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Strategies and advancements for improvement in arid vegetables

D. K. Samadia and S. M. Haldhar
ICAR-Central Institute for Arid Horticulture, Bikaner 334 006 (Rajasthan)
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Abstract

Dry-land horticulture has immense and diverse potentialities in providing nutrition rich food and social security to inhabitants of desert and tribal area of the north-western India, While assessing distinctness studies of the hot arid and semi-arid agro-climate of Rajasthan state during 19941997 for horticultural perspective, it is concluded that un-availability of requisite cropgenotype and production techniques are two main constraints in promoting vegetable cultivation. Traditionally, kachri (*Cucumis melo* var. *callosus* / *agrestis*), kakadia / snap melon (*Cucumis melo* var. *momordica*), mateera (*Citrullus lanatus*), tinda (*Praecitrullus fistulosus*) and guar (*Cyamopsis tetragonoloba*) is grown with mixed cropping. Besides, khejri (*Prosopis cineraria*) is playing very important role in long-established farming system, and its tender pods are vegetable use. With the establishment of NRCAH during 1993 at Bikaner, systematic research work for conservation and utilization of native crop-plants germplasm having vegetable significance was started. The crop-genotypes studies over 45 vegetables from 19952005 at CIAH demonstrated that there is magnificent scope in obtaining higher marketable yields, provided better and trait-specific genotypes, and adopting khejri based production site management concept (HBCPSMA),. Thus, the varietal and technological advancement in arid vegetables is a boon towards better nutrition and farmer's income under resource poor desert environment.

Key words: Kachri, snap melon, mateera, khejri, arid vegetable, hot arid agro-climate, Rajasthan, India

Introduction

The Indian *Thar Desert* is a marginal zone for agricultural production. Scanty and un-even rain, extremes of high (March-October) and low (December-January) temperature condition for the prolong duration and together these factors creates an associated abiotic stressed environment that limiting the crop choice, quality of produce, productivity and production. Out of 912 mean rainy days/annum in the hot arid region of north-western parts of Rajasthan, much of rains often come in only a few (13) heavy events during the monsoon season (JuneSeptember) and is erratic and un-predictable. In kharif season, high temperature (3542^{0}C) range and prolonged drought period (1525 days) together sandy soil creates an environment where few crops can survive under rainfed situations and thus, native crop-plants both the annual and perennial have equally vital role for food and fodder (Samadia, 2016 and Samadia and Haldhar, 2017).

Horticultural significant crop-plants produce and their product are rich source of carbohydrate, nutrients, vitamins, anti-oxidant and fibre, and thus are essential part of nutritious diet. In India, about 175 types of crop-plants are being used for vegetable purpose. The vegetable production in the country is largely un-even and concentrated mostly into the few states and areas where agro-climate is much favourable and mild for their production. In addition, the emphasis is only on few vegetables and that too are grown under high input and assured irrigation facilities. To meet-out ever increasing vegetable demand and utilization of indigenous resources, now, there is utmost need for massive and integrated efforts, and it should be firstly by developing high yielding crop-genotypes suited to the prevailing situations of defined agro-climatic zones and resource based production techniques under the climatic variability. Second is through exploitation of the native resources *i.e.* vast, varied and un-tapped land-scape and under-exploited horticultural species for their vegetable potentialities. In this way, the desert, arid, semi-arid and tribal area of Rajasthan state is un-tapped land resource where several popular and native crop-plants of horticultural significance can exploited for organized vegetable culture (Samadia *et al*., 2004 and Samadia, 2007) adopting production site management approaches (Samadia, 2016).

Materials and methods

The research work methodology is concentrated on conservation, utilization and maintenance of arid vegetable germplasm and documented genetic resource management programme is classified as surveys and explorations for crop-inventory and collection from variability pockets; characterization and categorization of germplasm for long-term conservation; evaluation, identification, purification and advancement of germplasm lines / material and use in improvement programme; large-scale testing of selected / developed progenies, performance studies for uniformity and stability of lines and varietal trials and testing of genotypes at

farmer's field and development of seed chain of recommended varieties. The valuation of national material, re-visiting and re-generation of developed material and its maintenance is described research work-plan for conservation and intensive / specific use of the material for breeding trait specific lines / value added genotypes and varieties in the targeted arid vegetables at CIAH, Bikaner.

Results and discussion

Arid agro-climate Need special attention for vegetable production

Production and marketing of high-value and diverse form of vegetable is now seen as key to generate more income per unit area, time and round the year, and also reducing poverty and better nutrition amongst the small farmers in the developing countries. India is the second largest producer of vegetables and the share is about 14 % of the world production. On the other hand, its distance from the world's number one (China) is quite large and this wider gap arises several questions related to the productivity of vegetable crops in the Indian fields, types and quality of genotypes and seed / planting material being used, adoption level of technologies, management and utilization of resources at the production sites (Samadia, 2007 and Samadia, 2008).

In recent years, there is spectacular change in consumption pattern of vegetables and promotion of nutritious diet in India. The increase vegetable consumption is further expected to enhance, and it is because of rising income levels, changing pattern of dietary mix, nutrition and health awareness, ease and round the year availability. On the other hand, present productivity level of many vegetables is low than the world average, and also areas of production-supply for each part of the country is not defined, and hence we cannot meet-out this increasing demand with time without integration, intensification, diversification and management of production sites for systematic vegetable cultivation in the variable climatic regions (Samadia, 2008, More and Samadia, 2008).

In hot arid region, mixed cropping of pearl-millet (*bajra),* cluster bean, moth bean or cowpea dominates traditional farming systems in millions of hectare. The indigenous cucurbits such as *kachri*, kakadia, *mateera* and *tinda* are rescue crops and provide subsistence income under rainfed conditions. In addition, native tree / perennial species such as *khejri, ker, lasora, kumat, khimp, phog, guarpatha* and tumba, and *khumbi* have horticultural attraction and ensuring nutrition rich vegetables to the desert dwellers. Here, systematic vegetable cultivation is very negligible and productivity level is too low, and it is primarily owing to un-availability of desirable crop-plant genotypes suited to environmentally stressed production sites, un-availability of quality seed / planting material of recommended crop-genotypes for growing with varying situations and lack of crop-genotype-climatic matching production techniques. Therefore, there are essentially two complementary requirements for obtaining higher and marketable quality vegetable production and productivity *i.e*. improvement in the genetic make-up of prioritized crops and development of favourable micro-climate at the production sites (Samadia, 2008, Samadia, 2016).

The Indian arid zone can grow a large number of vegetable crops compared to any hot desert of the world (Samadia *et al*., 2004). Some of well recognized and potential vegetable crop-plants have been identified for diversification of dry-land horticulture and are given in the table-1. Based on region specific surveys in the hot arid, semi-arid and tribal areas of Rajasthan and Gujarat and field research work over 25 years by me at CIAH, the extent of restrictions and opportunities have been assessed in respect to the horticultural development and recommendations have been carved out for dry-land vegetable production. In addition, innovative and resource based conceptual production approaches have been suggested for cultivation of vegetables under rainfed, limited or assured irrigated conditions with three distinct agro-climate of Rajasthan state. The importance of eco-significance native trees / shrubs having the potentialities of regional, traditional and minor vegetables in fresh, dehydrated or processed forms have also been highlighted for promoting resource based native or intensive production models under climatic adversity. By incorporating the un-exploited and indigenous floras at the production sites as component of wind-break, boundary-side, bio-fence, hedge-row, field-divider, strip-block or planting model would not only helps in creation of favourable micro-climate for cropping system but also ensure regular income from the socio-welfare species as monsoon supported harvest (Samadia, 2016).

Production factors analysis for arid vegetable improvement

Owing to variable and to some extent manageable agro-climatic conditions, availability of limited irrigation facilities and potentials for different types of production systems (rainfed, limited or assured irrigation) in vast spread arid farm-land, a careful selection of crops and their genotypes for a specific zone can be a gainful for the success in vegetable upgrading. The peculiar arid agro-climatic conditions impart unique quality in *kachri*, snap melon, *mateera*, bottle gourd, muskmelon, chilli and seed spices. An enormous scope to promote large-scale seed production in cucurbits, tomato, chilli, brinjal, okra, early cauliflower, pea, cluster bean, cowpea, Indian bean, *palak*, *methi*, coriander, cumin, and truck gardening for distance market in particular to the cole crops, onion, carrot, melons and chillies is do exists with irrigated farm-land. The indigenous products from *khejri*, k*er, kachri* and kakadia can be exploited for processing industry. Dry vegetable products have lot of market potential as concentrated vegetables. A condition of high temperature and low humidity help in solar-drying and the practice is already wide-spread for pods of *khejri* (*sangri*) and cluster bean and fruits of *kachri*, snap melon, round melon and chillies (Samadia *et. al*, 2004, Samadia, 2007 and More and Samadia, 2007).

In hot arid region, existing low productivity in vegetable crops can be enhanced by improving genetic make-

up, adopting production techniques and innovative approaches under integrated concept as crop-genotype-environment accepting. Here, special attention is needed to exploit native crop-plant genetic resources of horticultural significance for developing intensive and viable vegetable culture. For this, systematic breeding approaches on targeted crops is required on high precedence to develop desirable genotypes with multiple-use attributes including processing qualities and adaptability under abiotic stressed environment. In addition, vegetable production, marketable quality and productivity would depend upon availability and management of limited rain and irrigation water. The marketable yield potential of recommended crop-genotypes and productivity of resources can be further enhanced when due considerations given on *in-situ* rain-water harvesting, moisture conservation and adoption of improved techniques and practices in a strategic manner under innovative concept - Horticulture Based Crop Production Site Management Approaches (HBCPSMA, Samadia 2016).

Varietal development for arid vegetable production

Table 1. Prioritized crop-plants for vegetable improvement under hot arid agro-climate

Group	Crop-plants
Cucurbitaceous	Kachri (*Cucumis melo* var. *callosus* / *agrestis*), snap melon (*Cucumis melo* var. *momordica*), kakri (*Cucumis melo* var. common / *utilissimus* / *fluxuosus* / *acidulus)*, muskmelon (*Cucumis melo* var. *inodorous* / *cantaloupensis*), m ateera / w atermelon (*Citrullus lanatus*), round melon / tinda (*Praecitrullus fistulosus*), bottle gourd (*Lagenaria siceraria*), ridge gourd (*Luffa acutangula*), sponge gourd (*Luffa cylindrica*), ivy gourd / kundru (*Coccinia indica*), bitter gourd (*Momordica charantia*) and spiny gourd / kakoda (*Momordica dioica*).
Leguminous	Cluster bean / guarphali (*Cyamopsis tetragonoloba*), cowpea (*Vigna unguiculata*), Sem, Dolichos / Indian bean (*Lablab purpureus*), sword bean (*Canvalia gladiata*), pea (*Pisum sativum*)
Solanaceous	Chilli (*Capsicum annuum*), brinjal (*Solanum melongena*), tomato (*Lycopersicon esculentum*)
Cole crops	Cabbage (*Brassica oleracea* var *capitata*), cauliflower (*Brassica oleracea* var. *botrytis*), knol -khol (*Brassica oleracea* var. *caulorapa*)
Bulbous	Onion (*Allium cepa*), garlic (*Allium sativum*)
Root crops	Radish (*Raphanus sativus*), carrot (*Daucus carota*)
Okra	Okra (*Abelmoschus esculentus*)
Leafy	Methi (*Trigonella foenumgraecum* and *T. corniculata*), palak / s pinach (*Beta vulgaris* / *Spinacia oleracea*), coriander (*Coriandum sativum*), chaulai (*Amaranthus* spp), bathua (*Chenopodium* spp.), sowa (*Anethum sowa*)
Perennials	Khejri / *sangri* (*Prosopis cineraria*), drumstick / s *ehjan* (*Moringa oleife ra*), Indian aloe / *guarpatha* (*Aloe barbadensis*), phog (*Callgonum polygonoides*), khimp (*Laptadenia pyrotechnica*), ker (*Capparis decidua*), lasora / *gunda* (*Cordia myxa*), kumat (*Acacia senagal*), khumbi (desert mushroom)

Table 2. Areas explored and surveyed for vegetable crop -plant germplasm

S/No	Crop	Number of trips / explorations	Areas of crop or multi-crop specific short trips or exploration under institute, NBPGR and NATP (PBD)	No. of Acc.
1	Mateera	7 (1994, 1995)	Arid and semi-arid areas of Rajasthan	193
2	Kachri	7 (1994, 1995)	-do-	558
3	Snap melon	6 (1994, 1995)	-do-	90
4	Chillies	2 (1998, 2001)	Arid, semi-arid and tribal areas of Rajasthan and Gujarat	184
5	Muskmelon	1 (2000)	Arid, semi-arid and tribal areas of Rajasthan	55
6	Gourds	1 (2002)	Arid, semi-arid and tribal areas of Rajasthan and Gujarat	60
7	Beans	1 (2000)	-do-	10
8	Khejri	7 (2000–2002)	Targeted pockets in arid region of Rajasthan	15

Table 3. Registration of unique vegetable germplasm lines from CIAH, Bikaner

Name of germplasm	Registration Number	Agency
Mateera AHW-19	INGR - 98012	Plant Germplasm Registration and Notification, Germplasm Registration Committee of ICAR, NBPGR, New Delhi.
Kachri AHK-119	INGR - 98013	
Kachri AHK-200	INGR - 98014	
Snap melon AHS-10	INGR - 98015	
Snap melon AHS-82	INGR - 98016	
Kakri AHC-2	INGR - 98017	
Kakri AHC-13	INGR - 98018	
Sword bean AHSB-1	INGR - 427811	

Table 4. Collection, conservation and utilization of vegetable genetic resource at CIAH, Bikaner

Common, English or Scientific name	No. of germplasm under PGRM, CIAH			Year of evaluation, re -visits for utilization and / or regeneration of active genetic material fo r maintenance
	Collection & evaluation	Conservation in NBPGR	Breeding lines	
Kachri	591	528	68	1995, 1996, 1997, 2000, 2001, 2003, 2011
Snap melon / kakadia	120	53	65	1995, 1996, 1997, 2000, 2003, 2004, 2012
Muskmelon	74	55	60	1997, 1998, 2001, 2007, 2008
Kakri/Arya/Long melon	32	15	18	1996, 1997, 2002, 2003, 2006, 2015, 2016
Cucumber	12	-	01	1997, 1998, 2000, 2016
Cucumis prophaterum	02	-	-	2000
Cucumis trigonus	01	-	-	2000
Cucumis hardwickii	11	-	-	2000
Tumba	05	01	01	2000, 2008, 2009
Mateera / watermelon	217	64	65	1995, 1996, 1997, 2002, 2003,2009, 2010
Tinda / round melon	26	14	10	1995, 1996, 1997, 2002, 2003, 2007, 2017
Bottle gourd	85	20	20	1996, 1997, 2003, 2007, 2008, 2009
Ridge gourd	30	20	20	1997, 1998, 2003, 2004, 2015
Satputia torai	01	01	-	2000
Sponge gourd	25	15	15	1997, 1998, 2003, 2004, 2014
Bitter gourd	13	03	04	1997, 1998, 2003, 2004, 2013
Spiny gourd / kakoda	01	-	01 FGB	1997, 2002, 2015, 2017
Ivy gourd / kundru	01	-	01 FGB	2001, 2002, 2010, 2012, 2015
Pumpkin	04	-	04	1997, 2003, 2004
Summer squash	01	-	-	2009, 2010
Chillies	217	202	45	1999, 2000, 2002, 2003, 2008, 2009
Brinjal	78	25	30	1998, 2002, 2003, 2008, 2009
Tomato	125	14	14	1998, 2002, 2003, 2008, 2009
Cluster bean / guarphali	20	01	02	1995, 1996, 1997, 2011
Indian bean / semphali	45	30	30	1998, 2001, 2002, 2010, 2011
Sword bean / kombaphali	02	01	01	2001, 2002, 2003, 2009, 2016
Velvet bean / conchphali	01	-	01	2009, 2010
Cowpea / chavlaphali	08	-	03	1997, 1998, 2001, 2002, 2004, 2017, 2018
Pea	04	-	-	1997, 1998
Khejri / sangri	16	-	15 FGB	1995, 2000, 2001, 2002, 2010, 2011, 2012
Drum-stick / sehjan	05	-	01 FGB	1995-97, 2002-07, 2009-12, 2014-17
Curry-leaf / meetha-neem	01	-	01 FGB	1998, 2000, 2015, 2017
Indian aloe / guarpatha	03	-	03 FGB	1994, 1995, 2002, 2008, 2017
Palak	03	-	01	1995-97, 2002-04, 2012-2015, 2016, 2017
Methi / kasuri-methi	02	-	02	2004, 2005, 2008, 2015
Sowa / dill	03	-	-	2004, 2005
Ajowan	02	-	-	2004, 2005
Bathua	01	-	01	2012, 2013
Cabbage	04	-	-	1998, 1999
Cauliflower	02	-	-	1998, 1999
Knol-khol	02	-	-	1998, 1999
Radish	02	-	-	1998, 1999
Carrot	01	-	01	1998, 2012, 2013
Onion	02	-	-	1998, 1999
Garlic	01	-	-	1998, 1999

The concerted germplasm utilization and improvement programmes in the country resulted to development of good number of high yielding varieties and hybrids in potential vegetable crops suited to different agro-climatic zones. To meet-out the increasing vegetable demand with climatic resilience, the foremost need is to have massive

and integrated efforts for developing need based varieties / hybrids / trait-specific or value added genotypes and seed-chain of the recommended crop-genotypes suited to the production sites of the defined region of the state, because this is one of the most efficient and rapid means used for increasing production world-wide in native and adaptive vegetables. Despite of huge vegetable varietal wealth in the national net-work and their zonal recommendations, requisite production, productivity and quality of produce is yet not improved significantly. There are very few numbers of crop-genotypes with wider adaptability for marketable and quality yield levels with varying environmental situation, and doing well only under favourable sub-tropic agro-climate of the state. However, much research work to develop varieties, trait-specific or value added genotype is needed on native and un-exploited crop-plants of the regional significance, and also in adaptive and potential vegetables for cultivation in non-conventional areas with arid to semi-arid agro-climate (More and Samadia, 2007).

While assessing the arid agro-climate during 1994-1997, it was concluded that environmental constrains viz., low and erratic rainfall, extremes of high and low temperature and aridity conditions, and un-availability of appropriate cropgenotypes and production techniques are the limiting factors in thoughtful adoption of vegetable cultivation. With the establishment of national centre at Bikaner in 1993, initial research efforts were for germplasm conservation and utilization in the native cropplant species of the horticultural significance. Traditionally, k*achri* (*Cucumis melo* var. *callosus* / *agrestis*), kakadia / snap melon (*Cucumis melo* var. *momordica*), m*ateera*a drought hardy watermelon (*Citrullus lanatus*), tinda (*Praecitrullus fistulosus*) and guar (*Cyamopsis tetragonoloba*) is grown with mixed cropping under rainfed situations. Besides, khejri (*Prosopis cineraria*) is a perennial tree and playing vital role in long-established farming systems, and its pods are vegetable use (sangri). The crop evaluation and performance studies on 45 vegetables and their potential genotypes from 19952005 at CIAH, Bikaner demonstrated that there is tremendous scope for cucurbits, chilli, brinjal, tomato, pea, beans, cluster bean, onion, garlic, radish, carrot, cole and leafy crops with limited irrigation and adopting production site management approach as innovative tool in obtaining higher marketable yields, provided better and trait-specific genotype in prioritized arid vegetables (Samadia, 2008).

(A) Conservation and maintenance of arid vegetable germplasm

The landraces and local types / cultivars are source of genes for stresses tolerant, adaptability, quality and yield and therefore, collection and characterization is the pre-requisite for the potentially utilization of genetic resources. Realizing the importance of vegetable crops in the hot arid region of north-western parts of India, the systematic collection of germplasm was started since 1994 at Bikaner under mission mode of the NRCAH, NATP on plant bio-diversity and institute programme of CIAH. During 1994 to 2005 period, several crop-specific and multi-crop explorations were conducted for surveys and collection of vegetable germplasm from arid, semi-arid and tribal areas of Rajasthan and Gujarat, and also augmentation of germplasm in targeted crops was done for varieties and lines from national net-work including AICRP (VC) and NBPGR system (Pareek *et al*. 1999 and Samadia, 2003).

A data base was developed for compilation of R & D work on genetic resource management in vegetables at the institute and up to 2008, a total 1725 accessions were collected and evaluated and out of them 1060 germplasm were deposited in NGB at NBPGR for long-term conservation. The vegetable germplasm either collected by CIAH or assembled from NBPGR under NATP (PBD) or national net-work was evaluated for use in improvement programme at Bikaner. On characterization and evaluation under the extremes of arid agro-climatic conditions, vegetable crop germplasm exhibited wide range of variability for agro-morphological traits, flowering and fruiting behavior, maturity, yield and quality contributing characters, besides resistant or tolerant to abiotic and biotic stresses (Samadia, 2006, Samadia, 2007, Samadia, 2010, Samadia, 2011, Samadia, 2014 and Khan and Samadia, 2012).

Based on intensive field-crop performance studies over the seasons and years (1994-2016), the potential arid vegetable crop germplasm were identified and developed genetic material from the base germplasm is being maintained as active breeding lines (500) for use in the improvement programmes. The maintained material is comprised of *kachri* (68), snap melon (65), m*ateera* (65), muskmelon (60), round melon (10), *kakri* (18), bottle gourd (20), ridge gourd (20), sponge gourd (15), bitter gourd (4), chillies (45), brinjal (30), tomato (14), khejri (15), India bean (30), sword bean (01), cluster bean (02) and others (15) including perennial vegetables (Samadia, 2016).

(b) Utilization of arid vegetable genetic resource

To promote profitable and organized vegetable culture under hot arid agro-climate, systematic crop improvement work plans were formulated first time by me as PI of the project and stated in 1994. During the first five years (1994-1999) of project, the prime emphasis was on the native and drought hardy vegetable crops such as kachri, snap melon, kakri, mateera, tinda and cluster bean. The chilli work for the Mathania type was incorporated in 1998 and then intensive work on potential crops such as muskmelon, gourds, brinjal, beans and moringa was started from the year 2000 considering the requirement of superior genotypes for cultivation under the extremes of climatic variability. A mission mode approach for improvement in khejri was started in 2001. Trait specific breeding for heat tolerant in round melon, bottle gourd, muskmelon, tomato and brinjal was started from 2007. The germplasm characterization and utilization at CIAH resulted to the purification of promising and trait specific lines for detailed evaluation, and followed by selection and combination breeding over the period (1996-2017) resulted to studies on about 725 developed genotypes in the prioritized

vegetables and were used in varietal development trials under high temperature, abiotic stressed and resources poor conditions of hot arid agro-climate (Samadia *et al*., 2010 and Samadia, 2016).

The result of systematic purification followed by selection and hybridization breeding at CIAH, Bikaner over the period, a good number of high yielding and better quality producing genotypes have been developed in arid vegetables and recommended for commercial cultivation, large-scale testing at farmers fields / national net-work or use in breeding programmes. The varieties / selections recommended for the cultivation in arid region are in *mateera* (AHW-19, AHW-65 and Thar Manak), *kachri* (AHK-119 and AHK-200), snap melon (AHS-10 and AHS-82), *kakri* (AHC-2 and AHC-13), bottle gourd (Thar Samridhi), cluster bean (Thar Bhadavi), Indian bean (Thar Kartiki and Thar Maghi), sword bean (Thar Mahi), khejri (Thar Shobha) and brinjal (Thar Rachit). The developed lines of bottle gourd (AHLS-24), ridge gourd (AHRG-1 and AHRG-8), sponge gourd (AHSG-4, AHSG-5 and AHSG-16), round melon (AHRM-1 and AHRM-2), muskmelon (CIAH-1), chilli (HRM-1), brinjal (CIAH-22), ivy gourd (AHIG-1), palak (AHLP-1) and moringa (AHMO-1-4s) were used in selection / combination breeding from 2001-2010 and advanced material is in testing as value added genotype (Samadia, 2008, Samadia, 2012, Samadia, 2016, Samadia and More, 2008, Samadia and More, 2009, Samadia and More, 2011 and Samadia *et al*., 2005).

In addition, some trait specific breeding material is developed in targeted arid vegetable crops at CIAH, Bikaner and evaluated over the seasons and years (2005-2017) for their performance studies under high temperature and abiotic stressed arid environment. These lines consisted of kachri (AHK-411, AHK-564 and AHK-572), snap melon (DKS/AHS-2011/2), mateera (AHW RSS-1 and AHW BSM-1), kakri (AHC-1), ridge gourd (AHRG-15-4-1), sponge gourd (AHSG/2015/F5/1), bottle gourd (AHLS Oblong-1 and AHLS-Long/2015/F6/1), bitter gourd (AHBT-2), chilli (Mathania Selection-1), brinjal (AHB-1 and AHB-2), tomato (AHSL-1 and AHSL-2), cowpea (AHCP-1), Indian bean (KSB-66), cluster bean (AHG-20), velvet bean (AHVB-1), methi (AHLM-1), bathua (AHLB-1), carrot (AHDC-1), guarpatha (AHAB-S-1 and AHAB-B-1) and khejri (CIAH Selection-2).

(c) Priorities for germplasm utilization and focus on future thrust

Primarily I am working on the native crop-plants to promote horticultural production under hot arid environmental restrictions. Therefore, the foremost concern is on safe conservation, maintenance and effective utilization of genetic resource for developing varieties and also systematic arid vegetable culture in particular with kachri, snap melon, mateera, tinda, bottle gourd, cluster bean and khejri at the resource constraints production sites. In additions, developing appropriate breeding material and trait specific lines / value added genotypes through germplasm utilization in targeted vegetable crops is also in top priority for promotion of their cultivation under the abiotic stressed conditions such as high and low temperature, drought, limited rains or irrigation water, and suitability of varieties for organic, off-season or prolonged period of harvesting.

Breeding for improvement in yield, quality and productivity is a continuous nature of work, and in addition, varietal requirements for the three specific environmentally distinct agro-climatic zones of the Rajasthan state and continual increasing demand of vegetables invites timely up-gradation and re-setting of research prioritization. Realizing the need of hour, vegetable breeding emphasis should be focused on prioritized crops and it should be focused through use of germplasm and varietal wealth for developing varieties and value added genotypes in particular to the defined zones of the state for which crops are targeted. Beside, objectives for potential and native crops of commercial exploitation should be defined in respect to the national and regional perspective. Based on research work progress and gap analysis in germplasm utilization and varietal development in last 25 years, crop and trait specific prioritized needs have been identified for further in-depth analysis and the research strengthening to achieve targets on the issues highlighted as constraints and strategies is given below.

(i) Research constraints:

1) Insufficient germplasm in most of vegetable crop and ignorance of old lines / varieties in breeding,
2) Low priority on germplasm utilization to solve the problems through combination breeding,
3) Low priority to native and un-common vegetables for region and resource specific research,
4) Lack of new high yielding genotypes with in-built tolerant to abiotic and biotic stresses,
5) Absence of basic research and promotion facilities to work on wild and related species breeding,
6) Low level of scientific interest to carry long-term research work-plan on native vegetables, and
7) Low interest to solve long-standing crop problems with advancement of science and technology.

ii) Research strategies

a) Utilization of national genetic resources for breeding high temperature and abiotic stresses tolerant genotypes in round melon, bottle gourd, mateera, muskmelon, ridge gourd, sponge gourd, bitter gourd and tomato with better marketable fruit quality yield and cultivation under varying agro-climate of the state,
b) Utilization of native genetic resources for developing high yielding and better marketable quality varieties or trait-specific / value added genotypes for cultivation under abiotic stresses conditions in kachri, snap melon, spiny gourd, ivy gourd, cucumber (chikan-kakri of tribal area), arya-kakri, taur-kakri, wanga-kakri, palak, kasuri-methi, khejri, sehjan, curry-leaf, guarpatha and other regional adaptive vegetables including leafy, roots, tubers (yam, aerial yam and sweet potato) for their regional promotion

and preferences,

c) Utilization of national genetic material from favourable agro-climate and their large-scale trials for identification of region, environment and trait-specific genotypes in commercially viable crops (chilli, ginger, turmeric, garlic, onion and seed spices) in respect to hot arid to semi-arid and/or sub-humid and tribal zones of Rajasthan,

d) Distant hybridization and breeding for developing virus free genotypes in watermelon and chillies for cultivation under abiotic and biotic stresses,

e) Utilization of native germplasm for developing suitable brinjal genotypes having good quality fruit yielding characters with regional preferences and suitability for year the round cultivation under high temperature conditions, and tolerant to FSB,

f) Utilization of national genetic material to use in breeding for developing high and better quality pod yielding genotypes in potential vegetable legumes such as pea, cluster bean, cowpea, Indian bean, sword bean and velvet bean for production under variable resources and stressed conditions, and also identifying lines for organic cultivation,

g) Heterosis or combination breeding for developing genotypes resistant to fruit-fly infestation and virus-free in bitter gourd, ridge gourd, sponge gourd and pumpkin for cultivation under semi-arid and sub-humid zones of Rajasthan state,

h) Conservation and use of native okra germplasm from tribal area of Rajasthan and near-by areas of Madhya Pradesh and Gujarat to develop genotypes for cultivation under low-input, organic or rainfed conditions,

i) Utilization of early cauliflower and carrot germplasm of hot arid zone and onion and garlic from semi-arid and tribal areas of state for developing trait specific genotypes,

j) Utilization of national genetic material for breeding better quality and high yielding genotypes for low-cost protected cultivation and vertical harvesting in the prioritized vegetable crops under hot arid agro-climate, and

K) Utilization of regional, national or older genetic material for identifying genotypes for organic production and also use in breeding for developing better quality genotypes under low-input and have moderate harvesting and unique traits in the prioritized vegetable crops under hot arid agro-climate or define set of environmental conditions for production.

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