tomato crop and crop protection. Farmers produced a total of 11.4 kg F₁ seeds and able to get NRs 10,01,730 by selling their produce. The gross profit margin from production of F₁ seed comprises 350 times more in comparison to maize seed production. The economic analysis showed that the net profit per kilogram of tomato F₁ seed is 92%. F₁ seed production has been carried out even by rural women farmers after getting good schooling of knowledge and skill through training. It indicates that F₁ hybrid technology should be extended to other crops so that more farmers could get benefit from producing F₁ hybrid seeds as well as by growing F₁ hybrid crops.

Key words: F₁ hybrid, income, seed, tomato, women farmers

INTRODUCTION

The tomato (*Solanum lycopersicum* L., 2n = 2X = 24) is a tropical vegetable used fresh and in processed products (Tiwari, 1986). It is the second in production among vegetables in the world after potato (<http://faostat.fao.org>) and it's grown in almost every region of the world. Tomato ranked fifth among vegetables in terms of growing area which is 18,415 ha (ABPSD, 2012/13) with the productivity of 14.5 t/ha and grown widely in Nepal. It covers about 7.5% area of total 246392 ha occupied by more than 54 types of vegetables in the country (ABPSD, 2012/13). Diversity relative to its use and production environments is high and many landraces have been reported in Nepal (Upadhyay and Joshi, 2003). Different types of tomato varieties e.g. inbred varieties, hybrids, GMOs, etc. have been developed using this diversity to meet the consumers as well growers' demands.

Improved crop varieties and quality seeds are the most viable ways of improving agricultural production and food security in a sustainable manner (SQCC, 2013). Due to the high potential in fruit production of F₁ hybrids, many growers have given due attention to grow F₁ hybrids for a number of crops. Due to easiness of emasculation and pollination of tomato flowers, hybrid technology is widely adopted and single pollination can produce many seeds in tomato. Developing F₁ hybrids is the best way to combine disease resistance and fruit quality and marketable fruit yield from breeding lines, although hybrid vigor is not reported in tomato. Resistance genes can also be

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incorporated to the parental lines which can be accelerated using marker linked to important diseases (Joshi et al., 2014). The quality of seed is an important factor for increasing yield per unit area (Ali, 2009). Several hybrids have been developed from different public and private tomato breeding programs and tomato hybrids can be selected that had high yield and stability across years over the locations (Joshi et al., 2011).

Phytophthora and *Ralstonia solanacearum* are major setback for tomato production in Nepalese context and not many imported hybrids address these problems. Srijana is the first vegetable hybrid developed in Nepal which has good market quality and bacterial wilt resistance. This hybrid occupies almost 75% of the tomato area and is the most preferred variety of tomato in Nepal. The domestic demand for the tomato seeds is 4.1 t, of which 3.5 t are of open pollinated and 600 kg of F₁ seeds. About 100 kg seeds are of Srijana and rest F₁ seeds are imported varieties (SEAN, 2013). In addition, the demand for the hybrid tomato seed is rapidly expanding. Tomato is superlatively the leading vegetables in terms of number of hybrid varieties imported in the country. A lot of national currency is being spent every year to import hybrid seeds from India and abroad. Therefore, development F₁ seed production system is utmost necessary to increase the production, distribution and utilization of F₁ seed.

However, it is generally perceived that hybrid technology is costly and need high skill. If farmers could produce F₁ hybrid seeds, this technology will be rapidly increased in the country. This study was aimed to transfer the hybrid seed production technology to the farmers so that they can produce F₁ hybrid seeds of tomato in their environment and generate income adopting this technology as major agri-business. It was assumed that women farmers could adopt hybrid seed production technology as their long term agricultural business.

MATERIALS AND METHOD

This study was carried out in three consecutive years from September 2009 to August 2012 in three sites viz. Dhikurpokhari and Armala of Kaski district and Mattikhan of Syangja district. Altogether 12 plastic houses were constructed in these sites. Twelve women farmers were involved in the production of seeds of Srijana tomato.

GROWING PARENT LINES OF SRIJANA TOMATO HYBRID

Plastic houses were constructed using 120 GSM Silpaulin sheets for roofing. Sizes of the plastic houses were 15-x 5-m with the height of 4 m in the center and 3 m around the sides of plastic house. Under these plastic houses, 100-125 parent lines, of which around 20% were male parent lines, were transplanted in each location of Kaski and Syangja each year in April/May. After soil test 130 kg of agri-lime per 500 meter square was applied fifteen days prior to transplanting in first year. Well rotten farmyard manure @ 20 t/ha plus poultry manure @ 2 t/ha was incorporated in the soil ten days before transplanting. At the time of transplanting 3 kg of well decompose FYM plus 20 g DAP, 15 g urea, 10 g murate of potash and 0.5 g Carbofuran-3G per pit was applied. In addition, 1.5 g zinc and 1.5 g boron was used per plant. At the time of flower initiation, 5 g urea was top dressed and then 5 g urea was applied every 15 days interval up to crossing time. Multiplex @ 2.5 ml per liter of water was sprayed three times during the crop period for other essential micro nutrients

(ARS, 2011/12). It is very important to supply the pollen grains regularly during pollination, therefore, male parent was planted 7-10 days earlier than female parent and two times at 15 days interval after planting female parent (Jones et al., 2014).

CAPACITY ENHANCEMENT OF WOMEN FARMERS

Trainings were organized every year to five women farmers from Dhikurpokhari, Kaski, three farmers including Dalit Woman from Armala of Kaski district and four women farmers from Mattikan of Syangja district and got special technical knowledge on hybridization techniques in tomato and cultivation of tomato under plastic house condition for higher income. Similarly, the farmers at the vicinity area of seed production also got the information about tomato growing technology and various aspect of seed business. Technicians from ARS, Malepatan; DADO, Kaski and Syangja also upgraded their expertise in tomato growing/crossing technology. Manual/booklets were prepared and distributed in schooling process which definitely disseminated the generated information at wider scale. In addition to different trainings provided to the farmers, regular interaction among farmers and breeders helped farmers to develop confidence in production F₁ hybrid seeds of tomato.

EMASCULATION AND CROSSING

After initiation of flowering about 30-35 days after transplanting flowers were manually emasculated at the right stage (Figure 1A). For crossing, male flowers were collected in petri dish and kept in the warm sunny place for 10-15 minutes. Pollen grains were then poured in petri dish by opening upper tip of the male flower with the help of forceps. The stigmas of emasculated flowers were touched with pollen grains collected in the petri dish. The crossing was performed during between 8-11 am each day during this time.

SEED HARVESTING AND PROCESSING

Fruits were harvested 35-45 days after crossing. The selected full red ripe fruits were kept in plastic Carate overnight after harvesting as such for full maturation. Fruit were then cut with sharp knife and extracted pulp with seeds (Figure 1B) was kept one to two days for fermentation. The fermented pulps were washed 8-10 times with clean water and were sun dried for 3-4 days. These seeds were stored in the air tight container. Seed recovery was also measured based on the fruit weight.

SEED PACKING AND MARKETING

One-day interaction workshop was organized for marketing with stakeholders from government, farmers and seed entrepreneurs from Kaski, Syangja and Kathmandu. Marketing and production systems were discussed. Seed quality analysis especially seed viability was tested at Regional Seed Testing Laboratory, Bhairahawa. Truthfully labeled seeds of one and two gm packet were marketed in Kathmandu, Kaski, Syangja, Palpa and Gulmi districts.

ECONOMIC ANALYSIS

The economic analysis was conducted for tomato hybrid seed production at Kavre, Pani Tanki. Two plastic houses of 100 sq meters were constructed at two different farmer's fields. Total 155 plants

transplanted, of which 128 plants were female and 27 plants male. Emasculation and pollination were carried out by trained female farmers. Seeds were extracted separately from 1 kg of fresh crossed fruits in 6 replications and the average seed per kg fresh fruit was estimated. The price of seed was estimated based on the existing wholesale price in the market. Similarly, maize was cultivated in one ropani for seed production for the comparison of cost -benefit analysis between maize grain and tomato seed.

For net profit calculation two plastic tunnels of 100 sq m were constructed on-farm. Total 160 plants of which 144 females and 16 males were planted in the plastic tunnel with the spacing of 100- x 60-cm. Crossing was done by skilled farmers and single skilled farmer crossed up to 1500-2000 buds per day during peak season. About 40-50 fruits per plant were maintained. Crossing was taken up for four and half months and seeds were extracted from red ripe tomatoes. The detail inputs required for the tomato hybrid seed production in 100 sq meter were listed and cost of each input calculated. The market wholesale price of 1 kg of seed was obtained and the net profit was calculated.

RESULTS

MEAN SEED RECOVERY

In the three years experiment conducted on station for mean seed recovery per kilogram crossed fruits, from the three samples taken in three consecutive years, the mean seed recovery yield per kg of fresh crossed fruits ranged from 4.0-4.4 g (Table 1).

Table 1. Seed recovery from fruit of female parent after crossing with male parent tomato during 2010-2012 in Malepattan

Sample	2010	2011	2012	2010	2011	2012	2010	2011	2012	Mean seed recovery (g)
	Fruit wt (g)			Seed obtained (g)			Seed recovery per kg of fruit (g)			
1	1120	1060	970	4.6	5.3	4.0	4.1	4.7	4.1	4.3 (2010)
2	3150	1240	975	13.8	5.9	3.8	4.4	4.8	3.9	4.4 (2011)
3	3510	1450	1260	15.0	6.4	5.4	4.3	4.4	4.3	4.1 (2012)



Figure 1. Emasculation of tomato flower by farmer (A) and seeds extraction from fruits pollinated manually (B).

ECONOMIC BENEFIT FROM F₁ SEED PRODUCTION

F₁ cv Srijana is the product of hybridization between HRD-1 (female, indeterminate type) and HRD-17 (male, determinate type). Cross success in first, second and third year were 50%, 90% and 95% respectively. Eleven and half kg of quality F₁ seed has been produced with total income about NRs 10,00,000 (Table 2).

Table 2. F₁ seed production of Srijana tomato and income from the seeds during 2010-2012

SN	Farmer's name	Location	Seed produced (g)			Income (Rs)
			2010	2011	2012	
1	Hari KC	Dhikurpokhari, Kaski	219	159	200	51,560
2	Santu Subedi	Dhikurpokhari, Kaski	218	90	200	45,540
3	Aarati Subedi	Dhikurpokhari, Kaski	315	184	140	55,760
4	Sita Subedi	Dhikurpokhari, Kaski	230	38	40	29,820
5	Balika Subedi	Dhikurpokhari, Kaski	210	144	81	37,860
6	Laxmi Paudel	Mattikhan, Syangja	740	640	1470	2,63,800
7	Kausila Paudel	Mattikhan, Syangja	125	500	275	82,500
8	Dripa Chhetri	Mattikhan, Syangja	127	320	68	44,960
9	Khuma Paudel	Mattikhan, Syangja	73	584	109	16,740
10	Madhu M. BK	Armala, Kaski	489	596	900	1,87,650
11	Bishnu Basnet	Armala, Kaski	410	426	400	1,11,140
12	Jit B. Basnet	Armala, Kaski	406	268	190	75,600
Total			3562	3949	4073	10,01,730

The comparative analysis of tomato hybrid seed and maize seed showed a huge difference in gross return from hybrid tomato seed and maize grain production. From one Ropani, maize grain production gives gross return of NRs 540 whereas tomato hybrid seed gives gross return of NRs 189000. The gross profit from production of F₁ seed comprises 350 times more in comparison to maize seed. This indicates there is a large economic benefit in tomato hybrid seed production even in one Ropani of land (Table 3).

Table 3. Economic analysis of F₁ hybrid tomato seed production with comparison to maize grain production per kg per Ropani

SN	Description (in a Ropani i.e. 500 m ²)	Tomato	Maize
1	Mean seed yield (kg)	3.50	200.00
2	Seed price per kg (Rs)	90000.00	13.00
3	Gross income (Rs)	315000.00	2600.00
4	Total cost (Rs)	126000.00	2060.00
5	Net income (Rs)	189000.00	540.00

The comparative economic analysis of gross return from fresh fruit versus hybrid seed was carried out. The average market price of fresh fruit tomato was NRs 25 whereas the average seed obtained

from 1 kg of crossed fruit was 5 g and the market price of 5 g of seed was NRs. 400. The average gross return from 1 kg of fruit was NRs. 355 which shows the difference of NRs. 355 rupees in terms of gross return between fresh fruit and hybrid seed (Table 4).

Table 4. Economic analysis of fresh fruit vs hybrid seed

Description	Plastic house 1	Plastic house 2
No. of fruit crossed within 3 months	40	35
No. of crossed fruits per kg	25	20
Mean seed production per kg fruit (g)	5	4.5
Economic return from 1 kg fresh fruit (NRs)	25	25
Economic return from 1 kg fruit after seed extracted (NRs)	5 x 80=400	4.5 x 80=360

The total number of fruit and total weight obtained from 100 sq m during 4.5 months crossing was 5760 and 288 kg respectively. On an average 4 g of seed was obtained from each kg of fruit sampled which totaled to 1000 g.

The detail breakdown on cost of hybrid seed production for one kg comes up to NRs. 51876 and from 100 sq meter, approximately is 1 kg of seeds can be obtained which depends upon the speed and skill of the crossing personnel. The minimum wholesale price of the seed is NRs 86400 which means there is a profit of NRs 34,524 per kg of fruit per 100 sq meter. In one Ropani, five plastic tunnels can be constructed and from where 5 kg of seed can be obtained. With the above finding, it can be extrapolated that around NRs 172,640 can be obtained as net profit from one Ropani (Table 5). The economic analysis showed that the net profit per kilogram of tomato F1 seed is 92%.

Table 5. Economic analysis (net profit from F₁ seed per kg)

SN	Description	Size/ capacity	Cost (NRs)	Total (NRs)
1.	Plastic house	100 m ²	9070	9,070
2.	Labour	2 x 4.5 months x 150 NRs	40,000	40,500
3.	Scissor	2	150	300
4.	Plastic rope	-	500	500
5.	Forceps	2	100	200
6.	Fertilizers (chemical + FYM)	-	700	700
7.	Pesticides	-	600	600
8.	Petri dishes	4	100	400
9.	Cost of inbred (male and female)	2 g	200	200
	Total			51876

MARKETING

There were two types of seed for marketing: packaged under ordinary plastic cover and packaged under private companies brand. The produced seeds were marketed by the private seed companies of Kathmandu and Pokhara.

A minimum support price (MSP) of NRs 90,000/kg was fixed by NARC. A half day workshop of seed producers and potential seed companies was organised. An effort was made to establish an appropriate linkage between the seed producers and companies. The private companies and seed producers had an informal contract and the seed produced were collected, tested, packed in their own brands and marketed.

The good linkage was established with the private seed companies and the seeds produced were collected by the companies, packed and marketed in their respective brands after the project phases out.

DISCUSSION

There were more than 7000 plastic houses in western development region only to grow tomato in rainy season (RAD 2012, personal communication). Cultivation in such environment requires high yielding, consumer preferred, and disease tolerant and indeterminate type of cultivars. Among many crops, tomato has been commercially grown in the mid hill regions and has further scope of its area expansion due to high market prices in the recent years. Farmers have been showing keen interest to produce F₁ seed of tomato under the proper guidance of research organization like NARC. All the activities of the project contributed to fulfill the demand of quality F₁ seed of tomato cv Srijana in some extent.

Use of quality seeds alone can significantly increase the crop yield (SAARC, 2011). For food security seed security is fundamental one. Seed sector has been identified as high value commodity and suitable for rural area even where no transportation facility was there. Hybrids can provide increased yield stronger resistant to disease, greater adaptability, uniformity in maturity and other fruit quality traits (Jones et al., 2014).

OCCURRENCE OF DISEASE AND PESTS

During the process of project implementation, the frequent problems encountered in Kaski sites were of bacterial disease, i.e. *Erwinia rot* which was managed by application of copper fungicides. In addition, two fungal diseases like late blight and septoria were pre dominant in the crossing tunnels which were managed by using contact and systematic fungicides. Occurrence of white fly and helioverpa was observed in every year and in all locations throughout the project duration, which was managed by frequent spray of systematic insecticides. The prophylactic sprays for diseases (Late blights) and pests (aphids and whitefly) are strongly recommended for hybrid seed production.

INFRASTRUCTURE FOR HYBRID SEED PRODUCTION

Use of plastic in agriculture in Nepal was initiated by Japanese volunteer and Nepalese technicians in Dhading area since BS 2035/36 (1978 AD). In F₁ seed production there should not be moisture

present around stigma at least four hours for better receptivity. In mid hill situation it may be quite difficult to produce F₁ seed in open field condition because of high rain fall in June to August, when crossing should be performed. Plastic house could be constructed using bamboo or other materials like mild steel rods, angle iron, GI or CI pipes, etc.

MAJOR CONSIDERATION AND ISSUE FOR F₁ SEED PRODUCTION

Acquisition of inbreds, skill enhancement and strong technical monitoring are three important aspects which need to go hand in hand for the successful hybrid seed production.

Formal process for hybrid seed production

The parental lines of Srijana hybrid were maintained by Horticulture Research Division (HRD). An official MoU was signed between the third party after obtaining the letter of recommendation from Seed Quality Control Laboratory. The inbreds were provided to these parties at minimal cost basis and the technical monitoring was done twice as mentioned in MoU. The inbreds were obtained annually from HRD and monthly progress was updated to HRD by the hybrid seed producers.

Production and maintenance of inbreds

Hybrid tomato seed production requires the planting of inbred breeding lines that have originated from single plants chosen for their special traits. In hybrid seed production the purity of parents is extremely importance. Therefore, every effort was made to avoid seed mixture during planting and transplanting. In addition, any off-type plants were removed by trained personnel. This activity was repeated two or three times prior to pollen extraction or pollination.

Optimum stages identification

Flower must be at late bud stage of development (i.e. closed and not turned yellow). Care must be taken to ensure that the receptive stigma is not damaged during the emasculation. Fruit without marked sepals are discarded prior to harvest to prevent accidental mixture of fruit from open flowers with hybridized fruits. To obtain the optimum viability, the seeds should be extracted from fully ripened fruits. The number of buds crossed and retained per plant should be 80-90 per plant and the number of buds per cluster should be 3-4 for the quality seed production.

Skill enhancement and monitoring and supervision

Hybridization is skilled based work and the skill and speed of the workers is very important factor for success of hybrid tomato seed production. The amount of seed obtained directly depends upon the number of buds pollinated by single worker in one day. At the initial stage the crossing speed of the skilled labors is slow so there might be huge amount of loss of mature buds and the business might be in loss. It is recommended that a single worker should cross at least 2500-3000 buds per day during prolific flowering.

Monitoring and supervision is equally important for the maintenance of quality seed. The supervision should focus on removal of the off-types and to identify the non crossed fruits. Minimum two supervisions from the technicians at the time of first crossed fruit setting and during the first harvest are mandatory.

Status and access of tomato hybrid seed

Availability of good quality seed is insufficient in Nepal and farmers have to depend on Indian and third country for tomato F₁ seed which is comparatively costlier and of uncertain quality. Timely availability, maintenance of quality and appropriate type for Nepalese market are major issues in hybrid seed production.

The seeds worth millions used for this cultivation is imported from different countries. The hybrid seeds obtained from abroad in some cases may not be suitable for our agro-ecological conditions. In addition, the imported hybrids are very expensive and in spite of paying high price, the reliability of the hybrids is questionable. The consistency in quality and supply is another major problem in imported seeds. More than 50% tomato cultivation was collapsed in Bharatpokhari area of Kaski district due to inadequate research and recommendations.

FARMER VIEWS

With the increasing demand of F₁ seeds in commercial pockets information flow was definitely very useful during project period so that the farmers could produce F₁ seeds of Srijana in their own socio-economic situation. However, proper and regular guidance of the expert is necessary. For the management of diseases and insects integrated pest management practice was adopted and got succeeded to overcome various problems. Training was found as an effective learning tool to change the knowledge and skill of the participants. Twelve seed producer farmers and technicians got expertise in tomato hybridization techniques. Being high profit oriented nature of work, some farmers are very much motivated to continue this. However, they want NARC's regular support to provide parent lines and technical guidance. The parental lines for Srijana is maintained and distributed by Horticulture Research Division, NARC at Khumaltar. The inbreds are provided by the Division to those parties, who have the MoU with HRD.

The twelve farmers trained by the project were the human assets in hybrid seed production of tomato. However, follow up is necessary to further empower them. District Agriculture Development Office should internalize this program in district seed production program with technical collaboration with NARC and need to extend to other districts. NARC should provide parental lines and technical assistance to such seed producing farmers.

CONCLUSION

Women farmers were able to produce 11.4 kg F₁ seeds of Srijana tomato. They could continue to produce F₁ hybrid seeds themselves and make available quality F₁ seeds of tomato in genuine price. Farmers have adopted F₁ seed production and tomato production as good income generating technology. Twelve seed producing farmers got expertise in tomato hybridization techniques and they produce F₁ hybrid seeds in their own socio-economic conditions. With the increasing demand of F₁ seed in the market, this business will continue in the future. This success story indicated that, if technicians and farmers are trained, such high level technical work could be done by themselves. Such strategy of training on commercial F₁ tomato seed production should be expanded to other areas for harvesting the potential benefit of hybrid.

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