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REVIEW ARTICLE

Arid Horticultural Crops: Status and Opportunities under Changing Climatic Conditions

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Arid ecosystem, especially 'Thar Desert' of India possess highest flora and fauna among the desert ecosystems of the world. It has a very rich floral diversity consisting about 628 species, 352 genera and 87 families, mainly occupied by dry grassland, trees, thorny bushes, and arid fruits and vegetables of economic importance. The adapted species of hot arid zone have specific traits of high significance in future for climatic changes and/or the emergence of new diseases. On the other hand, herbal nutraceuticals and antioxidants are gaining momentum world over for human being as well as animal's health care and arid flora are treasure house of such traits. Mining of unique genes from arid flora provides ample scope for imparting abiotic stress tolerance in the high yielding commercial crop cultivars. Most of the native flora of this region viz. *Khejri, ker, kumat*, karonda, *kachri, pilu*, lasora, bitter apple, cactus pear, *phog, kheep*, etc are unexploited and underutilized which require sincere research efforts for their conservation and sustainable utilization at commercial level. Nutraceutical and nutritional profiling of selected indigenous and traditional crops and varieties, and their bioavailability can help to determine which crops should be promoted and marketed for the health benefits. Besides, arid regions have an ample scope for introducing a number of crops from isoclimatic regions for crop diversification and promotion of nutritional security. Furthermore, the Indira Gandhi Canal Project has increased the over-exploitation of 'Thar Desert' for agricultural activities which enhanced the domestication of animals, particularly dairy animals like cows, buffalos, goats and other ruminants in the region. Also, the area under fruits, vegetables and spices has increased substantially since past few decades. Thus, sustainable management of these arid horticultural native crop plants certainly reduces the poverty, malnutrition and improves the nutritional quality of the foods and ultimately ensure nutritional security of resource poor people living in hot arid climate. This review will be helpful in conserving native flora of arid region and their sustainable use during the scenario of climate change.

Key Words: Abiotic stresses, Arid horticulture, Biodiversity, Climate change

Introduction

Climate change is one of the major challenges in plant biodiversity which adversely affect the growth, yield and quality attributes of the plants. In the present scenario, global climate change is a major threat for socioeconomic activities including agriculture and forestry and is a major hazard for biodiversity and ecosystem (Lepetz *et al.*, 2009). India with diverse soil and climatic conditions comprised with several agroecosystems, provides a huge opportunity to cultivate a variety of horticultural crops but an arid ecosystem is most vulnerable to climate change. In the arid ecosystem, 'Thar Desert' is the ninth largest desert of the world, but it has abundant biodiversity status. The vegetation of this region is adapted to xerophytic conditions. It is a biodiversity hotspot of a huge flora and fauna which are flourishing under such a harsh conditions.

Arid region is characterized by low and erratic rainfall, frequent droughts, extremes of diurnal and annual temperatures, low humidity, poor availability of nutrients, high evapotranspiration rate and high wind velocity. During summer (March to June), the maximum temperature generally varies between 45°C and 50°C, while temperatures in winters (November to February) range between 15-25°C (Fig. 1 and 2). More than 88% of total annual rainfall received less than 25 cm during Monsoon season (July to October) [Fig. 3]. The soil of the 'Thar Desert' is characterized by poor soil fertility. It is dominantly sandy with 60-90% fine sand and 2-10% of silt-clay in the topsoil and it has very less organic matter. The sifting sand dunes is a natural phenomenon of this region. The soil has low to medium available phosphorus and medium to high available potassium. The average pH of the soil of the desert ranges from 7.6 to 8.5. Salinity and sodicity of the soil in some

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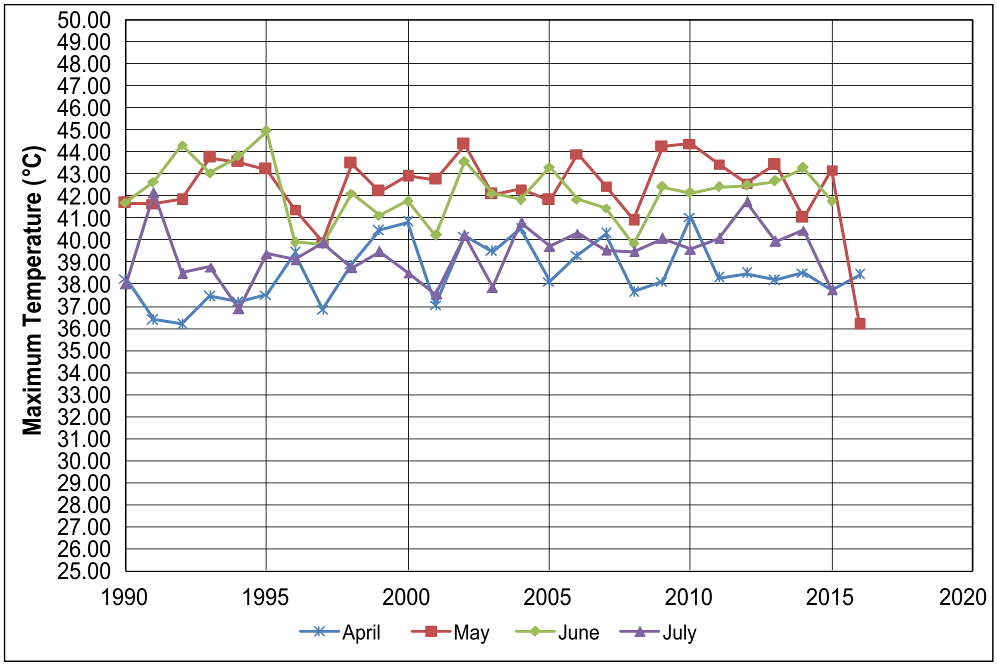

Fig. 1. Variations in the maximum temperature over the past 25 years during summer season

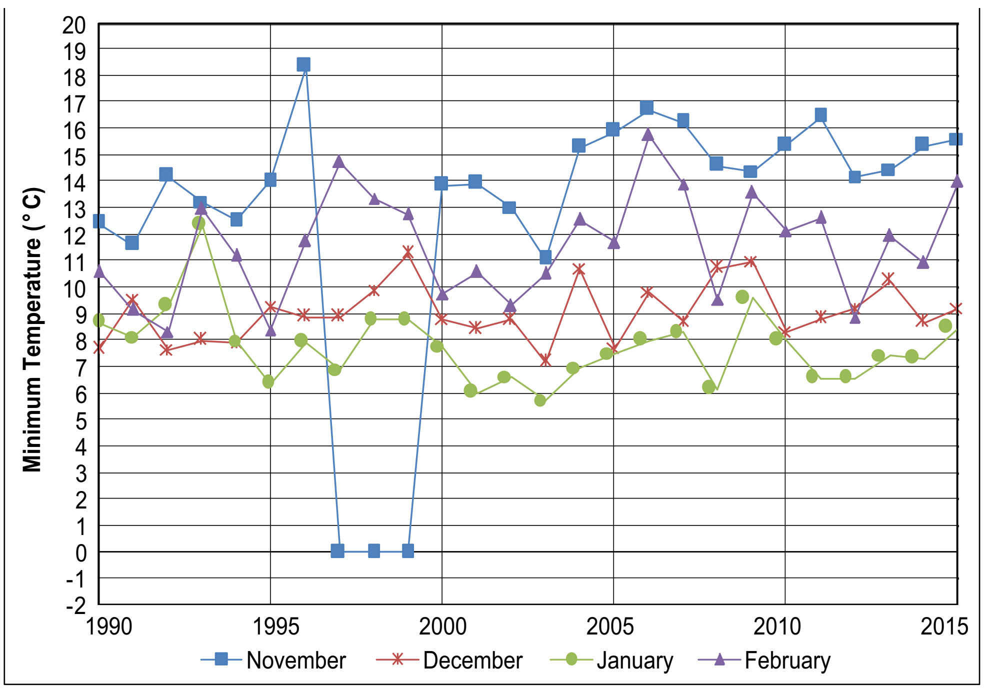

Fig. 2. Variations in the minimum temperature over the past 25 years during winter season

areas of the desert is higher, which is mostly confined to areas with depressions (Charan and Sharma, 2016). The isohyets map of Rajasthan shows that the eastern part of the desert receives high rainfall (up to 400 mm) as compared to the western part (about 100 mm) and hence, vegetation cover is comparatively dense in the eastern part. The vegetation of the region has adapted to these edapho-climatic extremities, which helps the plants to grow and sustain the adverse xerophytic conditions. It is reported that the 'Thar Desert' represents only 5%

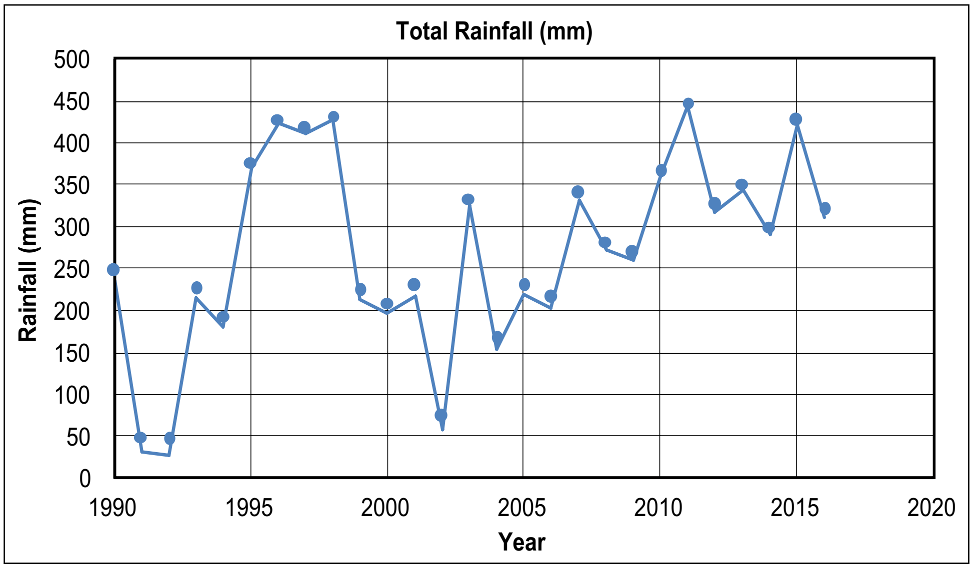

Fig. 3. Variation in total annual rainfall over the past 25 years

of the flora of India, which has about 17,500 flowering plants. The average population density in the 'Thar Desert' is 83 persons/ km^2 while in other deserts of the world; the population density is just 7 persons/square km. In India, more than 60% of the geographical area of the 'Thar Desert' lies in the Rajasthan state (Charan and Sharma, 2016).

For the last fifty years, the climatic regime has adversely affected, especially due to anthropogenic causes, at local as well as global level. A report of the Inter-Governmental Panel on Climate Change has projected hotter days and warm nights and a reduction in rainfall in arid regions by the 21st century. It is reported that the consequences of climate change may be very adverse for the biological diversity of the arid region (Charan and Sharma, 2016) and adversely affects the production and yield of crop plants. Perennial desert flora like *khejri, ker, phog, pillu, ber,* etc. provides a natural habitat for numerous herbaceous plants and soil microbes in arid zone. It is reported that most of the plants of the 'Thar Desert' are having different medicinal properties and therefore, they are being used by tribes for curing their ailments. In order to increase the function of terrestrial species of arid ecosystem, there is an urgent need to conserve and manage the flora of arid ecosystems. Moreover, horticultural crops are also sensitive to climate change through changes in atmospheric temperature, rainfall, soil moisture, humidity and wind velocity (Malhotra, 2017; Saroj, 2018). The major consequences of climate change on horticultural crops in this region are erratic rainfall patterns and unpredictable high temperature during dry spells which consequently reduce crop productivity and quality. However, it is not always to put adverse effects on crop plant, especially on arid horticultural crops. The sharp fluctuations in day and night temperature during autumn, spring and summer help in development of sweetness in sweet orange, kinnow, ber and date palm and arils colour and sweetness in pomegranate and *mateera* pulp (Sharma *et al*., 2018). Therefore, the conservation, characterization and utilization of arid biodiversity in terms of arid fruits and vegetables are the most important aspects in the present climate change scenario *per se*.

Effect of Weather Aberrations on Arid Crops

Weather aberrations from the normal climatic pattern, sometimes have adverse influence on various crops in the arid region. For example, in general, frost occurrence is a common phenomenon in arid regions during December–January, but sometimes it was happened in first fortnight of February. Similarly, severe hailstorm of marble size was occurred in Bikaner district of Rajasthan in the month of March, 2016, which badly affected cultivated crops especially, date palm, rapeseed and mustard. In 2019, prolonged winter and rains in the month of February-March significantly affected few crops like date palm and lasoda (*Cordia myxa*) and thereby delayed flowering. Generally, in date palm spathe emergence starts from the last week of January and completes up to February and flowering commences in the month of March. But this year, due to a prolonged winter coupled with rains during February-March delayed the spathe emergence and subsequent flowering in date palm. Also, flowering in date palm, completed in April, 2019 which ultimately will delay the fruit ripening. The fruits will ripe during rainy season in the month of July instead of June which will badly affect the fruit quality. Since, date palm harvested in arid regions at *doka* stage for commercial consumption and *pind* stage (attained during June-July) is not suitable for Indian conditions because of monsoon rains with dust storms occurred during June-July. Likewise, in phalsa also, under arid region, flowering mainly commences from the second fortnight of February and completes up to 20th March, and fruit harvesting/picking starts from third week of April and completed up to first week of May. This year due to prolonged winter, flowering commenced in the month of April, 2019, therefore fruit ripening started from the second week of May ultimately fruit picking/harvesting delayed by about 20-25 days. Sometimes, sudden rise in temperature during March (>40 ºC) may also affect arid vegetables mostly cucurbits. Early break of monsoon followed by prolonged cessation of rains will lead to total failure of arid vegetables. Such weather aberrations not only affect horticultural crops in arid region but also effect field crops, pulses, oilseed crops, etc.

Biodiversity of Hot Arid Region

India represents one of the greatest emporia of ethnobotanical wealth. Like other parts of India, in hot arid regions too, rural and tribal communities have precious information about utilization of indigenous plants. Besides, identification of plants as food, fodder, medicine, etc., their also exists similar experience on life sport species for exigencies like drought and famines, which is less utilized so far. Several researches made contribution on ethnobotanical aspects of 'Thar Desert' of western Rajasthan (Singh and Rathore, 2018). Traditional species of economic importance of the hot arid region have immense value as evolved in nature to survive under abiotic stress conditions. They have become adapted to cope with many natural hazards created due to global climate change and also developed resistance to the pest and diseases. Oozing of essential oil/gums by certain arid plants appears to play a vital role in protecting them against drought and higher temperature. Now a day, herbal nutraceuticals, antioxidants, adaptogen herbs, etc., are gaining momentum world over for human being as well as animal health care. The adapted species of hot arid zone have specific traits; such of these traits could prove very important in future for climatic changes or the emergence of new diseases (Singh and Rathore, 2018). The 'Thar Desert' has a very rich floral diversity, including dry grassland, trees, thorny bushes, and arid fruits and vegetables of economic importance. Among them, *khejri* (*Prosopis cineraria*) is known as *Kalpavriksh* and considered as the lifeline of hot arid zone of India which is integral part of an arid ecosystem.

One of the important geological features of the 'Thar Desert' is the presence of some ephemeral rivers, including Luni, Sookdi, Ghagghar, Bandi and Jojri river, which play an important role on micro-climatic conditions of the regions through which they traverse and hence, they affect the vegetation of the 'Thar Desert' (Charan and Sharma, 2016). A total of 62 families, 157 genera and 206 species were documented from the desert area. Among the existing families, Fabaceae is the largest family with 29 species, followed by Poaceae (26 species) and Asteraceae (15 species), Amaranthaceae (10 species), Cucurbitaceae (9 species), Convolvulaceae (6 species), Boraginaceae, Euhorbiaceae and Lamiaceae (5 species each), Acanthaceae, Brassicaceae, Capparaceae, and Zygophyllaceae (4 species each), Solanaceae, Apocynaceae, Asclepiadaceae, Menispermaceae, Tiliaceae, Malvaceae and Chenopodiaceae (3 species each), Aizoaceae, Caesalpinioideae, Cleomaceae, Cyperaceae, Hydrocharitaceae, Moraceae, Nymphaceae, Molluginaceae, Pedaliaceae, Plantaginaceae, Rhamnaceae, Salvedoraceae and Tamaricaceae (2 species each), while rest of 29 families are represented with one species. The habit wise analysis of the study shows that herbaceous vegetation (60.10%) were highest prevailing vegetation in 'Thar Desert' followed by shrubs (16.26%), trees (14.29%) and climber (9.36%) according to Charan and Sharma (2016).

Biodiversity of Horticultural Crops

Globally, drylands are a typical terrestrial system of the earth constrained with low water availability. Drylands occupy about 41.3% of the land surface in the world, where major proportion is arid and semi-arid regions (25.80%). Traditionally drylands have been largely used for livestock, but they are increasingly being converted into horticultural land. The livelihood of more than 1 billion people in some 100 countries is threatened by desertification. Nearly 1 billion of the poorest and most marginalized people, who live in the most vulnerable areas, may be the most severely affected by desertification. The total dryland population is 2.1 billion, indicating the home to one in three people in the world today. As far as India is concerned, arid region alone occupies about 12.02% of the geographical area. The hot arid region is spread over about 31.7 million ha area mainly in the states of Rajasthan, Gujarat, Andhra Pradesh, Punjab and Haryana, which inhabit on an average 61 persons per square km, making up a population of nearly 20 million people. The direct land degradation factor of dry lands are extremely low precipitation, low soil moisture, high evapotranspiration and indirect drivers are mostly human derived and include poverty, low adoption rate of advance technologies, traditional marketing system and sociopolitical dynamics (Saroj, 2018).

Arid fruit crops: Large number of fruit crops are being cultivated in arid regions. Some fruit crops are grown at the commercial level like pomegranate, date palm, ber, aonla, tamarind, custard apple, citrus, *etc*. In past few decades, considerable area has come up under fruits like aonla, ber, pomegranate, annona, fig and phalsa in different parts of the country. Ber has spread from northern states to the western and southern India from a mere 12,000 ha in 1978 to nearly 86,000 ha in 2015-2016 with a production of about 0.90 million tonnes. Similarly, the area under pomegranate has also leaped to over 2.16 lakh ha. Likewise aonla, presently cultivated on 80,000 ha with the production of 2, 80, 000 tonnes. This has become possible as a result of the research and developmental efforts of the different organizations of NARS. Under-utilized horticultural crops like., bael, jamun, karonda, mulberry, phalsa, lasoda, chirounji, *pilu*, mahua, wood apple, manila tamarind, *ker*, khirni, cactus pear etc. are not exploited well. Such fruit trees are not only hardy but have high nutritional and nutraceutical values which need proper attention. A list of arid fruits with other details are given in Table 1 (Vashishtha, 2005).

After massive research work on arid fruits, a large number of varieties have been released by different R&D organizations which are recommended for commercial cultivation in arid and semi-arid regions of the country (Table 2).

Underutilized arid flora: In the hot arid region of India, a large number of naturally grown plant biodiversity can be seen across the roadsides and on the sand dunes of barren lands (Table 3). These flora are totally grown under rainfed conditions and show typical characteristic of adaptation under harsh situation of an arid ecosystem. Other than cultivated fruit and vegetable crops in arid regions, these flora have economic importance for livelihood of this region and play a greater role to maintain

Table 1. List of major arid fruits in India

Botanical Name	Common name(s)	Family	Chromosome no. (2n)	Origin/distribution
Aegle marmelos (L.) Correa	Bael fruit, Bael	Rutaceae	36	Northern India
Opuntia ficus-india L. Mill.	Cactus pear, Prickly pear	Cactaceae	22-88	Mexico
Capparis decidua (Forsk.) Edgew	Capparis, Ker, Teet	Capparidaceae	14, 16 (2x)	Arid region of India
Buchanania lanzan L.	Almondette tree, Chironji	Anacardiaceae	-	Western Peninsula
Cordia myxa Roxb.	Cordia, Lasoda, Gonda	Boraginaceae	-	India
Annona squamosa L.	Custard apple, Sarifa	Annonaceae	14, 16	Tropical America
Phoenix dactylifera L.	Date plam, Khajur	Palmaeae	36	Around Persian Gulf, Iraq
Ficus carica L.	Fig, Anjir	Moraceae	26	South-East Asia
Emblica officinalis Gaertn	Indian gooseberry, Aonla	Euphorbiaceae	18, 28	Peninsular India
Zizyphus mauritiana Lamk.	Indian jujube, Ber	Rhamnaceae	24	Indian sub-continent
Syzygium cumini (L.) Skeels	Java plum, Jamun	Myrtaceae	40	Indian sub-continent
Carissa carandas L.	Karanda, Karonda	Apocynaceae	12	India
Prosopis cineraria (L.) Druce	Khejri, Jand, Sami	Leguminosae, Mimosaceae	-	Thar Desert of India
Morus alba L.	Mulberry, Tut	Moraceae	308	Northern China/Japan
Grewia subinaequalis DC.	Grewia, Phala	Tiliaceae	36	India
Salvadora oleoides Decne	Pilu	Salvadoraceae	24	India/Tropical Africa
Punica granatum L.	Pomegranate, Anar	Punicaceae	18	Iran, Afghanistan to Himalayas
Tamarindus indica (L.) Gaertn.	Tamarind, Imali	Caesalpiniaceae	24	Tropical Africa
Feronia limonia (L.) Swingle	Wood apple, Kainth	Rutaceae	18	India, Sri Lanka

Table 2. Recommended varieties of fruits for arid and semi-arid regions

Crops	Varieties suitable for arid and semi-arid ecosystem
Pomegranate	Ganesh, Dholka, Jalore Seedless, Mridula, Phule Arakta, Ruby, Amalidana, G-137, Jyoti, Basin Seedless, Goma Khatta, Bhagwa, Super Bhagwa, Solapur Lal
Ber	Gola, Seb, Umran, Banarasi Karaka, Kaithali, Mundia, Goma Kirti, Thar Bhubharaj, Thar Sevika, Thar Malti, Narendra Ber Sel-1 & 2
Bael	NB-5,NB-9, PantAparna, PantUrvashi, Pant Shivani, Pant Sujata, CISH Bael-1 & CISH Bael-2, Goma Yashi, Thar Divya, Thar Nilkanth
Aonla	Banarasi, Chakaiya, NA-6, NA-7, NA-10, Kanchan, Krishna, Anand-1, Anand-2, Lakshmi-52, BSR-1
Custard apple	Balanagar, Mammoth, Island Gem, APK (Ca) 1, ArkaSahan, Phule Janki
Fig	Poona Fig, Dinkar, Dianna, Conadria, Excel
Date palm	Halawy, Barhee, Medjool, Khalas, Khuneizi, Khadrawy, Zahidi
Lasoda	Thar Bold, Karan Lasoda, Maru Samridhi
Tamarind	PKM 1, Pratisthan, Yogeshwari, Ananta Rudhira
Guava	Allahabad Safeda, L-49, Chittidar, Lalit, Hisar Surkha, Pant Prabhat,
Phalsa	Thar Pragati
Wood apple	Thar Gaurav
Jamun	Goma Priyanka, Thar Priya
Chirounji	Thar Priya
Khirni	Thar Rituraj
Mulberry	Thar Lohit, Thar Harit

Table 3. Unexploited and economically important plant biodiversity of the arid region

S.No.	Common Name	Botanical Name	Uses
1	*Ker*	*Capparis decidua*	Pickle and vegetable
2	*Kumat*	*Acacia senegal*	Ingredient of panchkuta
3	*Pilu*	*Salvodora oleoides*	Tooth-paste making, fuel and furniture
4	*Fog*	*Caligonum polyconides*	Culinary utilization
5	*Kheep*	*Leptadenia pyrotechnica*	Vegetable and shelter
6.	*Tumba*	*Citrullus colocynthis*	Medicinal value and bio-pesticide

agro-ecological balance of an arid ecosystem. Besides horticultural importance, these naturally occurring plant biodiversity of arid region could be the potential source ofr biotic and abiotic stress tolerant genes. Thus, the conservation of such unexploited arid flora is also to be taken as a priority area for future prospective.

Arid vegetable crops: Various arid vegetables, including those of Solanaceae, Leguminaceae and Cucurbitaceae families are also grown in arid and semi-arid regions of the country. The cluster bean, moth, Mathania chilli, thorny brinjal and Indian aloe are some widely grown vegetables of the arid region. The crops belonging to family Cucurbitaceae are generally known as 'Cucurbits'. It consists of a wide range of vegetables either used for salad (cucumber) or for cooking (all gourds) or as a dessert fruit (muskmelon and watermelon) or candied or preserved (ash gourd). The majority of cucurbits are characterized by presence of bitter principle i.e. cucurbitacin in some portions of plant and at some stages of stages of development. Cucurbitacins are tetracyclic triterpins having extensive oxidation levels. Fruit is essentially an inferior berry and is called as 'pepo' due to hard rind when mature. The family Cucurbitaceae includes about 118 genera and 825 species, many of which are economically important crops, notably those of the genera are *Cucumis*, *Cucurbita*, *Citrullus*, *Momordica*, *Lagenaria, Luffa,* etc. Among cucurbits, watermelon, muskmelon, round melon, bottle gourd, ridge gourd, *kachri*, longmelon, snapmelon, etc. are mainly grown in arid regions of India (Table 4).

Table 4. Economically important vegetable crops of arid region

S.No.	Common name	Botanical name	Chromosome number (2n)
1	Bitter apple	*Citrullus colocynthis*	22
2	Bottle gourd	*Lagenaria siceraria*	22
3	Kachri	*Cucumis callosus*	24
4	Long melon	*Cucumis melo var. utilissimus*	24
5	Muskmelon	*Cucumis melo* L.	24
6	Ridge gourd	*Luffa acutangula*	26
7	Round melon	*Pracitrullus fistulosus*	24
8	Snapmelon	*Cucumis melo* var. *momordica*	24

Germplasm Conservation and Utilization for Mitigating Climatic Change

Despite the presence of harsh climatic conditions, the desert region is endowed with valuable natural plant genetic resources including fruit and vegetable crops. The ICAR-Central Institute for Arid Horticulture, Bikaner-334006, Rajasthan is conserving and maintaining the large number of germplasm of arid fruit and vegetables in National Field Repository of the institute (Table 5) and has credit to conserve highest germplasm of ber, bael, date palm, aonla, other minor fruits and arid vegetables in India. The institute is also DUS center for date palm, ber, aonla, bael, jamun, muskmelon and watermelon. These germplasm were also characterized and utilized further in crop improvement programmes.

The increased fruits and vegetable production in hot arid region can be achieved by developing drought hardy and high temperature tolerant varieties. Intensive breeding work on vegetable crops has been done at many research institutes, including ICAR-CIAH, Bikaner-334006, Rajasthan in the country which resulted in the release of several high yielding/disease resistant and abiotic stress tolerant varieties/hybrids. However, ICAR-CIAH, Bikaner is the only institute mainly working on arid fruits and vegetables and released several improved varieties suitable for arid environment (Saroj, 2017) [Table 6].

Besides, there are a large number of genetic materials of different vegetables have been identified which are tolerant to drought conditions (Table 7). Such genotypes can be utilized in crop improvement programme as well

Problems Associated with Arid Vegetables

The cultivated varieties are very much susceptible to certain diseases like powdery mildew, downy mildew, leaf curl, bud necrosis, mosaic, etc. and pests like fruit fly, shoot and fruit borer and root knot nematode. The prevailing high temperature leads to flower drop, late flowering, loss of tenderness in fruits, crookedness of fruits in cucurbits, increase in number of staminate flowers in cucurbits, loss of colour development in tomato, etc (Table 8). Keeping in view, the breeding programme must properly address these issues so as to develop biotic and abiotic stress resistant/tolerant varieties/hybrids coupled with better yield and quality characteristics.

Trait Specific Breeding Objectives

Fruit yield is not the only criterion to select a variety of any fruit crops but there are various considerations like plant architecture, early ripening, shape and size of fruits, colour, taste, softness, pulp recovery, storage life, processing quality, nutritional and medicinal attributes, resistant/ tolerant to different biotic and abiotic stresses etc. Similarly, vegetables are consumed in various ways

Table 5. Germplasm of fruit and vegetable crops conserved at ICAR-CIAH, Bikaner field gene bank

Common Name	Botanical Name	No.	Common Name	Botanical Name	No.
Fruits					
Ber	*Ziziphus spp.*	340	Wood apple	*Feronia limonia*	10
Pomegranate	*Punica granatum*	150	Mahua	*Madhuca latifolia*	50
Cactus pear	*Opuncia ficus-indica*	80	Chironji	*Buchanania lanzan*	30
Lasoda	*Cordia myxa*	66	*Khirni*	*Manilkara hexandra*	30
Date palm	*Phoenix dactylifera*	55	Custard apple	*Annona squamosa*	9
Aonla	*Emblica officinalis*	50	Sapota	*Achras zapota*	7
Ker	*Capparis decidua*	32	Jamun	*Syzigium cuminii*	50
Bael	*Aegle marmelos*	21	Tamarind	*Tamarindus indica*	25
Karonda	*Carissa carandus*	8	Fig	*Ficus carica*	3
Phalsa	*Grewia subinaequalis*	6	Marula nut	*Sclerocarya congesta*	1
Sweet orange	*Citrus sinensis*	3	Mango	*Mangifera indica*	52
Vegetable crops					
Kachri	*Cucumis melo var. callosus*	68	Drumstick	*Moringa oleifera*	10
Mateera/ Watermelon	*Citrulluslanatus*	46	Bottle gourd	*Lagenaria siceraria*	20
Snapmelon	*Cucumis melo var. momordica*	65	Bitter gourd	*Momordica charantia*	05
Chilli	*Capsicum annuum*	45	Ridge gourd	*Luffa acutangula*	20
Muskmelon	*Cucumis melo*	60	Sponge gourd	*Luffa cylindrica*	16
Kakdi	*Cucumis melo var. utilissimus*	18	Indian bean	*Lablab purpureus*	30
Pumpkin	*Cucurbita moschata*	04	Cluster bean	*Cyamopsis tetragonoloba*	02
Round melon	*Praecitrullus fistulosus*	10	*Khejri*	*Prosopis cineraria*	14
Brinjal	*Solanum melongena*	30	Indian Aloe	*Aloe barbadensis*	04
Amaranthus	*Amaranthus sp.*	02	Palak	*Spinacia oleracea*	01

Table 6. Varieties of arid horticultural crops adopted for mitigating ill impact of climate change

S.No.	Crop	Variety	Characteristics
Fruits			
1	Aonla	Goma Aishwariya	Early and drought tolerant.
2	Bael	Goma Yashi	It is a semi dwarf tree and suitable for dry land areas.
		Thar Divya	Precocious bearer and highly suitable for growing under dryland/rainfed hot semi-arid ecosystem. Drought tolerant, luxuriant growth and higher fruit yield under less precipitation and high temperature.
		Thar Neelkanth	Drought tolerant under aberrant agro-climatic conditions.
3	Ber	Thar Sevika and Thar Bhubhraj	Performing well under arid climate
		Thar Malti	Diseases and pest resistance
4	Jamun	Thar Kranti	Diseases and pest resistance
5	Pomegranate	Goma Khatta	Drought tolerant
6	Karonda	Thar Kamal	Moderately drought tolerant
7	Mulberry	Thar Lohit and Thar Harit	Frost (-2 ºC) and high temperature (49 ºC) tolerant
Vegetables			
1	*Kachri*	AHK-119 and AHK-200	Drought and heat tolerant
2	*Khejri*	Thar Shobha	Drought and high temperature tolerant, multipurpose variety
3	Snapmelon	AHS-10 and AHS- 82	Drought and high temperature tolerant.
4	Mateera	Thar Manak, AHW-19, AHW-65	Early maturingand hightemperature tolerant
5	Bottle gourd	Thar Samridhi	High temperature tolerant.
6	Ridge gourd	Thar Karni	Its fruit set at high temperature and resistant to mosaic disease and melon fruitfly under field condition.
7	Long melon	Thar Sheetal	Early and set fruits at high temperature during summer season under hot arid conditions.
8	Sponge gourd	Thar Tapish	Multiple-stress tolerant/ heat tolerant variety.
9	Cluster bean	Thar Bhadavi and Goma Manjri	Drought and high temperature tolerant
10	Drumstick	Thar Harsha	Tolerant to moisture and heat stress.
11	Brinjal	Thar Rachit	High yield under high temperature and abiotic stresses of hot arid environment.
12	Palak	Thar Hariparna	It tolerates high temperature conditions.

Table 7. Drought tolerant species and genotypes of vegetables

S.No.	Vegetables	Drought tolerant species/ genotypes	References
1	Brinjal	*Solanum microcarpon*, *S. gilo*, *S. macrosperma*, *S. integrifolium*, Bundelkhand Deshi.	Rai *et al.*, 2011
		S. sodomaeum syn. *S. linneanum*.	Toppino *et al.*, 2009
		SM- 1, SM- 19, SM- 30, Violette Round, Supreme.	Kumar and Singh, 2006
2	Chili	*Capsicum chinense*, *C. baccatum* var. *pendulum*, *C. eximium*, ArkaLohit, IIHR-Sel.-132	Singh, 2010
3	Melons	*Cucumis melo* subsp. *momordica* (Snapmelon): VRSM-58, AHS-10, AHS-82. *Cucumismelo* subsp. *callosus* (*Kachri*): AHK-119, AHK-200. *Cucumis melo* subsp. *chate*: *Arya*.	Pandey *et al.*, 2011; Kusvuran, 2012
4	Okra	*Abelmoschus caillei*, *A. rugosus*, *A. tuberosus*	Charrler, 1984
5	Onion	*Allium fistulosum*, *A. munzii*, Arka Kalyan, MST 42, MST 46	Singh, 2010
6	Potato	*Solanum acaule*, *S. demissum* and *S. stenotonum*, Alpha, Bintej	Arvin and Donnelly, 2008
		S. ajanhuiri, *S. curtilobum*, *S. xjuzepczukii*	Ross, 1986
		Kufri Sheetman, *S. chacoense*, Kufri Sindhuri).	Pandey *et al.*, 2007
7	Sweet potato	VLS6, IGSP 10, IGSP 14, Sree Bhadra	Singh, 2010
8	Tomato	*Solanum habrochaites* (EC- 520061), *S. pennelli* (IIHR 14-1, IIHR 146-2, IIHR 383, IIHR 553 , IIHR 555, K-14, EC-130042, EC-104395, Sel-28), *S. pimpinellifolium* (PI-205009, EC-65992, Pan American), *S. esculentum* var. *cerasiforme*, *S. hirsutum*, *S. cheesmanii*, *S. chilense*, *S. habrochaites*, *S. sitiens*.	Rai *et al.*, 2011
		Arka Vikas, RF-4A	Singh, 2010
		L. pennellii (LA0716), *L. chilense* (LA1958, LA1959, LA1972), *S. sitiens* (LA1974, LA2876, LA2877, LA2878, LA2885), *S. pimpinellifolium* (LA1579)	Symonds *et al.*, 2010
9	Wild watermelon	*Citrullus colocynthis* (L.) Schrad.	Dane and Liu, 2007

like salad, dessert, juice, etc., thus increased marketable yield alone will not be the sole breeding objective. Keeping in view, Ram (1997), Peter (1998), Peter *et al.* (2007), More and Khan (2009) and Prohens and Nuez (2009) suggested a number of breeding goals that will be taken into consideration during improvement programme of vegetable crops. Peter and Swamy (2006) also focused on the need of introduction of vegetable materials with specific traits. The traits of interest of different fruits and vegetables are given in Table 9.

Table 8. Limiting factors associated with crop production of arid vegetables

Group	Limiting factors
Cucurbits	Flower and fruit drop, late to produce pistillate flowers, loss of tenderness and early development of fibers, low female: male sex ratio due to high temperature, crookedness of fruits, high incidence of fruit fly, attack of powdery mildew, downy mildew, bud necrosis, shoe string virus, etc.
Beans and Pea	Low temperature injury, susceptibility to wilt, powdery mildew and bean mosaic virus, high loss due to pod borer.
Solanaceous crops	Flower and fruit drop, blossom end rot, fruit cracking, sun scald and improper colour development in tomato, damping off, blight, root knot nematode, fruit borer, shoot and fruit borer, thrips, leaf curl viruses, wilt and die back.
Bulb crops	Bolting, sprouting of bulbs, short shelf life, attack of purple blotch and Stemphylium blight, rotting in storage due to black mold, problem of thrips.
Okra	Flower and fruit drop, take more time for flowering, yellow vein mosaic virus, fruit borer.

Table 9. The germplasm of arid fruits and vegetables with trait of interest

Crop	Botanical name	Trait of interest
Fruits		
Date palm	*Phoenix dactylifera*	Early maturing to harvest at pind stage
Bael	*Aegle marmelos*	Cracking resistant
Aonla	*Emblica officinalis*	Frost tolerant
Mulberry	*Morus spp.*	High temperature tolerant
Lasoda	*Cordia myxa*	Frost tolerant
Citrus fruits	*Citrus spp.*	Drought, salinity and high temperature tolerant and free from viruses
Ber	*Ziziphus spp.*	Fruit fly resistant and frost tolerant
Pomegranate	*Punica granatum*	Drought tolerant and cracking resistant
Guava	*Psidium guajava*	Wilt resistant, tolerant to drought and sodic soil, dwarfing nature and nematode tolerant
Vegetables		
Khejri	*Prosopis cineraria*	Tingid bug and leaf, shoot and fruit gall resistant
Watermelon	*Citrullus lanatus*	Wilt and viruses resistant; yellow fleshed, less seeded, early, ice box type, good storage type, suitable for juice making, more seeded for oil purpose
Ridge gourd	*Luffa acutangula*	Fruit fly resistant
Sponge gourd	*Luffa cylindrica*	Fruit fly resistant
Bottle gourd	*Lagenaria siceraria*	Fruit fly resistant
Cucumber	*Cucumis sativus*	Biotic and abiotic stress resistant, gynoecious and parthenocarpic lines
Musk melon	*Cucumis melo*	Fruit fly and viruses resistant; good storage capacity, multiple fruiting, early lines, male sterile lines
Drumstick	*Moringa oleifera*	Leaf eating caterpillar resistant
Brinjal	*Solanum melongena*	High temperature tolerant, shoot and fruit borer resistant/tolerant
Chilli	*Capcicum spp.*	Hot type, heat tolerant lines, resistant to leaf curl virus
Tomato	*Solanum lycopersicum*	Biotic and abiotic stress resistant, long shelf life and good for paste
Onion	*Allium cepa*	Lines with high TSS and resistant to storage diseases
Garlic	*Allium sativum*	Lines with large bulb and clove

Research Strategy for Adaptation and Mitigation of Climate Change

Climate change has become one of the biggest challenges for the sustainable crop production. Prolonged droughts and desertification are the major issues faced by Indian hot arid zone where rural poor and small holders are most heavily affected. Therefore, the crops which can withstand to such conditions like drought, high temperatures and poor soils need more emphasis (Kumar *et al.*, 2019). Limited precipitation and low relative humidity are the characteristic features of arid regions of India resulting in the fair biodiversity of flora and fauna adapted over these harsh climatic conditions. In fact, arid horticultural crops have developed and/or modified their organs to perform certain vital physiological functions such as strong deep root system (ber, bael, aonla, wood apple, Jamun etc.), synchronized their flowering and fruit development with the season of moisture availability (*ker*, *pilu*, lasoda, aonla etc.) and other xerophytic characters like leaf shedding in summer (ber), scanty foliage (*ker*), spiny cladode (cactus pear), mucilaginous sap in plant part (*ker*, lasoda, *pilu* bael etc.), sunken stomata and fur/hairiness and waxy coating on the leaf surface (phalsa, ber, lasoda fig etc.), thorny nature, and selective or reduces absorption of cation (Na^+) and anions (Cl^- and SO_4^-) for survival under adverse arid conditions. Thereby, arid horticulture fits well under such adversities. Adoption of approaches such as integrated farming systems developed for these regions like, fruit-based diversified cropping models, *khejri*-based farming systems, multi-storey cropping models, protected cultivation, low tunnel cultivation, fruits and vegetable forcing etc. will be very useful in resource poor situations and have a positive impact on adaptation and mitigating adverse effect of climate change in the arid ecosystem. In most arid regions of the country, fruits and vegetables are cultivated only in small holdings, as a component of the regular farming system. But with the adoption of the above mentioned approaches in the true sense, arid horticulture is gaining further momentum at commercial venture.

The changing pattern in the area and production of major arid fruit and vegetable crops in arid and semi-arid regions shows a continuous increase in the area and productionof these crops. This is mainly due to systematic research efforts on arid zone crops, as these crops are somewhat adapted to harsher climatic conditions and can face changing pattern of climate. On the other hand, development of new varieties, establishment of nurseries for supply of quality planting materials andgood management practices made upon these arid crops over the years are the other dimension of development of arid horticulture.Whereas, low infrastructure support for postharvest handling, processing and value addition, lack of cold storage facilities and lack of proper marketing of produce are some of the long standing addressable issues for making the arid horticulture further prosper in the arid region and semiarid regions.

Technological Interventions

Adoptions of fruit based diversified cropping models, multistorey cropping system and *khejri* based cropping models etc. in the arid ecosystem have potential to mitigate the adverse effects of climate change on fruit and vegetable crops by creating microclimate. A set of several combinations of above models (ber, aonla, bael based models etc.) have been well established at ICAR-CIAH, Bikaner and continuous field days/visits/exhibitions are being done to adapters, cultivators, nurserymen etc. for taking advantages of these cropping systems in hot arid regions (Anonymous, 2015). Selection of crop and variety is very much important while establishing such models. Selection of over, ground storey and inter crops are such that which do not have adverse effect with component crops but may have positive/synergistic effect.The agro-techniques developed/improved for maximizing returns per unit area in vegetables under environmentally stressed areas are related to site selection, field micro-climate management, seed treatment method and time of sowing, maintenance of plant population, soil-water conservation, irrigation systems and scheduling foliar feeding and crop protection measures. Besides, post-harvest management, on farm value additions, organic and hi-tech farming and marketing has also been taken up for remunerative cultivation of arid vegetables (Saroj and Choudhary, 2019). There are several advantages of growing arid fruits and vegetables through adoption of these cropping systems under changing scenario of the climate, a few of them are enlisted here below.

Tree based diversified cropping models: Mono-cropping is a risky proposition in hot arid region. Therefore, integrated farming system, including perennial trees, annual crops, animal component, etc. is a better approach for such environmentally fragile ecosystem. The work done at ICAR-CIAH, Bikaner suggested that the fruit based diversified cropping systems improve the overall growth of arid fruits under multiple cropping models, alleviate the risk of crop failure, enhance productivity and income per unit area/volume as a result of efficient use of natural resources and can mitigate the ill effects of hot arid climate on crops. Thus, the utilization of arid germplasm against changing climatic conditions can be adopted using such systems. Agri-horticultural combinations with legume intercrops such as mung bean, moth bean, cluster bean, and cowpea are beneficial. In the rainfed orchards of guava and ber, cluster bean, okra and cowpea in *kharif* proved good in the medium rainfall region of Gujarat. Under South Indian conditions of Hyderabad; cowpea, green gram, cluster bean and horse gram in ber orchards and bitter gourd, tomato and okra in acid lime orchards have been grown as intercrops. In areas where large livestock population exists, horti-pastoral system would be beneficial. In the arid areas, the system could have combinations such as *khejri* (*Prosopis cineraria*) + ber + *dhaman* (*Cenchrus ciliaris*, *C. setigerus*) or *sewan* (*Laisuruss indicus*). In semi-arid areas, perennial trees (mango, tamarind and sapota,) could be grown with fodder crops.

Multi-storey combinations incorporating large trees, small trees, and ground crops can be used. In low rainfall (300-500 mm) zone, combinations such as *khejri* or ber + ber or drumstick + vegetables (legumes and cucurbits) in 500-700 mm rainfall zone, a combination of mango or ber or aonla or guava + pomegranate or sour lime or lemon or drumstick + solanaceous or leguminous or cucurbitaceous vegetables and in 700-1000 mm rainfall zone, a combination of mango or jackfruit/mahua/ tamarind/guava + sour lime or lemon or pomegranate or aonla + vegetables can be adopted. In the arid ecosystem, attempts have been made to develop models for crop diversification. It has been demonstrated that in ber based cropping system, cultivation of Indian aloe can be taken up as a remunerative intercrop (Saroj, *et al*., 2004). Similarly, in aonla based cropping system, it has been demonstrated that model consisting of aonla + ber along with moth bean or fenugreek can be adopted as a sustainable model for nutritional and income security of the inhabitants (Awasthi *et al*., 2007). Fruit based multistorey cropping system such as aonla-ber-brinjal-moth bean, aonla- drumstick-senna-moth bean-cumin can be profitably adopted by the farmers of arid region for better cash flow, nutritional and environmental security and sustainable livelihood. In areas where frost is severe, aonla-*khejri*-suaeda-moth bean and mustard can be another option (Awasthi *et al*., 2007).

A long-term investigation to understand soil fertility and scope of improvement in building-up of fertility and nutrient levels was carried-out adopting *khejri* based crop production site management approaches at ICAR-CIAH, Bikaner under hot arid agro-climate. A wide spectrum of varying land-use patterns (47 situations) were studied with or without *khejri* planting models. Results exhibited that the approach is effective in improving the organic carbon and nutrient status in sandy soils. The treatment code KS-39 (KM-11, field of *khejri* plantation of nine years age-group with cluster bean cultivation) exhibited more effectiveness for soil fertility build-up in comparison to different land-use patterns. Based on 6-year age-group, treatment code KS-13 (KM-1, field of 4m×4m khejri plantation with three cluster bean crops during the establishment period and normal field crop culture as organic plot) is found more effective for soil fertility build-up in comparison to other land-use patterns of the period (Samadia, 2014).

Protected cultivation: The desired environmental conditions can be simulated in protected structures not only to grow high value crops and mass multiplication of quality planting materials but also for the conservation genetic materials. High quality work has been done for the development of structural design, level of control system, selection of crops, management of crop and system, etc. specific attention is needed regarding structural design for arid ecosystem, where extremes of temperature and high wind velocity and dust storm are the common phenomena. Therefore, low cost and lesser height structures like a shade net and tunnel cultivation are gaining popularity in arid regions. In hot arid region, the cultivation of cucurbits in summer season gets affected by various environmental factors such as very high temperature, scorching sun, hot waves, scarcity of insect pollinators, etc. owing to very low yield of poor quality. Under such conditions, adopting low tunnel cultivation is the best option to get quality produce with low cost. The use of low tunnels with some modification becomes the reality of successful early season cultivation of cucurbits in arid regions (Choudhary and Saroj, 2018). This technology escapes the crop from low temperature during January-February and advances the crop by 45-50 days. It increases the concentration of carbon dioxide inside tunnels, thereby, enhance the photosynthetic activities and ultimately yield. The success of tunnel technology in the arid region includes selection of site, drip irrigation system, fertigation and integrated crop management (ICM) practices. The best time of sowing is the last week of December to first week of January in hot arid region. The poly-cover can be removed with the advancement of summer during February which leads quick flowering and fruiting. It was observed that tunnel cultivation of musk melon, long melon, watermelon, bottle gourd, ridge gourd, *tinda*, summer squash, *etc*. offers good opportunity for successful early season cultivation with B:C ratio of 2.21 to 2.43 (Choudhary and Saroj, 2019). This technology is spreading in arid regions at faster rate and within 5-6 years, more than 20,000 ha area has been covered in western Rajasthan under tunnel cultivation.

Drip technology: Availability of irrigation water is a major limiting input of crop production in arid regions, where not only rainfall is meager but underground water is also brackish. *In-situ* moisture conservation and water harvesting and recycling is a very important aspect for arid horticulture. During the establishment phase of orchard, water supply through pitchers, double-wall pots or trickle units, depending on agro-climatic conditions of the location are considered better than by the conventional ring basin method of irrigation. In rainfed orchards, *ex situ* or *in situ* water harvesting to catch run-off and soil and plant moisture conservation methods help not only in the establishment of orchards but also in increasing fruit productivity. Water use efficiency can be improved by checking evaporation losses by use of mulches and by modifications in canopy environment. The time and frequency of water application depend upon critical growth and development stages in different horticultural crops, and the agro-climatic conditions. Water stress should not be allowed particularly during fruit set and fruit development stage. In general, frequent irrigations during the flowering period result in in flower and fruit drop in many arid fruits. Among the controlled irrigation systems, drip irrigation is the most suitable for cucurbitaceous crops under arid conditions. Single lateral lines with on-line drippers were found to be the most suitable for different cucurbitaceous vegetable crops like *kachri*, snapmelon, muskmelon, long melon, bottle gourd, ridge gourd and watermelon (*mateera*). Increased fruit yield of about 25-30 percent was obtained in these crops in comparison to the channel system of irrigation under arid conditions. Based on seasonal agro-climatic and weather situations, crop potentiality and available resources, a complete production technology, adopting drip irrigation have been developed and recommended for commercial cultivation of arid zone vegetables (More *et al.*, 2007). Drip irrigation or more broadly known as micro-irrigation saves 30-70 per cent irrigation water and increase yield by 25-80 per cent.

IPM strategies: Comparatively problem of pest and diseases are lesser in arid region compared to humid region, but the kind of pest and disease species surviving over the years in arid climate are more devastating and sometimes difficult to manage. Moreover, with the change in climatic conditions such as prolonged winter with cloudy weather are very congenial for incidence of the disease and pests. In general, incidence of pest and disease apparently depends upon the weather aberrations of a particular region. For example, if there is an increase in relative humidity in the environment during long period of time, there are more chances of occurrence of diseases of the crop plants. Similarly, it also favors for pest attack. For their management at the appropriate time, IPM strategies have been standardized in arid fruits and vegetable crops. Therefore, integrated pest management (IPM) practices should be followed to reduce load of insecticides. Alternatively, soil should be exposed to the sun during summer by deep ploughing to kill hibernating pupa of insects.Field sanitation and proper canopy architecture should also be maintained for perennial fruit trees in order to reduce pest/disease incidence and to produce quality fruits. In addition to this, commercially available Cue-lure traps 8-10 in one-hectare area should be installed to manage fruit fly (Haldhar *et al.*, 2014).

Opportunities in Arid Horticulture to Combat the Ill Impact of Climate Change

Bringing additional area under horticulture on good land is least possible, therefore the untapped potential of nontraditional areas like arid and semi-arid regions must be exploited. The arid region is endowed with vast land resource (about 12% of the geographical area of the country), hardy natural biodiversity, surplus family labourers, increasing canal command area, plenty of solar and wind energy, high animal population, etc. which offers great potential for successful utilization of wastelands for commercial cultivation of fruits, vegetables, seed spices, medicinal and aromatic plants, ornamental plants, tuber crops, etc.

In spite of, harsh conditions for life, the region is bestowed with rich biological diversity. The genetic diversity of arid ecosystem is of great significance because of its adaptability to various biotic and abiotic stresses. Perhaps, it is the storehouse of 'genes' of stress tolerance and represent germplasm which need to be collected and conserved for its utilization as donor in developing stress tolerant/resistant varieties or inducing tolerance in otherwise fragile but economically important crops including arid fruits and vegetables (Malik *et al.*, 2018).

Often, arid fruits and vegetables are being grown in resource poor environment, therefore, they possess a hardy nature against the climatic changes. They have numerous xerophytic characteristics which are helping in tolerating adverse climatic conditions of the arid region. The strong deep root system of ber, bael, aonla, wood apple, Jamun and wild watermelon (*Citrullus colosynthes*); synchronized their flowering and fruit development with the season of moisture availability (*ker*, pilu, lasoda, aonla etc.) and other xerophytic characters like leaf shedding in summer (ber), scanty foliage (*ker*), spiny cladode (cactus pear), mucilaginous sap in plant part (*ker*, lasoda, *pilu*, bael etc.), sunken stomata and fur/hairiness and waxy coating on the leaf surface (phalsa, ber, lasoda fig etc.), thorny nature (ber, bael, karonda, *ker* etc.), and selective or reduces absorption of cation (Na^+) and anions (Cl^- and SO_4^-) are well known characteristic features of arid vegetation for survival under adverse arid conditions (Saroj, 2018).

The arid and semi-arid fruit such as ber, aonla, *ker*, lasoda, karonda, bael, *pilu*, phalsa, wood apple, chironji etc. have tremendous scope for mitigation of the ill impact of climate change. These fruits are nutritious and nutraceutically rich in numerous bioactive compounds and some of these are of high processing quality; besides several other uses. The demand for such fruits are growing tremendously in local as well as export market for processing purposes. These plant types are highly fit for diversification in agriculture, as they have unique resistant and tolerant traits to withstand against the global climatic changes (Saroj and Jatav, 2019).

In addition to this, physiological, biochemical and molecular understanding of the mechanisms of adaptive behavior of arid flora in extreme hot and dry environment is the future thrust area in arid biodiversity research. To conduct a high throughput research for developing tolerant varieties of arid fruits and vegetable crops against various biotic and abiotic stresses, needs more emphasis on genomic and biotechnological interventions for crop improvement point of view. The genome editing using high throughput technologies such as CRISPR/CAS9 may also be emphasized for genetic improvement of arid fruits and vegetables for desired traits (Tian *et al.*, 2017; Kurkute *et al.*, 2017).

Further, the need should be addressed through collection and evaluation of natural biodiversity of arid flora to develop a strong gene bank including cryopreservation for conserving indigenous germplasm and introduction of desired genotypes for breeding purpose against changing scenario of climate. *In situ* conservation of neglected and underutilized species, landraces of bael, jamun, *ker*, *phog*, *pilu*, *khejri,*etc. should be promoted to protect from disappearance. The development of high yielding, nutrient rich, short duration with desired branching habit, early flowering, less inter-nodal length, suitable for processing and export purpose need to be bred for supporting the livelihood of arid ecosystem. Emphasis must be given on exploration of heterosis breeding for desirable traits like earliness, preferred fruit size, extended harvesting, uniform quality coupled with high marketable yield. The multiple disease and pest resistant/tolerant varieties/hybrids of arid fruits and vegetables should be developed through use of molecular breeding tools such as marker assisted selection (MAS). The farmers' participatory breeding approach is another important aspect of crop improvement in arid ecosystems.

Advance production technologies suited to diverse socioeconomic conditions of arid ecosystem should be standardized. Focus on production of quality seeds and planting materials should also be given to increase productivity and quality. The technologies like *in-situ* orchard establishment, use of suitable rootstocks, proper canopy management, low cost protected cultivation, precision farming, organic cultivation, IPM, INM etc. should be given due consideration in order to address the climatic changes. The availability of quality irrigation water is a limiting factor for crop production in the arid zone. Therefore, emphasis should be given to conserve and enhance the water use efficiency to harvest more crops per drop of water.

The livestock component is an integral part of agriculture in arid regions; therefore, the sustainable development of arid ecosystem can be achieved only by diversification of arid horticulture with the integration of animal component, poultry, fishery, bee keeping, forestry, *etc*. Monocropping is often risky due to uncertainty of climatic conditions. Various fruit-based agroforestry systems have been standardized by integrating multiple compatible components which are practically feasible, economically viable and environmentally sustainable. The adoption of such systems will not only minimize the risk of crop failure due to adverse weather conditions but highly economical with multiple outputs.

The challenges which require strategic attention are insufficient trained human resource, sub-optimal use of resources, the unavailability of quality seeds and planting materials, unorganized and scattered areas of fruit and vegetable production, high post-harvest losses and minimum farm level processing, poor marketing infrastructure, weak linkage with agro-based industries, etc. which should be addressed by proper policy interventions at grass root level.

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