

Upliftment of arid zone economy through horticultural and protected cultivation

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Climatic vagaries of arid zones make cultivation of annual crops risky and unsustainable. Horticultural sector proved beyond doubt its potentiality for gainful economy in such fragile ecosystems. Immense opportunity existed in arid zone for quality production of some of the most water economizing horticultural crops. In recent years arid and semi-arid regions witnessed a greater shift from traditional to commercial horticulture with constant government support and technical input of research and development institutions. Technologies developed on ber, pomegranate, date palm and other arid fruits by Central Arid Zone Research Institute, Jodhpur, Rajasthan showed significant impact on development of dry regions at national level. However, after near plateau for some time, horticultural scene in arid region was brightened up with introduction of newer options viz. commercial tissue culture techniques in date palm and pomegranate, protected cultivation of high value crops and new varieties and technologies in region's adapted species. However, expanding the scale of horticultural production is often hindered by lack of market access, technological awareness and abiotic stresses.

Key words: Arid horticulture, Abiotic stress, Cultivation, Horticulture, Protected

A vast land resource (39.54 m ha) in the country characterized as arid region is considered underutilized for cultivation due to climatic vagaries. Under the constraint climatic situation as well, immense opportunity exist for quality production of some of the most water economizing horticultural crops. Arid region has vast potential and opportunities in bringing the horticultural industrialization. In recent years arid and semi-arid regions witnessed a greater shift from traditional to commercial horticulture with constant government support and technical input of research and development institutions. Nonetheless, even under extreme conditions, some of the fruits crops develop best qualities like kinnow, mosambi, date palm, pomegranate, ber, aonla seed, spices, medicinal plants and several other indigenous fruits and vegetables which cannot be

grown in other part of the country. The selection of crops coupled with improved technology can play an important role in achieving higher and sustainable income from this part of the country.

Horticultural sector made strides at national level with record production of 300.6 mt from 24.85 m ha area in 2016-17. At national level, the production of horticultural crops showed an increase of 9.78% during 2016-17 over 2012-13. However, in Rajasthan, the production of these crops reached up to 67.51% during the same period. Suitable crops, their improved varieties, important agro-techniques and benefit-cost ratio in their cultivation under arid conditions were instrumental in enhancing the income.

Important fruit crops and available technological options making strides in increasing the prosperity in arid

zone are discussed here.

Ber

The Indian ber or jujube (*Ziziphus mauritiana*) is one of the life support multipurpose fruit species in arid and semi-arid regions of India. Ber fruit is richer than apple in protein, phosphorus (P), calcium (Ca), carotene and vitamin C, and excel oranges in phosphorus, iron, vitamin C, calorific values and carbohydrates. Besides, the use of fruits for table-purpose, it can also be processed to prepare preserve, candy, dehydrated ber, jam and ready to serve drinks. It showed wider adaptability to soil and agro-climatic conditions prevalent in tropical and subtropical regions and enhanced resilience of fragile ecosystems.

The work done on delineation of suitable varieties, standardization of propagation and other production technology helped farmers in

Table 1. Important fruit crops, varieties, major agrotechniques and B:C ratio under arid conditions

Crops	Improved varieties	Spacing (m ²)	Propagation	Important agrotechniques	B:C ratio
<i>Ber</i> (<i>Ziziphus mauritiana</i>)	Gola, Seb, Umran, Illachi, Tikadi	6x6	I-budding during June-July	Pruning and management of fruit fly	2.36
Pomegranate (<i>Punica granatum</i>)	Bhagwa, PhuleArakta, Ruby, Ganesh	4x4	Tissue culture/cutting	Canopy management, defoliation, nutrient and pest management	2.67
<i>Aonla</i> (<i>Emblica officinalis</i>)	NA7, Chakaiya, Kanchan, Krishna, Anand-2	6x6	budding	Irrigation and nutrient management	1.87
Date palm (<i>Phoenix dactylifera</i>)	Barhee, Khalas Khunaizi, Medjool, ADP-1	8x8	Offshoot, Tissue culture	Irrigation, nutrient management, pollination, offshoot removal	2.0
<i>Orange</i> King x Willow leaf	Kinnow	6x6	Budding	Irrigation scheduling, nutrient and pest management	1.99
Sour lime (<i>Citrus aurantifolia</i>)	Kagzi, Vikram, Pramalini	5x5	Seeds/budding	Irrigation scheduling, nutrient and pest management	1.89
Sweet Orange (<i>Citrus sinensis</i>)	Mosambi	6x6	Budding	Irrigation scheduling, nutrient and pest management	2.13
Gonda (<i>Cordia myxa</i>)	Maru Samridhi	6x6	Budding	Defoliation and irrigation scheduling	2.40
Guava (<i>Psidium guajava</i>)	Allahabad Safeda, Lalit, L-49, Red Flesh	5x5	Air layering, Wedge grafting	Pruning, Irrigation scheduling and nutrient management	2.4
<i>Bael</i> (<i>Aegle marmelos</i>)	Dhara Road, Faizabadi Local, NB-9, NB-5	6x6	Budding	Irrigation management	1.84
<i>Kair</i> (<i>Capparis decidua</i>)	Local	5x5	Seeds, cutting	Harvesting, marketing and value addition	2.28
<i>Khejri</i> (<i>Prosopis cineraria</i>)	Thar Shobha, CAZRI Selections	6x6	Budding	Harvesting, marketing and value addition	2.51

enhancing their income. Polytube nursery technique of *ber* for mass multiplication of seedlings becomes transplantable after 30 days of budding. Hardened plants in this manner have more than 90% survival in transplanting. The technique were standardized for long distance transport of saplings. Since *ber* bears fruits on current season's growth, annual pruning during May-

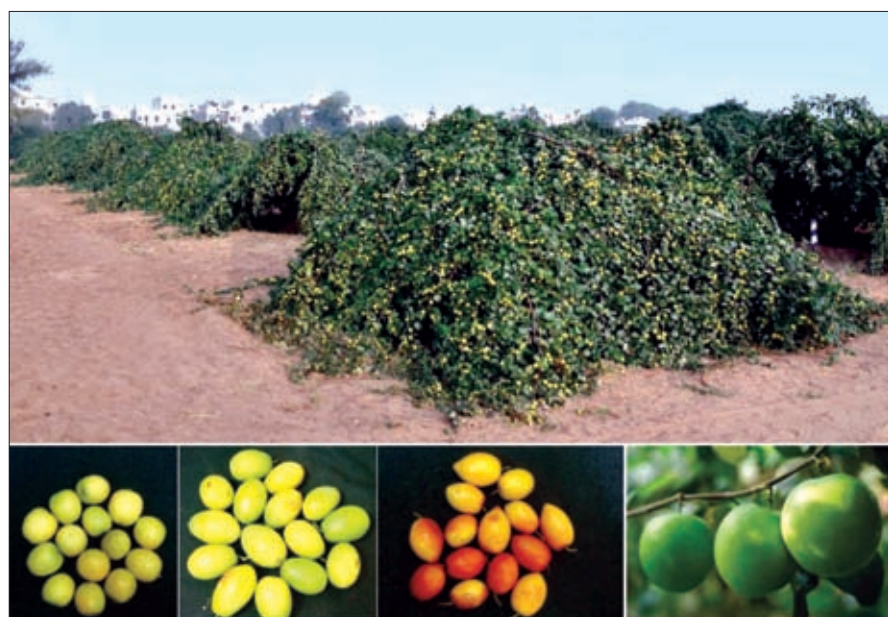
June is considered most important cultural operation in improving *ber* productivity. Fruit fly is one of the most devastating insect which cause huge economic loss to *ber* growers. However, cent per cent control of fruit fly may be accomplished with summer ploughing and chemical sprays of quinalphos (1.0 ml litre⁻¹)/metasystox/monocrotophos (1.0 ml litre⁻¹) at pea stage of fruits with

second spray after 15 days.

Usually after 25 to 30 years after planting, the fruit yield of *ber* tree starts diminishing. Such trees can be given lease of productive life of another 15 to 20 years when they were headed back at 9 inches (22.5 cm) above ground in mid-May followed by smearing of cut surface by copper oxychloride to prevent infection. Budding with recommended varieties on newly emerged shoot removal of side shoot emerging from rootstock parts results in development of optimum canopy within three years. Intercropping with moong bean in alleys of such rejuvenated *ber* gives additional income.

Pomegranate: an emerging cash crop in Thar desert

The area under pomegranate is expanding fast especially in arid Rajasthan owing to its tolerance to saline or sodic soil/water. It has tremendous scope in national and international market for table purpose and processing. The development of newer varieties like Bhagwa, Phule Arakta and super Bhagwa with attractive colour and



Gola

Mundia

Tikadi

Thailand Apple



Sequential steps of rejuvenation of ber orchard

better-quality attributes played significant role in fast adaption in large-scale. The availability of tissue culture raised pomegranate seedlings played significant role in making available the planting material for large-scale plantation. As a result of support from the government and increasing interest of the farmers, the area under pomegranate cultivation increased from 793 ha in 2010-11 to more than 6,000 ha in 2016-17.

Improved production management

Pits of about 60 cm × 60 cm × 60 cm were dug at a spacing of 4 m × 4 m to accommodate about 625 plants ha⁻¹. The ideal time of planting in arid regions is July-August and February-March. The plants should be trained to retain 4 to 5 main stems from the ground level. Main pruning and skirting (removal of lower branches) should be done just after fruit harvest however, light pruning for flower regulation should be done after stress period. Shoot pinching is also desirable in pomegranate to regulate current season growth and fruit development. Mrig bahar (flowering in July-August and fruits ripen in December to March) is recommended in arid region, which

can be achieved by withholding water in May - June or spraying of ethrel (2.5 ml litre⁻¹). The manure and fertilizer are applied during July with regular irrigation through drip system. Under arid condition, a dose of 25 kg farmyard manure, 625 g N, 250 g P₂O₅ and 500 g K₂O/plant/year for the trees more than four-year-old is sufficient. Full dose of farmyard manure and phosphorus and half of nitrogen and potassium should be applied during July and remaining half dose in October. Multi-micronutrient solution (ZnSO₄@0.5%, MnSO₄@0.5%, Borax @ 0.4%) or Solubor (20% B) @0.5% can be given as three foliar sprays at monthly intervals. Maintenance of plant water status especially at the pre- fruiting stage through uniformly regulated drip irrigation and foliar spray of micronutrient that in turn regulates water uptake and translocation helps in obtaining good quality produce in pomegranate.

On an average 80 to 100 fruits should be retained on fully grown up trees to produce export quality fruits. Fruit yield of 12 to 15 tonne ha⁻¹ can be obtained from a well-maintained orchard (5-year-old). Therefore, fifth

year onwards a net return of ₹ 3.50 to 5.0 lakh/ha annum was expected from pomegranate production.

Lasora (*Cordia myxa*)

Gonda, lasora or lehsua is a potential underutilized fruit vegetable in arid regions. Once established, it gave good returns even under rainfed conditions with few supplementary irrigations. Green unripe fruits of *gonda* are important as fresh vegetable and preparation of pickles. Fruit availability during scarce period (April-May) makes it as high priced (up to ₹ 100 to 120 kg⁻¹) vegetable in the region. The fruits can be easily dehydrated after blanching for were during off season. Its fruits are important constituent of famous 'Panchkuta', a traditional mixed vegetable of Rajasthan, hence plays important role in economy of poor people in arid regions.

The planting of *gonda* trees on farm boundaries were dual benefits of creating favourable micro-climate and prevent the crops from adverse impact of hot dry winds. Nursery techniques standardized at CAZRI is able to produce true-to-type seedlings within four months. Budded plants are more productive (60 to 80 kg fruit tree⁻¹) and precocious and it starts fruiting in second year of plantation compared to 4 to 5 years in seedling trees. A high-yielding variety 'Maru Samridhi' is also developed through selection with production of more than 100 kg fruits tree.

Defoliation during January and canopy management are important for getting high yield. Withdrawal of irrigation during December-January promotes leaf defoliation which is essential for regular and early fruiting. Chemical leaf defoliation was found to be very beneficial with respect to fruit yield and quality in our region.

The greatest advantage with *gonda* is its ability to grow and produce profitable crops even under limited irrigation only for 2 to 3 months. The irrigation (about @400 litre/plant) at 10 days interval from February to April is essential. The fruit harvesting starts in mid-March and completed by end of April.



Pomegranate: an emerging cash crop.

Date palm

The date palm (*Phoenix dactylifera*) is one of the most potential fruit crops in dry arid zone of the country with irrigation facilities. In India, it is cultivated in 12,493 ha area in Kachchh district of Gujarat with a production of 85,351 tonne/annum of *doka* stage fruits. Date palm requires prolong hot dry summer, moderate winters and almost rain free period at fruit ripening (July-August) and assured supply of irrigation water. With the introduction of canal irrigation, date palm is one of the suitable cash crops as block plantation as well under multistorey farming system. Recently, Government of Rajasthan entered into Public-Private-Partnership (PPP) to reorient the overall date palm production potential in India with the production of date palm plants through tissue culture at Jodhpur. Large acres of arid farmland in Rajasthan, Gujarat and south Indian states brought under tissue culture date palm cultivation resulting the area under date palm increased upto 813 ha with production of about 800 tonne of fresh fruit/year in Rajasthan only.

The suitable varieties for arid regions are Barhee, Khunaizi, Khalas, Medjool, Khadravi, Jamli and Sagai which are sweet at *doka* stage (fit for table purpose). The fruits of date palm harvested at the end of June or first week of July to avoid spoilage by rain. Farmers are getting good value for their produce and there is more interest to take up this among the farming community in Rajasthan. Under recommended package of practices, the fruiting started in 3rd year (3,000 kg ha⁻¹). However, 5th year onwards economic yield of 65 kg tree⁻¹ and the monetary benefit of ₹ 3.5 to 4.5 lakh ha⁻¹ may be expected. The Government of Rajasthan is promoting date palm farming in arid desert regions of north-western Rajasthan and giving tissue culture raised sapling to farmers at a subsidized rate under the centrally-sponsored *Rashtriya Krishi Vikas Yojana*.

Aonla

Aonla (*Emblica officinalis*) is

another important minor fruit crop of commercial significance in semi-arid and arid regions. It is hardy, prolific bearer, and highly remunerative more so because it can be grown without much care in variable agro-climatic and soil conditions. The fruit is recognized for its nutritive and therapeutical values. The fruit is rich source of vitamin C (400-900 mg⁻¹/100g), pectin, iron, calcium and phosphorus and main ingredient of many Ayurvedic formulations. *Aonla* has huge scope in arid region for growing under limited irrigation and with poor quality water provided processing industries are there in the vicinity of growing areas. Processed products of *aonla* like pickle, squash, candy, shreds, preserve and dried products have great marketability scope.

Khejri

Khejri (*Prosopis cineraria*) is considered life-line tree of desert being an important component of farming system. Owing to its multiple uses, atmospheric nitrogen-fixing ability and suitability in agro-forestry systems, it was conserved in arable land since ages. Its highly nutritious leaves constitute important source of fodder for livestock while nutritious pods are valued as vegetable for human beings. The immature pods are used as vegetables both fresh as well as after dehydration, while ripe dried pods having 9 to 14% crude protein and 6 to 16% sugar can be powdered and used in the preparation of bakery items such as biscuits and cookies.

High-yielding types with desirable pod quality was identified at CAZRI for production of quality pods. Production of quality pods (tender pods with less tannin content) can be achieved through budding or *in-situ* budding of elite germplasm. Package of practices for quality tender pods production through *in-situ* budding was standardized. Tree seeds may be sown in previously prepared pits (60 cm × 60 cm × 60 cm) at a desired spacing (6 × 4 m² / 6 × 6 m² / 4 × 4 m²) and seed should be sown after first monsoon rain. Next year during

July-August, one-year-old seedling should be budded *in-situ* with elite genotype at a height of 6 inches (15 cm) through I-budding. The sprouts emerging from rootstocks should be removed periodically. Trees should be trained with 3 to 4 main primary branches. As against normal pruning in November–December, for harvesting of quality pods, trees should be pruned in second fortnight of June. The major advantages are precocious, start producing tender pods in third year than in 8-9 years in traditional *khejri*. Budded *khejri* become thornless so harvesting of leaves (for fodder) and pods is easy. These trees are capable of producing both fodder (loong) and pods every year while in traditional *khejri* one has to compromise either for pod or fodder. Since canopy is short, cultural operations are easy and it is more productive (20-25 kg pods tree⁻¹) with quality tender pods. The good quality dried pods of *khejri* are high in demand and sold in the market for as high as ₹ 600/- kg⁻¹.

Kair

Kair (*Capparis decidua*) is an under-exploited drought hardy multipurpose, woody shrub or small tree found throughout arid regions of Indian sub-continent. It is of great value to the inhabitants in a variety of ways.

The green immature fruits are rich in protein, carbohydrates, fats and minerals (Ca, P and Fe); immature fruits are either pickled or made into a delicious vegetable curry. It is the most important ingredient of the famous *panchkuta* vegetable of Rajasthan which is prepared from dried fruits or seeds of five different species. *Kair* also has ecological significance as it has soil binding ability to control erosion caused by wind and water. Although *kair* is rarely cultivated as an organized orchard, large quantity of fruits is harvested from naturally growing population either in common land or from farmers field. The people in rural areas harvest the fruits in March-April and sell in urban market at higher cost. Good amount of revenue is generated by the people as the only cost involved is of

harvesting. The dried fruits are sold in the market at very high rate up to ₹ 1,000/- kg⁻¹ since the product is 100% organic.

Role of vegetables and protected cultivation

Native vegetables viz. snap melon/*kachra* (*Cucumis melo* var. *momordica*), *kachri* (*C. melo* var. *agrestis* or *C. callosus*), *mateera* (drought-tolerant watermelon, *Citrullus lanatus*), vegetable cluster bean (*Cyamopsis tetragonoloba*) were grown as mixed crop with field crops under rainfed situation during *kharif* to generate extra income. Seed purpose watermelon (*kalingada*) possess high amount of nutritious seeds, when used as mixed crop and would provide an additional income of ₹ 5 to 6 thousand/ha to rainfed farmer. Under irrigated situation, chilli, onion, garlic and carrot are cultivated as truck farming. In general, the prices of most of the vegetables were always high owing to a large gap in demands and supply from local produce. The commercial cultivation of other vegetables can be a remunerative option, if grown with improved cultivation practices. These include tomato, brinjal, okra, cole crops (cauliflower and cabbage), leafy vegetables (fenugreek, amaranth and spinach) and melons (musk melon, long melon and cucumber), gourds (bottle-gourd, round gourd, ridge gourd and bitter gourd), and beans (cowpea and cluster bean).

A comparative analysis of different vegetable crop sequences revealed that ladyfinger-tomato-melon cropping sequence with drip irrigation was found superior with regard to production (cumulative yield, 117.2 tonne/ha) as well as high water use efficiency (1.73 kg m⁻³) while, introduction of gladiolus flower in sequence (i.e. tomato-gladiolus-ladyfinger) provided the maximum returns (₹ 5.99 lakh/ha).

Protected cultivation: a promise for vegetable production for enhanced income

The current statistics showed that vegetables productivity of arid part of Rajasthan is merely 1.8 tonne/ha

which is far below the productivity of the Rajasthan (10.6 tonne/ha) and India as a whole (17.5 tonne/ha). In fact, open field cultivation of vegetables in arid regions is challenged due to erratic weather which resulted in less productivity. The demand of vegetables was increasing but supply from local produce was limited, resulting in high price in local market, especially of perishable vegetables. Protected cultivation was an inevitable option that not only provided protection to the crops from aberrant weather but also provided favorable micro-climate for optimal plant growth and production and ensures supply of high quality vegetables even in off-seasons.

Avenues in protected cultivation

Looking to its promise in such a fragile ecosystem, where open field vegetables cultivation is risky, the area under protected cultivation is increasing at fast pace. Government is also providing subsidies through various schemes to promote this venture in arid region. The common protected structures in these areas were naturally ventilated polyhouse, shade-net house, insect proof-net house and low tunnel or row cover. The commercial polyhouse and shade-net house were made in roughly 1,000 m², 2,000 m² and 4,000 m² area. It involved a huge establishment costs but looking to its multifarious benefits and promise in arid environment, its adoption is picking at fast rate. The recurring cost of cultivation (excluding the cost of infrastructure) of tomato and cucumber were 5.12 and 6.6 lakh/ha whereas gross return were 21.5 and 19.3 lakh ha⁻¹ in 7 and 6 months respectively.

Greenhouse cultivation in arid and semi-arid areas is even possible during winter (off-season) and summer with some

critical interventions viz. sprinkler on roof top and side curtain along with fogger, shade cover inside naturally ventilated polyhouse, and with the use of suitable cultivars. High-water productivity and nutrient use efficiency are added advantage of protected cultivation, which is utmost requirement in this water scarce region. Cultivation of cucumber in polyhouse gave more system water productivity (13.5 kg m⁻³) than tomato (12.8 kg m⁻³) after accounting for the water used. In general, per acre recurring cost of cucumber and tomato in naturally ventilated polyhouse in arid region ranges from 1.5 to 2.0 lakh, which can provide a gross return of ₹ 5.0 to 8.0 lakh depending on season and market price. The average yield of cucumber may vary from 20 (in summer) to 40 tonne acre⁻¹ (in normal season), though sometime may reach up to 55 tonne acre⁻¹ and provided a gross return to a tune of ₹ 10 to 12 lakh from single crop.

Management practice of protected cultivation

Cucumber is predominantly grown vegetable in protected conditions in arid region, which is followed by tomato, while capsicum preferred least among these. Greenhouse cucumber cultivation is remunerative owing to increasing demands for high quality seedless (parthenocarpic) fruits that fetched higher price than open field cucumber, especially during off-season (during winter and late summer and early *kharif*). Likewise, tomato also fetched high price in normal and particularly off-season seasons.





Followings are the good management practice followed in greenhouse cultivation:

- Right choice of cultivars is crucial in greenhouse cultivation. Terminator and Rica in cucumber and Myla, NS (TR) 4266, NS (TR) 4343, IA 07 in tomato were evaluated at CAZRI and found most suitable for arid greenhouses cultivation.
- Planting on raised beds were preferred over flat beds and seedling transplanting over direct seeding was advised during winter cucumber.
- Transplanting in both tomato and cucumber is preferred over direct seeding, which is practised in cucumber. This is to be avoided in winter crop as longer period in seed germination and seedling growth is required.
- Planting at raised bed (90 cm width) that accommodated paired rows of cucumber and tomato with 50 cm between the two rows. Plants are spaced at 45 cm apart in zig-zag fashion in both the rows.
- Incidence of soil-borne diseases and nematodes under intensive cultivation in succession is emerging issues in protected cultivation. To manage these, integrated management approach: soil treatment involving deep summer ploughing followed by soil solarization by plastic covering (air tight) of saturated soil followed by soil fumigation with suitable fumigant (e.g. formaldehyde, methan, sodium) or sterilant (e.g.

silver- H_2O_2) in prescribed quantity and method.

- Based on season, scheduling of water and nutrient supply so that best possible balanced vegetative and reproductive growth are attained.
- Regular pruning of auxillary shoots is essential operation to train plants to single or double leader system which allow balanced plant growth and fruiting. Removal of lower leaves after attainment of proper fruit size is essentially done in tomatoes, while in cucumber it is required for adequate sunlight and air movement. This is done especially during winter only after lower fruits are harvested. In cluster bearing cucumber hybrids, maximum 2-3 fruits/node were retained.
- Double stem training in tomato is found promising to enhance tomato fruit yield by up to 42%, besides reducing requirement of 40% less seeds, which compensated the extra expenditure on training one extra stem in double stem training. In this, fruit yield increased without compromising the fruit size and quality and yield increase was due to increased fruit numbers.
- The effect of low temperatures that prevailed under low-cost protected structure can be alleviated by grafting. Grafting commercial cucumber onto cold hardy fig-leaf gourd (*Cucurbita ficifolia*) rootstock was found to improve cucumber yield by 30% than non-grafted

cucumber.

- To manage high temperatures, some improvement in structures design such as increase in vent size and adequate shading, intermittent operation of sprinkler on top and side wall and mid-day operation of fogger beneath the shade net inside polyhouse. Besides, if possible use of fan-pad evaporative cooling, air circulating fan operated by electricity or solar power would be better. Research on improving drought and heat stress tolerance through grafting by using resistant rootstocks is also underway.

In arid regions- cultivation of horticultural crops pays: a success Story

Shri Satta Ram Choudhary of Jasti village, Barmer district of Rajasthan developed successful model farm under rainfed conditions of extreme desert. Earlier he was just surviving by growing subsistence crops such as pearl millet, sesame, moong bean, moth bean, cluster bean cucurbits etc. Motivated by the scientists, he decided to grow multi-species fruits orchard by harvested rainwater. He constructed a water harvesting pond of 10 lakh liter capacities. A total of 800 plants of different fruit species supplied by CAZRI were planted by him in planned way in 2012.

Shri Choudhary planted five rows of *gonda (lasora)* on boundary towards wind ward side. *Ber* (450) cv. *Gola* at spacing of 6 m × 6 m as block plantation intercropped with moong bean and moth bean. High value fruit pomegranate and sour lime was planted as sole near the farm pond. With the technical input and constant supervision of CAZRI scientists, he started getting the returns from orchard from third year onwards (about ₹ 1.0 to 1.5 lakh from *ber* and ₹ 0.15 to 0.25 lakh from *lasora* fruits) that has since increased to a net profit of ₹ 0.8-1.0 lakh year⁻¹. Besides, the monetary benefits, his family member are now getting year-round employment. This has inspired many farmers of the region.

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