

# Production Technology of Hybrid Tomato Seed Srijana, Khumal Hybrid-2 and Khumal Hybrid-3

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## Abstract

Tomato ranks as the third most important vegetable crop in Nepal based on area and productivity. Tomatoes are cultivated both seasonally and off-season. The cultivation of tomatoes, both in open fields and plastic houses, is in increasing trend. Hybrid varieties are widely used, and almost 100% of the tomatoes grown in plastic tunnels are hybrids. Nepal Agriculture Research Council (NARC) has released three hybrid tomato varieties; Srijana at 2010 and two new hybrid tomato varieties; Khumal Hybrid-2 and Khumal Hybrid-3 recently. These hybrids are resistant to diseases like blight and suitable for cultivation in both open fields and tunnels. These are also highly favored by farmers and consumers alike, and about 80% of the tomatoes grown in plastic tunnels in Nepal are Nepali hybrid varieties. Hybrids have the major advantage of high productivity, earliness, uniformity, better transport quality, and abiotic and biotic stress resistance. This paper provides a comprehensive overview of the seed production and management techniques for the hybrid tomato varieties; Srijana, Khumal Hybrid-2 and Khumal Hybrid-3. These hybrid varieties, with their enhanced disease resistance and adaptability to different climatic conditions, hold great potential for tomato farmers in Nepal. As demand of these hybrid seed is higher, majority of seeds are produced through private partnership program.

**Keywords:** Hybrid seed, Plastic tunnel, Seed production, Tomato, Varieties

## Introduction

Tomato ranks as the third most important vegetable crop in Nepal based on area and productivity. It contains essential nutrients like vitamins A, B, C, E, calcium, and phosphorus, and can be consumed both raw and cooked. Tomato farming is increasingly expanding in Nepal. In the fiscal year 2066/67 B.S. (2009/10 A.D.), tomato cultivation covered 15,609 hectares with a total production of 242,018 metric tons, whereas, by the fiscal year 2078/79 B.S. (2021/22 A.D.), it had increased to 22,911 hectares with a production of 422,703 metric tons (MoALD, 2022) indicating a 46% increase in cultivation area. Both seasonal and off-season tomatoes are cultivated in Nepal. Off-season cultivation is done from Ashad to Mansir (mid-June to mid-December) and seasonal cultivation from Poush to Jestha (mid-December to mid-June). Off-season tomatoes fetch a better market price and are easier to sell (Shrestha and Gautam, 2076). There are many hybrid varieties in the market which are being grown by the farmers.

Hybrid (F1) cultivar is the F1 progenies crosses of two inbred lines. Inbred lines are used to develop population of single crosses, 3-way crosses, double crosses, back crosses and complex crosses (Walter, 1986). Selection of parents for a population may involve consideration of the heterotic relationships among available genotypes. The restoration of phenotypic performance by crossing inbred lines to produce a hybrid is called heterosis where the increase in size, vigor or productivity of a hybrid plant over the average or means of its parent. The hybrid cultivars cannot be reproduced from seed of the hybrid generation (Anonymous, 1980). Hybrid seed is used for the commercial production of number of crops. Each of these crops must meet four requirements for the successful production and use of hybrid seed;

- a) Heterosis is exhibited by the F1 progenies of crosses between the parents
- b) Fertile pollen can be eliminated from the female parent
- c) Pollen from the male parent is effectively transported to the female parent
- d) Hybrid seed can be produced reliably and economically (Wright, 1980).

In 2067 B.S. (2010 A.D.), the Nepal Agricultural Research Council registered 'Srijana' hybrid tomato cultivar. The cultivation of tomatoes, both in open fields and plastic houses, is increasing daily. Nowadays, tomato cultivation using plastic tunnels, particularly for farmers living in areas 800 to 2,200 meters above sea level, has become a popular method. Hybrid varieties are widely used, and almost 100% of the tomatoes grown in plastic tunnels are hybrids. These hybrid varieties are highly favored by farmers and consumers alike, and about 80% of the tomatoes

grown in plastic tunnels in Nepal are Nepali hybrid varieties. To meet the rising demand, the National Horticulture Research Center has partnered with private seed producers to produce hybrid tomato seeds for several years. In the fiscal year 2078/79 B.S. (2021/22 A.D.), 151 kilograms of hybrid seeds (valued at approximately 15 million NPR) were produced through the Private Partnership Program (PPP). The production and supply of seeds is increasing in formal sector in Nepal with a surge of community based and contract seed production led by community groups and private seed companies respectively (Gaire et al. 2016). This initiative has created job opportunities and prevented a large outflow of funds. The center has also released two new tomato hybrid cultivars, Khumal Hybrid-2 and Khumal Hybrid-3, which are resistant to diseases like blight and suitable for cultivation in both open fields and tunnels from Terai to hills. This article provides technical knowledge on producing seeds for these tomato hybrid cultivars.

## Climatic Requirement

Warm and sunny weather is ideal for growing tomatoes. Temperature plays a crucial role in the success of tomato cultivation, with an optimal range of 20–30°C for general growth and 28–30°C for fruit development. At temperatures above 35°C, fruiting does not occur, and below 18°C, pollination is impaired. The optimal night temperature for tomatoes is between 13°C and 21°C. If night temperatures drop below or rise above these levels, it can halt the fertilization process, causing fruit drop and preventing fruit formation.

Temperature also affects the coloration of tomatoes. When temperatures fall below 10°C, Lycopene and Yellow carotenoid, which give tomatoes their red and yellow colors, respectively, do not develop, causing the fruit to remain green. The optimal temperature range for Lycopene and Carotenoid development is 20–25°C. However, temperatures below 10°C or above 40°C hinder color development in tomatoes.

## Tomato Varieties

Tomato varieties can be categorized into self-pollinated and hybrid varieties based on their genetic source.

Hybrid tomatoes have become increasingly significant in recent years. The production of hybrid seeds requires two self-pollinated pure lines (parental lines). Srijana is produced using the female parent (HRD1) and male parent (HRD17) Khumal Hybrid-2 is produced using the female parent (HRA14) and the male parent (HRD7), while Khumal Hybrid-3 is produced using the female parent (HRA20) and the male parent (HRD2).

### Srijana

Srijana is the first hybrid variety of tomato developed in Nepal. It is characterized by tall plants, and the fruit ripens 75-80 days after transplanting. The fruits are red and heart-shaped, with a thick skin (4-4.8 mm) and a mildly sour taste. The average fruit weighs 50-60g. The plant height can reach 4.5 to 5m. The average yield in open fields is 2.0-2.5 MT. while in plastic houses, it can reach 4.0 to 5.0 MT. per hectare. This variety is resistant to bacterial wilt and less prone to blight but can be affected by fusarium wilt and nematodes. Registered in 2067 BS (2010), it is recommended for cultivation in the Terai, mid-hills, and high-hills.

### Khumal hybrid-2

This hybrid variety has tall plants, and fruits are ready for harvest 70–80 days after transplanting. The fruit is red and slightly flattened, weighing an average of 70–80g. The variety has an average yield of 60–70 MT. per hectare. It shows moderate resistance to blight and is recommended for cultivation in areas from the lowlands to the high hills. The characteristics of the parent line of Khumal hybrid-2 is briefly described below:

**Female Parent: Semi determinate (HRA14):** The plant is of medium height, and its growth stops at certain nodes. As the plant continues to grow, flowers form at each node along the main stem, limiting its height.

**Male Parent: Indeterminate (HRD7):** The plant continues to grow, with flowers developing every third node. The indeterminate growth pattern requires staking for support.



**Figure 1:** Khumal Tomato Hybrid-2 plant and fruit

### Khumal hybrid-3

This hybrid variety has tall plants, and fruits are ready for harvest 65–75 days after transplanting. The fruit is red and round, weighing an average of 65–75g. The variety has an average yield of 55–60 MT. per hectare. It shows moderate resistance to blight and is recommended for cultivation in areas from the lowlands to the high hills. The characteristics of the parent line of Khumal hybrid-3 is briefly described below:

**Female Parent: Semi determinate (HRA20):** The plant is of medium height, and its growth stops at certain nodes. As the plant grows, flowers form at each node along the main stem, limiting its height.

**Male Parent: Indeterminate (HRD2):** The plant continues to grow, with flowers developing every third node. This indeterminate variety requires staking for support.



**Figure 2:** Khumal Tomato hybrid-3 plant and fruit

**Table 1:** Morphological characteristics of three Nepali tomato hybrid varieties

| Characteristics                      | Srijana            | Khumal hybrid tomato -2 | Khumal hybrid tomato -3 |
|--------------------------------------|--------------------|-------------------------|-------------------------|
| Growth type                          | Indeterminate      | Indeterminate           | Indeterminate           |
| Plant height (cm)                    | 145 ±19            | 143±13                  | 136±12                  |
| Days to flowering from transplanting | 30±3               | 24±4                    | 22±4                    |
| Flowers/cluster (no.)                | 6±1.5              | 6±1.2                   | 6±0.9                   |
| Fruits/cluster (no.)                 | 6                  | 5                       | 5                       |
| Days to fruit maturity               | 68±6               | 66±6                    | 65±5                    |
| Yield (MT/ha)                        | 68±7.7             | 74.5±8.5                | 62.4±7.7                |
| Average yield per plant              | 2996±162           | 2856±348                | 2852±254                |
| Fruit size                           | Medium             | Medium                  | Medium                  |
| Fruit color                          | Red                | Deep red                | Deep red                |
| Average fruit wt.(g)                 | 58±7               | 80±11                   | 76±8                    |
| Fruit shoulder shape                 | Slightly depressed | Slightly depressed      | Feebly depressed        |
| Fruit end shape                      | Flat               | Flat                    | Flat                    |
| Locule number                        | 5                  | 5                       | 4                       |
| Average fruit length (mm)            | 40.5±3.3           | 44.5±3.9                | 45±4.2                  |
| Average fruit width (mm)             | 42.6±2.9           | 50.8±7.1                | 49.6±4.7                |
| Seeds per fruit (no.)                | 130±12             | 104±9                   | 120±8                   |
| Insect pest (1-9)                    | 3.5                | 2.3                     | 3.0                     |
| Late blight (1-9)                    | 4.7 (MR)           | 3 (MR)                  | 3 (MR)                  |

### Nursery preparation

The ideal temperature for seed germination is between 20°C and 30°C. Tomato seedlings should be grown in plastic plug trays filled with a mixture of one-part compost and two parts coco peat. To protect the seedlings from frost and low temperatures, they should be kept in plastic domes or warm places. Seedlings are ready for transplanting 25–30 days after sowing. Healthy and virus-free seedlings are crucial for successful tomato farming.

Seedlings are often destroyed by green grasshoppers during the rainy season and brown grasshoppers during the winter and dry season. To protect the nursery, insecticides should be applied. Sometimes, in the early morning, cutworms can be found cutting the seedlings at the soil surface, causing them to collapse. If this problem is

observed, Malathion powder should be spread on the soil, followed by irrigation. In case of an attack by aphids, Rogor or Imidacloprid (1 ml per liter of water) should be mixed and sprayed.

### 1. Seedling rot disease

Seedlings can rot at various stages, such as Seeds rotting in the soil before sprouting, Seedlings rotting at the base (the stem appears to be constricted as if tied by a wire, causing death). This disease primarily occurs under conditions of high temperature, excessive moisture, waterlogged soil, or high seedling density. To prevent this, treat the soil with Bavistin, disinfect the seeds, and maintain proper hygiene in the nursery. The disease tends to thrive in conditions where there is a lack of proper air and water drainage. For grown seedlings, use fungicides such as Dithane M-45 (2 grams per liter of water) or Bavistin (1.5 grams per liter of water).

### 2. Soil requirements

Tomatoes can be grown in all types of soil, but the ideal soil should have a pH of 6–7, should be well-drained, and should be rich in organic matter. Loamy and sandy clay soils are most suitable for tomato cultivation.

### 3. Soil preparation and fertilizer use

For growing hybrid tomato seeds, small pits should be prepared, and for each plant, apply 2–3 kg of compost, 5g of urea, 15g of DAP (diammonium phosphate), 5g of potash, 2g of biozyme, 1g of zinc, and 1g of borax before planting. After 20–25 days, top-dress with 5g of urea per plant. After harvesting the second fruit, apply 5g of urea, 7g of DAP, and 3g of potash per plant, and carry out weeding and hoeing. After every 2 or 3 harvests, apply 5g of urea for continuous fruit production and maintaining size.

### 4. Micronutrient requirements

Micronutrients play an essential role in the growth and development of tomatoes. Among the 16 required micronutrients, boron, zinc, iron, and copper (copper sulfate) are the most critical for tomatoes. These nutrients are required in small amounts, but their deficiency can severely affect the growth and development of the plants. The lack of these nutrients results in stunted plant growth, reduced flowering and fruiting, and other issues. Therefore, during planting, nutrients such as biozyme, zinc, and borax are applied.

## Planting time

Tomato seedlings are typically transplanted from Chaitra to Ashad (mid-March to mid-July) in the hills at elevations of 800 to 2,200 m. For mid-hill regions (1,000 to 1,600 m), seeds are sown from Falgun to Baisakh (mid-February to mid-May).

### 1. Transplanting seedlings in a plastic tunnel or greenhouse

Seedlings should be transplanted when they are 15 to 20 days old, or when they have 4 to 5 leaves. In open-field tomato crops, diseases and pests are more common, and the plants often suffer from various stresses. Additionally, pollen placed on the female part can be washed away by rain, and there can be disorganized pollination by flying insects like bumblebees and bees. Therefore, seed production should be carried out inside a plastic-covered greenhouse. Ideally, the greenhouse should be built with plastic roofing and mesh surrounding it.

In the crossing block, the male variety seedlings should be planted separately. Typically, 10% of the plants should be male and should be transplanted 10 days before transplanting the female variety seedlings. Since the male plants have indeterminate growth, they do not need to be replanted if insect pest and disease management is done properly. The male flowers continue to provide pollen for the female plants.

### 2. Planting distance

For seed production of Srijana, female line HRD1 is indeterminate type and these new hybrid varieties, female varieties like HRA14 or HRA20 are medium height, and require regular movement during pollination. The distance between rows should be 90 cm, and between plants should be 50 cm. Male varieties like HRD17, HRD7 or HRD2 should be planted at a distance of 75 x 60 cm.

## Weeding and irrigation

Weeding should be done for the first time 20–25 days after transplanting. Depending on soil moisture, irrigation should be done every 7–10 days, and the lower branches emerging from the stem should be removed. Watering should be done daily until the seedlings are well-established. After transplanting, water should be applied every 2–3 days, ensuring the water reaches only the roots. Wetting the entire plant and leaves can increase the incidence of

diseases like blight. In a plastic greenhouse, more water is required, so drip irrigation is recommended.

## Pruning and Staking

For female plants, 2 to 3 branches should be allowed to grow per plant in Srijana, whereas 3 to 4 branches in Khumal hybrid 2 and Khumal hybrid 3, and other shoots emerging from the axils should be pruned. Unnecessary branches touching the soil should also be removed. This allows good air circulation, reducing pest and disease incidence, and helps the plants utilize nutrients more efficiently, improving fruit and seed quality. Lower yellow and old leaves should be removed from the stem, making pollination easier. Tools used for pruning should be cleaned with ethyl alcohol or dipped in a solution of 1-part cow's milk to 3 parts water to prevent disease transmission.

Since both male and female plants are medium to tall in height, staking is essential to prevent fruit rot and disease. There are various methods of staking tomatoes. For female plants, place bamboo stakes between every 4 plants, with a height of 150 cm for HRA14 and HRA20 and 175 cm for HRD1 plants. Tie the first tie at 30 cm from the ground, with subsequent ties spaced 30–40 cm apart. For semi determinate plants require 3 to 4 layers of tying, while indeterminate plants require 4 to 5 layers. In both male (HRD17, HRD2, HRD7) and female plants (HRA14, HRA20), allow 3 to 4 branches per plant and remove the rest.

After a month or four weeks of transplanting, two branches will emerge on the tomato plant. Branches below this level should be removed. You can also one branch be left at each higher node, allowing up to 4 branches per plant. Branches or leaves touching the soil should also be removed. Bamboo stakes should be placed to support the plants to prevent them from collapsing. If bamboo is not available in sufficient quantity, soft plastic or nylon ropes can be used to provide support from above. This improves air circulation within the plant, prevents fruits from dragging on the ground, ensures even sunlight exposure, and makes pruning, pollination, pest control, and spraying easier. All these practices contribute to producing high-quality fruit and seeds.

## Rouging

The process of removing undesirable, weak, and disease-infected plants is called rouging. Even with careful attention, sometimes suspicious unwanted plants can be found. For instance, if there are clear differences in the leaves, flower color, and fruit size, plants infected with bacterial blight or viral diseases must be removed.

## Seed production

To produce hybrid seeds for these varieties, 6 g of female seeds (HRD1/HRA14/HRA20) and 2 g of male seeds (HRD17/HRD7/HRD2) per ropani of land is needed.

### 1. Emasculation

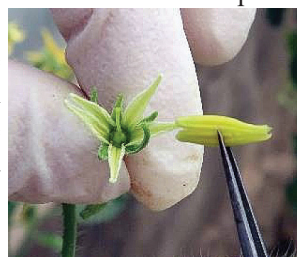
In the process of emasculation, the flower's male parts (the anthers) are removed before the flower matures to prevent self-pollination. This ensures that the flower can only receive pollen from another plant (usually from the selected male parent), allowing for controlled cross-pollination. The emasculation is done carefully to ensure the female parts (stigma and ovary) remain undamaged.

### 2. Collecting Male Flowers

Male varieties (HRD17, HRD 7, HRD 2) should be harvested when the flowers are fully open, but before the pollen falls, either in the evening or in the morning. This allows for the collection of pollen in various ways. The harvested flowers should be kept in a room overnight, and the next morning, pollen can be collected by sieving through a 1 mm mesh. For collecting pollen from many flowers, a vibrator can also be used. For a few flowers, the tip of the anther can be lightly cut and squeezed with forceps to drop pollen onto a Petri dish.

### 3. Dusting of pollen

After emasculation, pollen from the desired male parent is collected and dusted onto the stigma of the emasculated flower. This leads to fertilization and the production of hybrid seeds. The dusting is done manually, often using a brush or other small tool to ensure precise application.



Emasculated flower



Dusting of pollen

Figure 3: Emasculation and pollination

#### 4. Pollination and Fruit Care

For female varieties (HRA 14, HRA 20), the male parts should be removed (emasculation) from flowers that have not opened their petals yet but are ready to bloom from 6 AM to before 11 AM. The stigma of these emasculated flowers should be touched with pollen to perform the pollination process. If pollination is done at the right time, the fruits formed from flowers with abundant pollen will have a higher seed count. Care must be taken not to damage the female part (pistil) during pollination. If there is a chance of pollen shortage, flowers should be collected while they are blooming abundantly, and the pollen should be stored in a vial that prevents air from escaping in a desiccator in the refrigerator for up to a week. Only 3–4 fruits should be allowed to grow per cluster. During pollination, care must be taken not to injure the female parts; otherwise, the flowers may fall off. Similarly, a pest attack can prevent the proper development of pollen. If fruit is attacked by worms, it will not be useful for production. Fruits can be harvested 40–45 days after pollination.

These steps are crucial in producing **hybrid tomato seeds**, where controlled pollination leads to the development of plants with desired traits from both parent plants.

### Pest and disease management

#### 1. Pests and their control

1. **White Fly:** The white fly, which appears in plastic houses during warm weather, sucks the sap from tender leaves from underneath, weakening the plant and transmitting viral diseases. To control this pest, yellow sticky traps should be hung, and a solution of 1 gram of Acetamiprid or 1 milliliter of Imidacloprid should be mixed with 1 liter of water and sprayed.
2. **Aphids:** During cooler weather, aphids suck sap from the soft parts of the plant, weakening it and transmitting viral diseases. To control these pests, a solution of 1 milliliter of a systemic insecticide should be mixed with 1 liter of water and sprayed.
3. **Leaf Miner:** The larvae of this pest are very small and burrow inside the leaves, causing white trails to appear on the leaves. To control this pest, a systemic insecticide like Rogor should be sprayed at a rate of 1 milliliter per liter of water.
4. **Fruit Borer (*Helicoverpa armigera*):** This pest attacks fruits during dry weather, rendering them useless. All affected fruits should be removed and destroyed. Use pheromone traps or spray a systemic insecticide like Rogor at a rate of 1 milliliter per liter of water.
5. **Mites:** Mite infestations can occur during hot and dry weather, hindering plant growth. Fine webs may also appear on the leaves. To control mites, spray a solution of 1 milliliter of Karathane per liter of water.

#### 2. Diseases and their control

Whether seed-borne or non-seed-borne, all diseases weaken plants and can lead to complete crop failure if not managed in time. Commonly observed diseases and their control methods are as follows:

1. **Late Blight:** Caused by the fungus *Phytophthora infestans*, this disease affects both surfaces of the leaves in conditions of high humidity and cool nights. If symptoms appear, spray a solution of 1.5 grams of Krilaxyl per liter of water.
2. **Early Blight:** This disease, caused by the fungus *Alternaria solani*, presents as circular black spots on the upper surface of leaves and spreads quickly in warm, moist weather. To control this disease, spray a solution of 2 grams of Dithane M-45 per liter of water.
3. **Septoria Leaf Spot:** Caused by the fungus *Septoria lycopersici*, this disease shows spots surrounded by a black ring with ash-colored centers on the leaves and spreads in warm, moist conditions. To control this disease, spray a solution of 2 grams of Dithane M-45 or 1.5 grams of Krilaxyl per liter of water, or use a solution of Trichoderma.
4. **Fusarium Wilt:** The fungus *Fusarium oxysporum* attacks, causing yellowing on one side of the plant and gradually spreading upward. For disease control, mix 2 grams of Bavistin with 1 liter of water and water the soil around the roots.
5. **Bacterial Wilt:** Caused by the bacterium *Pseudomonas solanacearum*, this disease can cause sudden wilting of the plant when it is fruiting. After infection, the plant should be uprooted and buried, ensuring no water accumulates in the planting area. The soil should be treated with a 2% formalin solution, and

proper crop rotation should be implemented.

6. Powdery Mildew: Caused by the fungus *Oidium neolyopersici*, this disease appears as a white powdery substance on the upper surface of the leaves, which eventually leads to leaf drop. To control this disease, prune the plant for better air circulation and spray with a solution of 2 milliliters of Karathane per liter of water.
7. Blossom End Rot: This is especially caused by a calcium deficiency, resulting in a dark, sunken spot (0.5–1 inch wide) at the blossom end of the fruit during warm, dry weather. To control this, remove affected fruits and raise the soil pH above 6. Calcium should be applied to the soil and sprayed on the plants.

## Harvesting and Processing Fruits

Fruits should be harvested when they change color to red and kept in a room for 1–2 days. The middle thorn should be pressed to extract the seeds and jelly-like substance into a plastic container, leaving it for fermentation for 24 hours. Afterward, wash with water. The tiny seeds that float on the water should be removed, as they are light. The cleaned seeds should be placed in a fine cloth bag and hung to drain excess water. Then, the seeds should be spread on a thin cloth and covered lightly with another cloth to dry in the sun. Once dry, remove inert materials and store the seeds in an airtight container or desiccator for preservation. This method produces high-quality seeds.

## Way Forward

- Collection and utilization of genetic resources from local and exotic sources should be done.
- Expand collaboration with international organizations (CG centers, WorldVeg etc) for germplasm exchange
- Collaboration with private seed companies/cooperatives and agro-vets should be done.
- Improvement of technical capacity of researchers should be done.
- Training to technician cooperatives and farmers on hybrid seed production should be done.
- Establishment of molecular breeding facility should be done.

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