



Integrated farming system in arid and semi-arid regions: Need and significance

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(Received: 20.03.2018; Accepted: 29.06.2018)

Abstract

Agricultural production systems have so far successfully addressed the national requirements of agricultural products through increasing productivity by the large scale use of non-renewable resources and simplification of production systems achieved by transition from mixed farming to specialized farming. This intensification of agricultural production systems has led to many negative environmental consequences like loss of biodiversity, degradation of soil and water resources, enhancing the greenhouse gas emission, declining profitability, increasing risks and inadequate employment and has thus raised the concerns about the economic, environmental and social costs of this success. Therefore, it is imperative to design and implement new agricultural production systems, to enhance farm productivity & profitability, environmental quality, resource use efficiencies along with improving household nutritional security. These seemingly diametrically opposed objectives could be simultaneously achieved by implementation of integrated farming systems approach (IFS). This paper describes the significances of IFS in terms of enhancing productivity, profitability, employment generation, resource conservation and adaptation and mitigation to anticipated climate change with special reference to arid and semi-arid regions of India. The major constraint in implementation of IFS, and suggestion for enhancing their large scale adoption are discussed.

Keywords: Integrated farming system, productivity, returns, climate change, sustainability

Introduction

Worldwide, agriculture has become increasingly specialized in response to political, regulatory and economic pressures (Russelle *et al.*, 2007; Hendrickson *et al.*, 2008). The intensification and specialization of agriculture productivity has also left negative environmental consequences and has brought into question the economic viability of large number of farms (Wilkins, 2008) and has further led to an array of negative impacts on the environment (Tilman *et al.*, 2002) like loss of biodiversity, soil erosion & dysfunction, depletion of ground water levels, contamination of water, and increasing concentration of greenhouse gas in atmosphere (Franzluebbers *et al.*, 2011). Therefore, the concerns about the economic, environmental and social costs associated with specialization and intensification driven gains in productivity has been increasing. Furthermore, increasing uncertainties of climate and commodity prices have put into question the "specialization higher productivity" as a path of development (Evans, 2009). Hence, it is necessary to evolve and migrate towards agricultural production systems which will not only improve productivity and farm income but will also protect and improve environmental quality, and the ecosystem services on which agriculture depends (Barrett, 2010; Godfray *et al.*, 2010; Garnett *et al.*, 2013; FAO, 2014; DeFries *et al.*, 2015;).

Diversified agricultural production systems such as integrated farming systems (IFS) systems appear to be promising alternative and way forward for agricultural

development in the face of shrinking land and water resources for agriculture, climate change, volatility of commodity and input prices, and declining soil quality. Studies conducted across the India have shown that IFS provided opportunities to harness the complementarities and synergies among different agricultural sub-systems and/or enterprises which augment productivity and profitability (Jayanthi *et al.*, 2003; Manjunath and Itnal, 2003; Ravisankar *et al.*, 2010; Manjunath and Itnal, 2003a,b; Gill *et al.*, 2009), gainful employment (Jayanthi *et al.*, 2001; Gill *et al.*, 2009), ensure efficient resource recycling (Behera and Mahapatra, 1998; Kumar *et al.*, 2012), higher resource use efficiencies (Gill *et al.*, 2005; Surve *et al.*, 2014) along with improving soil quality, enhancing biodiversity and preserving natural resources and the environment. This article presents a brief overview of needs and significance of IFS in arid and semi-arid regions of the country.

Spread of arid and semi-arid regions

In India, the arid and semi-arid regions occupy prime position with respect to size, pedo-climatic diversity, and human and animal population. The semi-arid regions (having annual rainfall 500-1000 mm and moisture index between -0.33 to -0.67) cover about 113.8 million ha and are concentrated mainly in western and southern peninsular part of the country. The part of semi-arid regions having annual rainfall of 500 -750 mm with 90-120 days of crop growing period is classified as a dry semi-arid region. The part of arid

region having 500 -750 mm annual rainfall with 90-150 days of crop growing period are classified as moist semi-arid region. The dry and moist semi-arid regions are spread over 41.6 and 72.2 million ha, respectively. Crop production in the semi-arid regions is principally rainfed except in the state of Punjab, Haryana and Uttar Pradesh. Sorghum, soybean, pulses, small millets, cotton, chickpea and peanut are major rainfed crops. Rice, wheat, and Indian mustard are major irrigated crops. Livestock rearing is major subsidiary occupation.

The area receiving <500 mm annual rainfall with <66.7 moisture index having light textured soils is classified as arid regions. The arid region is further sub-divided as hot and cold spread over 31.7 and 7 million ha, respectively. The hot arid regions concentrated in the state of Rajasthan (61%), Gujarat (20%), Punjab (5%), Haryana (4%), Andhra Pradesh (7%) and Karnataka (3%). The cold arid region is concentrated in Ladakh region of Jammu and Kashmir, Chamba, Lahul-Spiti and Kinnur in Himachal Pradesh. The arid regions, both cold and hot are characterized by low and erratic rainfall, extremes of temperatures, high ET, strong winds and light textured soils having low fertility and water holding capacity.

The western Rajasthan which constitutes 61% of the total hot arid region of India represents a fragile low biomass producing ecosystem. This region is characterized by erratic ($CV > 50\%$) and low ($100-400\text{ mm y}^{-1}$) rainfall, high evapotranspiration ($1600-2000\text{ mm y}^{-1}$), strong winds (Rao and Singh, 1998), sparse vegetation cover, lack of good quality groundwater. The crop growing period is <90 days and crop production is low and unstable. High biotic pressure has resulted in the overexploitation of resources and poses a serious threat to the sustainability of the region (Gupta and Partap Narain, 2003). The rainfed region is characterized by monocropping system with crops like *Pennisetum typhoides*, *Cyamopsis tetragonoloba*, *Vigna aconitifolia*, *Vigna radiata* and *Sesamum indicum* which are planted both as sole and mixed crops in various proportions. *Arachis hypogea*, *Gossypium sp.*, *Triticum aestivum*, *Brassica juncea*, *Cicer arietinum*, *Plantago ovata*, *Cuminum cyminum* are major irrigated crops of this region. Amongst the fruit crops ber, aonla, citrus and date palm are promising for this region. Livestock rearing is an integral component of farming system and have a significant role in the agrarian economy of the hot arid regions.

Farming systems in arid and semi-arid regions

Historically, the arid and semi-arid regions are lands of low crop productivity and crop failure are common in these regions. To minimize or evade the negative consequences of frequent crop failure, farmers of these regions have evolved many combined protective-productive systems by integrating woody perennials and livestock into the farming systems, with main objectives to fulfill food, feed and fuel requirements of the household, and better returns from available resources. Minimizing production risks, diversifying sources of income and increasing land productivity along with improving sustainability of production system are other important

objectives of mixed farming systems. The inputs and outputs of the different enterprises are integrated inextricably into these systems. Livestock use crop residues as feed and provide meat or milk, which improve family nutrition and health. Livestock also provide draught power, manure for crop production and dry dung is also used as fuel. The sale of animal and their products (milk, meat, egg) improves household income.

A comprehensive account of prevailing farming systems of the hot arid region has been presented by Bhati and Joshi (2007). They concluded that livestock rearing with range and pasture development is the main agricultural activity in the areas receiving annual rainfall < 250 mm. Mixed farming encompassing agroforestry systems, mixed cropping, livestock and pasture management are the main livelihood options in the areas receiving annual rainfall between 250 - 350 mm. Crops and cropping systems diversification, agroforestry and livestock farming are the major systems of sustenance of farmers in areas receiving annual rainfall >350 mm. Thus, traditional agroforestry and livestock are the integral components of farming systems of the hot arid region. Development of irrigation facilities (introduction of canal irrigation), increased groundwater irrigation (due to increased rural electrification, improved drilling technologies), availability of new technologies, advent of green revolution, increased farm mechanization, construction of road networks and marketing (Kar, 2014) along with government policies which favored few crops have caused a drastic change in land use and farming systems of these regions.

Groundnut and cotton are replacing the traditional rainfed crops like pearl millet, moth bean, cluster bean, sesame, etc. while area under wheat and Indian mustard is increasing in irrigated areas and furthermore, the tractor drawn tillage replaced the animal drawn tillage with the objectives to cover a large land area in the given period. To facilitate smooth movement of tractor the woody perennials (tree and shrubs) were uprooted from the crop fields and resulted in the decline of area under traditional agroforestry, particularly in irrigated areas. Thus, with the expansion of irrigation facilities along with increased agricultural mechanization, the interest in traditional mixed farming systems comprising mixed cropping, livestock and extensive agroforestry declined, and agricultural system became more and more specialized arid and semi-arid regions. The large scale adoption of specialized agriculture led to an array of problems like loss of biodiversity, increased production and economic risks, degradation of soil quality, depletion of ground water resources, etc. and threatening the farmers' livelihood and sustenance of agriculture itself.

Significances of IFS

As the arid and semiarid regions are becoming more and more populated, the demand of agricultural products has been increasing and the availability of natural resources particularly water and land is decreasing. It is a great challenge, especially in arid and semiarid regions, for the restrictions of resources for agricultural production in those

regions are usually more severe than those in other regions. Therefore, there is a need for an agricultural system that supply more products with the conservation of natural resources and ensure a better environment for human living. In this context, IFS seems to be an attractive option as it provides multiple benefits like higher yields and income, efficient resource utilization, enhance employment generation, reduced risks and improve nutritional security. Some of the advantages of IFS compared to that of the conventional farming system are:

Higher production, return and employment

With the increase in population along with an increase in urbanization and industrialization the availability of land for agriculture is decreasing. In contrast, the demand of agricultural products is increasing with an increase in population. This warrants having a production system that increases the yield per unit of land area in unit time. The results of numerous research conducted in arid and semi arid regions demonstrated that IFS significantly increased land productivity compared to arable cropping (Jayanthi *et al.*, 2003; Gill *et al.*, 2009; Channabasara *et al.*, 2009; Bhati *et al.*, 2008; CAZRI, 2014; Patidar and Mathur, 2017). Integration of dairy, fishery and poultry with arable crops led to enhanced productivity compared to that of sole arable cropping in irrigated regions of Punjab and Haryana. Gill *et al.* (2009) demonstrated that IFS (rice-wheat + dairy + fishery + piggery) recorded 79% higher productivity than sole rice-wheat cropping. The results of an another study with 1.0 ha land in irrigated areas of Punjab shown that IFS involving rice wheat (0.6 ha) with dairy (0.4 ha) and 100 poultry had two-times higher yield (25.5 t ha⁻¹ rice equivalent yield) than sole rice-wheat (1.0 ha, 12.5 t ha⁻¹ rice equivalent yield). Results of a study conducted at Srigruppa, Karnataka showed that IFS (rice-rice, maize sunflower, vegetable, fodder crop, goat, fish and poultry) had 26% higher yields than conventional rice-rice cropping (Channabasara *et al.*, 2009). Jayanthi *et al.* (2003) conducted a study at Coimbatore, TN and reported that IFS comprising crop + fish + poultry and crop + fish + goat had 31.8 and 32.3 t ha⁻¹ rice equivalent yield compared to 12.2 t ha⁻¹ from sole arable cropping.

Co-cultivation of trees with arable crops is found to be promising option for improving land productivity. The *Prosopis cineraria*, *Hardwickia binata*, *Acacia senegal*, *Acacia nilotica*, *Ziziphus mauritiana*, *Tecomella undulata* are suitable tree species for co-cultivation with arable crops in hot arid regions. The results of various studies conducted at ICAR-CAZRI demonstrated that growing of trees with arable crops/ grass increase the total yield per unit land compared to sole crop or grass production in hot arid regions (Harsh and Tewari, 1993; Bhati *et al.*, 2008; CAZRI, 2014; Patidar and Mathur, 2017; Verma *et al.*, 2017). Results of a long-term study conducted in hot arid region of Rajasthan showed that integrated production of arable crops with *P. cineraria* provided good yield of arable crops along with a bonus yield of dry leaves and twigs (0.65 to 1.05 t ha⁻¹) and fuel wood (1.8-2.6t ha⁻¹) from the *P. cineraria* tree. A study conducted at

ICAR-CAZRI demonstrated that seed yield of of pearl millet, green gram and cluster bean was higher in association with *Prosopis cineraria* than sole arable cropping (CAZRI 2014). The cluster bean, green gram and pearl millet had 11, 14 and 18% higher seed yield in association with *Prosopis cineraria* compared to yield from sole cropping. Kaushik and Kumar (2003) reported higher fodder yield in *P. cineraria* -based production system (*P. cineraria* in association with pearl millet *Brassica tournefortii*) than sole cropping from arid regions of Haryana. The results of study conducted in arid region of Haryana demonstrated that yield of barley improved (16.8 86.0%) in association with *Azadirachta indica*, *Acacia albida*, *P. cineraria* and *T. undulata*. The highest improvement in yield (86.0%) was in association with *P. cineraria* followed by *A. albida* (57.9%), *T. undulata* (48.8%), and *A. indica* (16.8%)(Kumar *et al.*, 1998).

The higher land productivity of ber based cropping system compared to that of sole ber or sole crop/ grass has been reported from arid regions. A 5-20% higher yields of intercrops in association with ber than sole cropping have been reported (Gupta *et al.*, 2000; Saroj *et al.*, 2003; Singh *et al.*, 2003; Bhandari *et al.*, 2014). The results of an eight year study conducted by ICAR-CAZRI highlighted that a density of 200 ber plant ha⁻¹ is optimum for co-cultivation of arable crops in hot arid regions of Rajasthan, (Bhati *et al.*, 2008). Amongst the arable crops, green gram gave better yields in good rainfall years, cluster bean gave better yields in drought years, and cowpea showed yield stability in most of the year. The system provides i.e. food (cow pea grain: 386 kg ha⁻¹ year⁻¹), fruit (3076 kg ha⁻¹ year⁻¹), fuel wood (1353 kg ha⁻¹ year⁻¹) and fodder (to sustain 700 -1000 animal days ha⁻¹ year⁻¹). Verma *et al.* (2017) gave a detailed account of ber based integrated production system of hot regions and demonstrated that the integration of arable crops increased fruit yield of ber. Arya *et al.* (2011) reported that fruit yield of ber with intercropping of arable crops (cluster bean, moth ben, Indian mustard, Brinjal) was higher (8.4 to 8.6 t ha⁻¹) compared to sole ber (5.6 t ha⁻¹) at Bikaner, Rajasthan. The results of a study conducted at Dantiwada, Gujarat indicated that intercropped ber (ber, pearl millet, green gram, cluster bean, sorghum) had 9.1 t ha⁻¹ fruit yield compared to 8.5 t ha⁻¹ fruit yield from sole ber (Patel *et al.*, 2003). A study conducted by ICAR-CAZRI at Bhuj revealed that intercropping of ber with legume crops (cluster bean, moth bean and cow pea) increased ber yield by about 100 kg ha⁻¹ than sole ber. The integration of tree in pasture improved fodder yield in hot arid regions. The results of a study conducted by ICAR-CAZRI at Jodhpur revealed that intercropping of *Cenchrus ciliaris* with *Hardwickia binata* had higher dry matter fodder yield (26.39 t ha⁻¹) compared to sole *C. ciliaris* (22.59 t ha⁻¹) (Patidar and Mathur, 2017). There are numerous processes that confer increased efficiency or productivity of different enterprises in IFS by reducing input requirements, increasing input use efficiency or both. Some of the most common examples are the replacement of synthetic fertilizer with livestock produced manure, legume-derived nitrogen, woody perennials added plant nutrients; using crop residues, pastures grown, tree lopping biomass as a forage

source to reduce livestock supplementary feeding, increase stocking rate and livestock growth; and the use diversified crops to reduce pest and disease pressure.

Adequate profits from farming are essential for ensuring sustainable livelihood of the farmers. The IFS provides an opportunity to enhance profitability through higher productivity and reducing the production costs. The use of waste or by-products of one enterprise serve as input for other enterprises in IFS, which led to a reduction in cost of production. For instance, in the crop-livestock IFS, the by-products of crops, i.e. crop residue are utilized as feed for livestock and they convert them into economic products (meat, milk, wool), and the byproducts of livestock, i.e. dung is used as manure for supplying plant nutrients to crop production and thus curtailed the cost involved for purchasing of inorganic fertilizer. Furthermore, the diversified production systems minimize the need for external inputs (Ryschawy *et al.*, 2012; Wilkins, 2008).

A study conducted to evaluate economic performance of different production systems in semi-arid regions of Haryana revealed that the integration of milch buffalo and crossbreed cattle with cropping lead to 35 and 346% higher returns than sole cropping (Singh *et al.*, 1993). Gill *et al.* (2009) demonstrated that the integration of dairy, dairy + horticulture and dairy + vermicomposting enhanced returns by 56, 62 and 110% compared to sole cropping in Uttar Pradesh. The rice-wheat is an important cropping system in irrigated areas of Punjab. Substitution of rice wheat cropping systems with rice-wheat + dairy enhanced net returns by 12-22% (Gill *et al.*, 2009). From a study in Coimbatore, Tamil Nadu, Jayanthi *et al.* (2001) reported that integration of fish + poultry and fish + goat with arable cropping gave 170 and 262% higher net returns than sole cropping. Thus, the results of these studies demonstrated that IFS resulted in higher profits and a better use of intermediate farm resources such as manure, draft power, and crop residues.

The integrated production involving tree and crops is found to be more remunerative than a sole tree or crop cultivation in arid and semi-arid regions. Results of studies conducted at ICAR-CAZRI shown that pearl millet + *Acacia senegal* and *Hardwickia binata* + *C. ciliaris* had 61 and 655% higher returns than sole *C. ciliaris* and pearl millet, respectively (Harsh and Tewari, 2007). The integration of legume crops (cluster bean and mung bean) with ber was more profitable (B: C ratio 2.03 to 2.15) than sole ber (B: C ratio 2.1), and legume crops (B: C ratio 1.42 to 1.93) production in arid regions (Meghwal and Henry, 2006). The economic performance of integration of legume crops (cow pea, cluster bean and moth bean) with of aonla, ber and pomegranate was evaluated in arid regions of Gujarat. Amongst the tested crops, the cluster bean performed well in orchards; and ber + cluster bean had highest profitability (B: C ratio of 1.83) followed by ber + moth bean (B: C ratio 1.65) (Dayal *et al.*, 2005). Kaushik *et al.* (2017) evaluated profitability of various agri-silvi-horti systems involving different cropping sequences (cowpea-wheat, cluster bean wheat, and pearl millet oat), and silvi-horti system (shisham + aonla, shisham + guvava, khejari +

aonla, and, khejari + guvava) in semi-arid environment at Bawal, Haryana. Results of the study demonstrated that agri-silvi-horti systems had 2.9-4.8, 5.0-6.3, and 19.0-27.2 folds greater net return compared to the sole cultivation of cluster bean barley, cow pea wheat, and pearl millet oat cropping sequences, respectively. A study from arid region of Gujarat indicated that *Ailanthus excelsa* and *Azadirachta indica* based agri-silvicultural system gave 26 and 59% higher income than sole cropping (Patel *et al.*, 2008). Results of a long-term study conducted at ICAR-CAZRI shown that IFS (comprising *P. cineraria*, *H. binnata*, and *A. tortilis* based agroforestry, and *Z. mauritiana* based agri-horticulture, *Z. rotundifolia* based silvi-pasture, agri-pasture and sole arable cropping system) had a higher IRR and B: C ratio than sole arable cropping in hot arid regions of Rajasthan (Bhati *et al.*, 2009; Tanwar *et al.*, 2014). Besides ability to provide higher income than conventional sole cropping, the IFS also deserve mention for the difference in pattern of flow of income viz a viz sole cropping and. The income from conventional cropping is season-specific (income available at specific-time of year just after harvesting season of crops), which bound the farmers to take the money from formal and informal credit sources at a very high rate of interest, and also led to the forced sale of farm produces to money lending agencies. In contrast, IFS has the ability to provide a flow of money for the farmers throughout the year by way of the sale of a variety of farm produce (milk, egg, mushroom, vegetables, fruits, food grains) (Behera and Mahapatra, 1999; Maheswarappa *et al.*, 2001; Kumar *et al.*, 2013), which helps to meet the money requirement of farmers throughout the years and protect the farmers from forced sell.

The labour requirement in crop based production system is season and time bound, and generally has a peak labour requirement during planting and harvesting time of crops. During the rest period of year and season the farmers do not have adequate employment opportunity. Diversifying agricultural production could utilize labor more efficiently at farm and /or regional scales (Hoagland *et al.*, 2010). Integration of other enterprises with crop production provides an opportunity to enhance employment generation. Integration of dairy, dairy + fishery and dairy + fishery + piggy with arable cropping generated 138.2, 136.6 and 171.9 additional man days compared to the sole arable cropping system (Gill *et al.*, 2009). Results of a study conducted at Coimbatore indicated that integration of fish and goat with arable cropping generated additional 207 man days year⁻¹ compared to sole cropping (Jayanthi *et al.* 2001). Besides the ability to generate extra employment, the IFS ensure that women get higher opportunities to engage in farming activities, particularly in case of poultry, milch cattle, sheep/goat rearing, vegetable production, etc. (Sharmin *et al.*, 2012), and increase their access and control over the farm resources (Setboosarn, 2002).

Reduced economic risks

The agricultural production system is vulnerable to production and economic risks. Aberrant weather condition and huge fluctuation in prices of both input and outputs are

major risks involved in agricultural production. IFS reduce both production and economic risks. It has been demonstrated that diversifying income sources generally reduces fluctuations in cash flows within the same year and also between the years (Pannell, 1995; van Keulen and Schiere, 2004). The IFS caused a reduction in income variability compared to specialized system of agricultural production. IFS has potential to minimize the production and economic risk associated with sole arable cropping, and decrease the vulnerability of producers to the impacts of aberrant weather conditions. Cropping in arid and semi-arid regions of India are predominantly rainfed, and prone to risk of crop failure due to drought and other aberrant weather conditions. Diversification of farming with agroforestry, horticulture, livestock, and plantation crops would help in minimizing risk associated with sole cropping, and raising the income of farmers (Behera and France, 2016).

Low and uneven distribution of rainfall is a major constraint of arable crop production in hot arid regions of India, and generally the crops fail to produce acceptable yields. The results of many studies conducted in this region show that in case of crop failure, the woody perennials provide fodder, fruit or fuel wood. There are evidences which indicated that rainfall scarcity induced reduction in the yield of crops are more in sole cropping compared to that of in integrated production system. Faroda (1998) reported that the yield reduction of mung bean was higher in sole cropping compared to that in *Ziziphus* based integrated production system under subnormal rainfall conditions (51 % less rainfall than long term average 360 mm year⁻¹) in hot arid region of Rajasthan. This integrated production system provides a year round supply of fodder for five sheep/goat and fuel wood for a family of 4 members. Delayed onset of monsoon is a common weather aberration in hot arid regions. Results of study conducted by ICAR-CAZRI indicated that under extremely delayed onset of monsoon (first week of August), the IFS (comprising agri-horticulture, agri-pasture, silvi-pasture) fetched higher returns than sole cropping, and IFS yielded 7712 L milk, 292 kg meat along with fodder sufficient for 8 ACU (4 cow, 8 buck and 4 ram) and 6500 kg FYM (Tanwar *et al.*, 2014). Additionally, IFS gives opportunity to farmer to adjust the allocation of production inputs (water, forage, water, capital) among the enterprises in response to climate and price fluctuations. For instance, if there is very low rainfall during the reproductive phase of crop and prospects of grain yield are low, the crop can be used for forage purpose under IFS. Similar situation may arise if grain price is very low compared to livestock product prices.

Better recycling and use-efficiencies of resources

IFS provides opportunities to capture ecological interactions among different enterprises to make agricultural ecosystems more efficient at cycling and preserving natural resources and the environment, improving soil traits, and enhancing biodiversity. The IFS involving crop, livestock, trees and pasture lead to the more efficient recycling of energy and matter in the soil-plant-animal-atmosphere continuum. In

crop-livestock integrated production system, crop residue (by-products of crop) is utilized as fodder for livestock and dung (by-product of livestock) is utilized for providing nutrients to crop. The integration of poultry and fish in production system further strengthen the chain of recycling of resources by use of poultry droppings as fish feed. Thus, IFS comprising diverse and interdependent enterprises (crops, forestry, horticulture, dairy, poultry, fishery, piggery) leads to better utilization of resources through efficient recycling of the by-product of one enterprise as an input for other enterprises (Shekinah *et al.*, 2005; Gill *et al.*, 2009). Co-cultivation of woody perennials with arable crops helps efficient nutrient cycling via the tree's ability to absorb the nutrients from deeper layers of soil and supplying the absorbed nutrients to crops by litter fall. Gill *et al.* (2009) reported that recycling of organic resources in IFS provided 79 and 58% N, and P₂O₅ requirement of the field and plantation crops, which signify the ability of IFS in reduction of dependency on external nutrient sources.

Maintaining soil organic matter (SOM) is the key component for sustaining crop productivity. IFS comprising livestock, poultry, piggery, pasture and woody perennials enhance the SOM content through nutrient cycling and organic matter use, and sustain the agro-ecosystem (Schiere *et al.*, 2002; Watson *et al.*, 2005; Petersen *et al.*, 2007; Russelle *et al.*, 2007; Wilkins, 2008; Hilimire, 2011). Furthermore, the inclusion of nitrogen fixing woody perennials and pasture legumes enhance N content in the soil. Water and wind erosion are major soil degradation process in arid and semi-arid regions. The inclusion of trees and pasture in a production system reduces the soil erosion. Thus, IFS involving livestock, woody perennials and pasture with arable crops have the potential to enrich soil, reduce erosion and promote efficient nutrient cycling. Results of a study conducted in semi-arid regions of Rajasthan indicated that *Prosopis cineraria*, *Dalbergia sissoo*, *Acacia leucophloea* and *Acacia nilotica* trees enhanced soil biological activities (soil microbial biomass C, N and P) and amongst the different tree species, *P. cineraria* based system brought maximum enhancement of soil biological properties (Yadav *et al.*, 2011). Singh *et al.* (2014) reported that integration of tress (ber, gonad, aonla, khejari, ardu and mopane) with wheat enhanced organic carbon and nitrogen content of soil by 7 and 8%, respectively compared to sole tree plantation. Results of earlier researches demonstrated that integration of fish, livestock, poultry, etc. with crop enhanced resource (water, nutrient, land) use efficiencies (Shekinah *et al.*, 2005; Samra *et al.*, 2003). The IFS provides opportunity for multiples use of water with in the same farm like in producing crops, fishes, dairy, mushrooms, poultry, duckery etc. (Singh and Gautam, 2002) and thus lead to better use of water and higher water productivity (Sharda and Juyal, 2007; Gill *et al.*, 2005). It has been reported that integrated production of fish and fish + pig with arable cropping had 56 and 86% higher water productivity (WP) than sole cropping in Punjab (Gill *et al.*, 2005). Surve *et al.* (2014) demonstrated that IFS (comprising crop + horticulture + dairy + poultry + fishery) had 164% higher WP than sole cropping.

Climate change mitigation and adaptation

The results of many studies, including the recent report of the IPCC (2014) authoritatively reaffirm that climate change and variability will impact crop production across the world due to the effects on plant growth and yield by elevated CO₂, higher temperatures, altered precipitation regimes, and increased frequency of extreme events, as well as modified weed, pest, and pathogen pressure (Lobell *et al.* 2011). Adaptation, the strategy adopted to minimize negative impacts of change in climate change on crop production is a key factor for ensuring food production in the future. Strategies like change in planting date and varieties, and improving and expanding irrigation moderate negative impacts temporarily (Matthews *et al.* 2013). In contrast, more radical agro-ecological measures, including diversification of agroecosystem (monoculture dominant) as, IFS accompanied by soil management, water conservation and enhancement of agro-biodiversity is supposed to have greater and more durable benefits. Tuomisto *et al.* (2012) compared energy balance, GHGs (greenhouse gases) balance and biodiversity impacts of conventional, organic and integrated farming systems, and reported that IFS had potential to improve energy and GHGs balance and biodiversity compared to both conventional and organic farming systems. Ghahramani and Moore (2016) quantified effects of climate change on crop and livestock component of IFS through a simulation study, and reported that returns from livestock were smaller and less variable compared to that of crops under changing climate. Results advocated that shift in the enterprise mix in mixed-farming towards increased livestock may be helpful strategies in adaptation to climate change and managing the associated financial risks. Sequestering carbon has been emerged as a major goal of lowering the atmospheric CO₂ concentration, and IFS has an enormous potential of storing C in the ecosystem (Dasgupta *et al.*, 2015). The integration of tree with arable crops has potential to reducing vulnerability to uncertain and shifting climate (Van Noordwijk *et al.* 2011). The trees improve biodiversity, modify nutrient and water flows, store carbon and buffer micro-climate, and thus play an important role in both adaptation and mitigation of climate change. It has been demonstrated that agroforestry systems have higher potential to sequester C than monoculture. Dhyani *et al.* (2016) estimated carbon sequestration potential of AFs in India and reported that the amount of carbon sequestered in soil under different AFs varied from 0.003 to 3.98 Mg C ha⁻¹ year⁻¹. Ajit *et al.* (2016) quantified the CSP of AFs in 26 districts of 10 selected states of India. The average carbon sequestration potential (CSP) ranged from 0.05 to 1.03 Mg C ha⁻¹ year⁻¹ with an average value of 0.21 Mg C ha⁻¹ year⁻¹. Results of a study conducted by ICAR-CAZRI in Kachchh region of Gujarat revealed that silvi-pastoral system sequestered 36.3 to 60.0 % and 27.1 to 70.8 % more total soil organic carbon (SOC) compared to sole tree and sole pasture systems, respectively (Mangalassery *et al.*, 2014). Thus, integration of tree and livestock with arable crops has potential to minimize negative effects of climate change on agricultural production.

Suitable IFS for arid and semi-arid regions

The production system involving various enterprises that ensure food and nutritional security, higher profit, gainful employment, efficient recycling of resources along with conservation of natural resources (water, soil) and environment and minimize production and economic risks is an ideal farming system. The crop production, dairy, goat and sheep rearing, fishery, poultry, agroforestry, mushroom cultivation, duckery, *Azolla* cultivation, apiculture are components of farming activities (Raman and Balaguru, 1991; Yadav and Prasad, 1998). The integration of two or more of these farming activities in accordance to natural resources, capital, labor, available infrastructure and marketing facilities, socioeconomic needs, and government policies is essential to develop suitable location specific IFS. Numerous suitable IFS consisting integration of arable crops, livestock (cattle, sheep, goat), poultry, fishery, duckery, *Azolla*, mushroom, biogas production has been developed in arid and semi-arid regions through both on-station and on-farm research (Bhati *et al.*, 2008; Singh *et al.*, 1999; Jayanthi *et al.*, 2001; Singh *et al.*, 2007; Gill *et al.*, 2009; Surve *et al.*, 2014).

Growing of arable crops in association with horticultural plants, i.e., agri-horticulture is an attractive option for improving nutritional security, productivity, profits, employment in arid regions. Suitability of component crops to pedo-climatic conditions and compatibility among component species are key determinants of performance of agri-horti system. Bhandari *et al.* (2014) gave detailed account of suitable species composition of agri-horti systems for north western hot regions of India.

Future thrust

Ensuring adequate food, feed, fiber and income along with conservation of natural resources for increasing population are the biggest challenges of the 21st century. In repeated experiments, the IFS as an approach has outperformed the conventional and specialized farming systems in all dimensions of a multi-functional agriculture i.e. food security, environmental, economic, and social functions. But IFS as an approach always carry the burden of past and a tag of reinventing the wheel as it has been a traditional way of farming in many countries. Hence, the challenge today is to evolve advanced IFS in accordance with available resources, infrastructure facilities and technology capable of providing sufficient agricultural production with high socio-economic outputs and multiple environmental benefits. But in spite of numerous advantages the adoption of IFS in arid and semi-arid regions has been abysmally low. There are many reasons for it, but high managerial skills required to run a farm with IFS approach and marketing of multiple products in small quantity are major ones. For example, inadequate transport, processing and marketing can limit economic benefit from milk, meat, fruit and vegetable in rural areas and restrict the full realization of the economic potential of integration of livestock and horticulture in farming. Lack of incentives and policies for promotion of IFS; inadequate research and

developmental programme, weak co-ordination among different stakeholders are some other limitations. Therefore, benefits of IFS cannot be exploited on a larger scale without creation of adequate storage, transportation and marketing facilities for agricultural produces in rural areas. A renewed and interdisciplinary research effort is urgently needed toward fine-tuning of IFS by effectively integrating different enterprises with crops to balance productivity demands with social and environmental sustainability issues in accordance to change in resources, marketing facilities, labor availability and technological advancement. IFS should have as a high priority for research and development programme and policies. Adequate coordination among different agricultural programme, policies, institutes and agencies for agricultural and rural development is must for quick and wider implementation of IFS.

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Strategies and advancements for improvement in arid vegetables

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(Received: 8.09.2018; Accepted: 3.10.2018)

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 1994-1997 for horticultural perspective, it is concluded that un-availability of requisite crop-genotype 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 1995-2005 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 (June-September) and is erratic and un-predictable. In kharif season, high temperature (35-42°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 be 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*, *khip*, *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 farmland, 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*, *ker*, *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 (<i>Cucumis melo</i> var. <i>callosus</i> / <i>agrestis</i>), snap melon (<i>Cucumis melo</i> var. <i>momordica</i>), kakri (<i>Cucumis melo</i> var. <i>common</i> / <i>utilissimus</i> / <i>fluxuosus</i> / <i>acidulus</i>), muskmelon (<i>Cucumis melo</i> var. <i>inodorous</i> / <i>cantaloupensis</i>), m ateera / w atermelon (<i>Citrullus lanatus</i>), round melon / tinda (<i>Praecitrullus fistulosus</i>), bottle gourd (<i>Lagenaria siceraria</i>), ridge gourd (<i>Luffa acutangula</i>), sponge gourd (<i>Luffa cylindrica</i>), ivy gourd / kundru (<i>Coccinia indica</i>), bitter gourd (<i>Momordica charantia</i>) and spiny gourd / kakoda (<i>Momordica dioica</i>).
Leguminous	Cluster bean / guarphali (<i>Cyamopsis tetragonoloba</i>), cowpea (<i>Vigna unguiculata</i>), Sem, Dolichos / Indian bean (<i>Lablab purpureus</i>), sword bean (<i>Canvalia gladiata</i>), pea (<i>Pisum sativum</i>)
Solanaceous	Chilli (<i>Capsicum annuum</i>), brinjal (<i>Solanum melongena</i>), tomato (<i>Lycopersicon esculentum</i>)
Cole crops	Cabbage (<i>Brassica oleracea</i> var. <i>capitata</i>), cauliflower (<i>Brassica oleracea</i> var. <i>botrytis</i>), knol -khol (<i>Brassica oleracea</i> var. <i>caulorapa</i>)
Bulbous	Onion (<i>Allium cepa</i>), garlic (<i>Allium sativum</i>)
Root crops	Radish (<i>Raphanus sativus</i>), carrot (<i>Daucus carota</i>)
Okra	Okra (<i>Abelmoschus esculentus</i>)
Leafy	Methi (<i>Trigonella foenumgraecum</i> and <i>T. corniculata</i>), palak / s pinach (<i>Beta vulgaris</i> / <i>Spinacia oleracea</i>), coriander (<i>Coriandum sativum</i>), chaulai (<i>Amaranthus</i> spp), bathua (<i>Chenopodium</i> spp.), sowa (<i>Anethum sowa</i>)
Perennials	Khejri / sangri (<i>Prosopis cineraria</i>), drumstick / s ehjan (<i>Moringa oleifera</i>), Indian aloe / guarpatha (<i>Aloe barbadensis</i>), phog (<i>Callgonum polygonoides</i>), khimp (<i>Laptadenia pyrotechnica</i>), ker (<i>Capparis decidua</i>), lasora / gunda (<i>Cordia myxa</i>), kumat (<i>Acacia senegal</i>), 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 for 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
<i>Cucumis prophaterum</i>	02	-	1	2000
<i>Cucumis trigonus</i>	01	-	-	2000
<i>Cucumis hardwickii</i>	11	-	1	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	-	1	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 / chavlapphali	08	-	03	1997, 1998, 2001, 2002, 2004, 2017, 2018
Pea	04	-	1	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	-	1	2004, 2005
Ajowan	02	-	-	2004, 2005
Bathua	01	-	01	2012, 2013
Cabbage	04	-	1	1998, 1999
Cauliflower	02	-	1	1998, 1999
Knol-khol	02	-	-	1998, 1999
Radish	02	-	1	1998, 1999
Carrot	01	-	01	1998, 2012, 2013
Onion	02	-	-	1998, 1999
Garlic	01	-	1	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 network 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 unexploited 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, *kachri* (*Cucumis melo* var. *callosus* / *agrestis*), *kakadia* / snap melon (*Cucumis melo* var. *momordica*), *mateeraa* 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 1995-2005 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), *mateera* (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 (AHL-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 (AHL-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 (AHL-Long/2015/F6/1), bitter gourd (AHBT-2), chilli (Mathania Selection-1), brinjal (AHB-1 and AHB-2), tomato (AHS-1 and AHS-2), cowpea (AHCP-1), Indian bean (KSB-66), cluster bean (AHG-20), velvet bean (AHVB-1), methi (AHL-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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Suitable potato cultivars in non-traditional areas of north-western Rajasthan of India

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(Received: 30.08.2018; Accepted: 4.10.2018)

Abstract

Studies were conducted during 2015-17 at ICAR-Central Institute for Arid Horticulture, Bikaner in collaboration with ICAR-Central Potato Research Institute, Shimla to find out suitable potato cultivars for processing as well as for table purpose under North Western Rajasthan. Seven potato cultivars (Kufri Khyati, Kufri Garima, Kufri Chipsona-4, Kufri Pukhraj, Kufri Frysona, Kufri Surya and Kufri Jyoti) were raised under sprinkler irrigation as well as drip. Tuber yield varied significantly from variety to variety under both irrigation systems. Under sprinkler irrigation, Kufri Chipsona-4 gave higher yield (53.5 q/ha) followed by Kufri Frysona (48.00 t/ha) and Kufri Jyoti (46.5 t/ha) while minimum yield was observed in Kufri Pukhraj (33.9 t/ha) and Kufri Khyati (38.8 t/ha). Kufri Garima and Kufri Surya gave intermediate yields (43.0 and 39.9 t/ha), respectively. However, under drip irrigation, Kufri Frysona gave higher yield (43.5 t/ha) followed by Kufri Chipsona-4 (42.9 t/ha) and Kufri Garima (37.5 t/ha) and minimum yield was observed in Kufri Pukhraj (20.0 t/ha). Kufri Frysona gave higher medium sized tuber yield (14.6 t/ha) followed by Kufri Surya (11.2 t/ha) and Kufri Chipsona-4 (9.30 t/ha) under sprinkler irrigation while, under drip irrigation Kufri Jyoti produced the highest medium sized tuber yield (11.7 t/ha) as compared to other. Thus, processing varieties Kufri Chipsona-4 and Kufri Frysona were found suitable and proved to possess high dry matter content and were the most efficient varieties in the arid region while for table purpose Kufri Garima and Kufri were found suitable for processing and table purpose, for cultivation in north western Rajasthan

Key words: Arid region, Bikaner, agronomic use efficiency, nitrogen, potato, yield, varieties

Introduction

India is the second largest potato producer in the world after China (FAOSTAT 2013). Potato is one of the most important food security crops in the country (Thiele et al. 2010; Singh and Rana 2013) and it plays a vital role in food security for ever increasing world population (Thiele et al., 2010; Scott and Sourez, 2011; Scott and Sourez, 2012). Presently, India is producing about 45-48 million tonnes of potato annually from about 2 million hectare of area. The demand for potato has considerably increased during the last decade in India in response to economic development (Singh et al. 2014) and rapid growth of the processing industry (Keijbets 2008; Rana et al. 2010). Actually, 80% of potato is still grown in the Indo-Gangetic Plains in India during *rabi* (winter) season (Minhas et al. 2011) with more than half of the production being concentrated in the states of Uttar Pradesh and West Bengal. At present in India, about 68% of potato production is consumed as fresh while the rest is utilized as seed (8.5%) and processing purposes (7.5%) or the remaining goes as waste (16%) due to various reasons that includes rotting and wastage during the entire potato supply chain (Rana, 2015; Singh et al., 2011, Singh and Rana, 2012 and

Singh and Rana, 2013).

In Rajasthan, potato is supplied for consumption from neighbouring states like Punjab and Uttar Pradesh. The cold stored potato in North India, when transported to distant states in the western Rajasthan, undergoes serious quality deterioration. Augmentation of local potato supply is consequently the best way of facing the increase in demand and reducing the consumer price in the western Rajasthan. India aims to produce 125 million tonnes potatoes from 3.6 million hectare area in 2050 for ensuring food security (Singh et al. 2014). However, it is possible only if the cultivars of potato are extended to non-traditional areas. Rajasthan in general and Bikaner district in particular are dominated by the hot arid climate. The state in general and the study area in particular are not known for potato cultivation (Rana et al., 2017).

ICAR-CIAH, Bikaner and ICAR-Central Potato Research Institute for past three years have made a systematic effort to introduce potato crop in the *Thar* deserts of Rajasthan by identifying locally adapted suitable varieties, which can produce economic yield under arid region. The south-west part of Rajasthan falls under arid region and known for

groundnut, pulse in *kharif* and wheat mustard, methi growing belt owing to well developed canal irrigation network. Agriculture of this region is completely dependent on canal water supply because groundwater is saline. In last few years, decline in water availability and irregular canal water supply associated with various pest problems caused reduction in their yield and subsequently farm income. Farmers are bound to shift to some other remunerative crops. Potato cultivation would be a possible alternate to increase the farm income, if efficient and reliable irrigation management strategies are adopted to maintain optimum moisture in the effective root zone. It can be achieved best with the use of modern irrigation system coupled with suitable irrigation scheduling under limited water resources, particularly in arid region.

Micro-irrigation (drip and sprinkler) is available with the farmer of Bikaner district which enables high frequency application of water in and around root zone of the plants (Arya et al, 2016 and Kumar et al., 2009). Potato has a sparse and shallow root system and nearly 70% of total water is used by the crop from upper 30 cm soil layer. It requires 400-600 mm of irrigation water depending on climatic conditions, soil type, length of growing season, duration of variety, purpose of crop and methods of irrigation etc. These micro-irrigation methods of irrigation/fertigation economise on water (about 30-50% saving) at the same time giving 15-30 higher yield with upto 25% saving on fertilizers.

Potato is not a new crop for the state of Rajasthan but mostly confined to the areas with better soil and good rainfall conditions like; Kota, Dholpur, Bharatpur, Sirohi, Jhalawar and Sri Ganganagar districts. As per the information available with us there is very negligible area under potato in western part of Rajasthan including Bikaner. The metrological database and ICAR-CPRI Simulation models have that Western Rajasthan has a good area suitable for potato cultivation. Area and production of groundnut in Bikaner district is 75626 ha and 135336 tonnes, respectively which was 22.52 and 25.49% area and production under Bikaner district of Rajasthan. Water requirement of groundnut and potato is almost same (400-700 mm) to meet the demands of metabolic activities of plants, evaporation and transpiration. Therefore, suitable potato varieties can be grown very well in Western Rajasthan.

In order to increase the area under potato, there is need to venture into non-traditional areas like hot arid zone under potato cultivation through better scientific management as per edaphoclimatic conditions. Keeping above facts in view, an attempt was made to assess the performance of potato varieties at ICAR-Central Institute for Arid Horticulture, Bikaner (Rajasthan) in collaboration with ICAR-Central Potato Research Institute, Shimla (Himachal Pradesh) to find out production potential of the popular and new potato varieties and their performance under different irrigation methods in North Western Rajasthan.

Materials and Methods

An investigation was carried out at Experimental Farm of ICAR-Central Institute for Arid Horticulture, Bikaner

(Rajasthan) in the collaboration with ICAR-Central Potato Research Institute, Shimla (Himachal Pradesh) to assess the performance of potato cultivars for processing as well as for table purpose under hot arid region during two consecutive years i.e. 2015-16 and 2016-17. The surface soil samples taken before planting of potato crop were analyzed for their physico-chemical properties employing standard analytical techniques. The soil of the experimental field was sandy in texture with low organic carbon (0.1%), pH (7.70), available N (90 kg/ha), available P (11.5 kg/ha) and available K (297.4 kg/ha). The climatic parameters were also recorded during experimental periods and depicted in Fig. 1. The experiment was laid out in factorial randomized block design and replicated six times. The analysis of variance was done based on pooled data of two consecutive years.

The healthy seeds of seven potato cultivars viz. Kufri Khyati, Kufri Garima, Kufri Chipsona-4, Kufri Pukhraj, Kufri Frysona, Kufri Surya and Kufri Jyoti were procured from ICAR-CPRI, Shimla. Well sprouted potato seed tubers were planted in the 2nd week of November during both the years under sprinkler and drip irrigation system with recommended management practices. In this experiment, 1/3rd of N was applied through neem coated urea and DAP in side-band along with a uniform dose of 80 kg P₂O₅ through di-ammonium phosphate and 100 kg/ha K₂O through muriate of potash during planting time while 1/3rd of N was applied as through neem coated urea at 35 days after planting i.e. at the time of earthing up and the remaining 1/3rd N was applied through neem coated urea at 50 days after planting i.e. at the time of bulking stage. The haulms were cut at 100 days and harvesting of tuber was done 15 days later. Irrigation was applied through on line drippers and low height sprinklers at weekly intervals before crop enters into wilting stage.

The observation on growth parameters viz., plant height, number of branches/plant and number of compound leaves/plant at 55 days were recorded. The yield and yield attributing characters of tubers were recorded after harvesting of the potato. Tubers after final harvesting were also classified into different grades viz., large, medium and small size of tubers.

Results and Discussion

Growth parameters under non-traditional areas of north-western Rajasthan

Various growth parameters viz., plant height (cm), number of branches/plant and number of compound leaves/plant for all the varieties grown under sprinkler and drip system was recorded at 55 days after planting. Data presented in table 1 showed that growth parameters were increased irrespective of variety. There was wide variation in mean plant height of potato varieties under sprinkler (50.9 cm) and drip irrigation (37.1 cm). The other parameters like number of branches and number of compound leaves/plant were slightly higher under drip system compared to sprinkler system. Thereby, dwarf and bushy plant growth was observed in drip system and sprinkler system of irrigation. Among different

cultivars, maximum plant height was recorded in Kufri Chipsona-4 (70.7 cm) followed by Kufri Frysona (59.1 cm), Kufri Surya (48.7 cm), Kufri Khyati (48.1 cm) and Kufri Pukhraj (46.7 cm) while minimum in Kufri Garima (37.2 cm) under sprinkler system. Similarly, under drip system maximum plant height at 55 days after planting was recorded in Kufri Chipsona-4 (51.9 cm) followed by Kufri Frysona (46.5 cm), Kufri Surya (39.8 cm), Kufri Jyoti (43.2 cm), Kufri Pukhraj 31.3 cm), Kufri Khyati (30.1 cm) while minimum in Kufri Garima (26.3 cm). The observations showed that Kufri Chipsona-4 is vigorous type while Kufri Garima is comparatively dwarf type. However, the number of branches and number of compound leaves/ plant did not follow the same trend, which is obvious that these variations are due to their genetic nature of the variety. Spieler (1994) also reported that microsprinkler protects crops from adverse climatic conditions which help in better growth and development of plant.

Yield of potato/plant under non-traditional areas of north-western Rajasthan

In case of yield/plant, K Chipsona-4 gave maximum yield (935.8 g/plant) followed by Kufri Frysona (839.5 g/plant) and Kufri Jyoti (813.9 g/plant) while, Kufri Pukhraj (593.0 g/plant) gave minimum yield followed by Kufri Khyati (678.4 g/plant) under sprinkler irrigation system (Table 2). Percent increase in yield/plant was 14.4, 27.17, 57.81, 41.57, 17.64, and 37.25 percent for Kufri Khyati, Kufri Garima, Kufri Chipsona, Kufri Frysona, Kufri Surya and Kufri Jyoti respectively as compared to K Pukhraj under sprinkler irrigation. In case of drip irrigation K Frysona (636.5 g/plant) gave higher tuber yield/plant followed by K Chipsona (626.7 g/plant) and K Jyoti (504.7 g/plant).

Yield and number of potato/plant under non-traditional areas of north-western Rajasthan

Average yield and number under different grades/plant varied due to variety and irrigation system (Table 3). Mean yield under small, medium, large grade was 49.7, 166.1, 543.1 g/plant under sprinkler, whereas under drip it was 28.4, 126.5, 348.9 g/plant. Similarly mean number of tuber under small, medium, large grade were 2.85, 2.74, 6.15 per plant under sprinkler whereas, 1.72, 2.10, 3.34 per plant was recorded under drip irrigation. Kufri Frysona (62 g/plant) gave higher small size tuber/plant followed by Kufri Chipsona-4 (59.9 g/plant) under sprinkler whereas under drip Kufri Chipsona-4 gave higher (66.1 g/plant) followed by Kufri Khyati (37.1 g/plant). In medium size maximum yield/plant were observed in Kufri Frysona (255.7 g/plant) followed by Kufri Surya (196.5 g/plant) under sprinkler whereas, under drip Kufri Jyoti (170.0 g/plant) gave maximum yield/plant followed by Kufri Garima (150.20 g/plant). In case of Large size tuber K Frysona gave higher yield per plant (712.6 g/plant) followed by Kufri Jyoti (617.4 g/plant) under sprinkler while, under drip Kufri Frysona gave higher large size of tuber per plant (508.9 g/plant) followed by (542.0 g/plant).

Kufri Khyati, Kufri Frysona and Kufri Chipsona-4 gave higher number of small, medium and large sized tuber per plant (3.4, 3.99 and 9.32) respectively under sprinkler. While under drip irrigation Kufri Chipsona-4, Kufri Garima, Kufri Frysona gave higher number of tubers per plant (3.51, 2.71 and 4.46 tubers/plant, respectively).

Maximum large size tuber yield/plant (>75 g) recorded was 712.6, 617.4, 573.8 and 521.8 g/plant for Chipsona-4, Kufri Jyoti, Kufri Garima and Kufri Frysona, respectively. Whereas, maximum medium sized tuber/plant was observed under Kufri Frysona (255.7 g/plant) followed by Kufri Surya (196.5 g/plant) and Kufri Chipsona-4 (163.3g/plant) (Table-3) while maximum small sized tuber was obtained from Kufri Frysona (62.0 g/plant) followed by Kufri Chipsona-4 (59.9 g/plant) Kufri Surya (48.8 g/plant) under sprinkler irrigation.

Average weight of potato/plant under non-traditional areas of north-western Rajasthan

Average weight of small, medium and large size tubers varied under both the irrigation system (Table 4). Higher average weight of tubers under small, medium and large size tubers was 23.7, 72.9, 123.86 g obtained in Kufri Khyati, Kufri Surya and Kufri Chipsona-4 respectively under sprinkler irrigation, while under drip average weight of tubers under small, medium and large size tubers was obtained in the Kufri Chipsona-4 (21.94 g), Kufri Frysona (64.05 g), Kufri Garima (113.07 g). Minimum average weight of tubers under small was 9.43 g under Kufri Frysona, while under average weight medium and large size tubers was 45.93 and 81.99 g obtained in K Pukhraj, under sprinkler irrigation. While under drip average weight of tubers under small, medium and large size tubers were obtained in the Kufri Khyati, Kufri Garima and Kufri Chipsona (10.99, 51.15 and 76.50 g), respectively.

Yield of potato/ha under non-traditional areas of north-western Rajasthan

Tuber yield varied significantly from variety to variety (Table 2) under sprinkler irrigation system. Maximum tuber yield, which was significantly higher over other varieties, was obtained from Kufri Chipsona-4 (53.48 t/ ha) followed by Kufri Frysona (47.97 q/ ha) and Kufri Jyoti (46.51q/ ha) while minimum yield was observed in Kufri Pukhraj (33.89 q/ ha) and Kufri Khyati (38.76 q/ ha). Kufri Garima and Kufri Surya gave intermediate yields (43.09 and 39.86 q/ha), respectively. Kufri Khyati, Kufri Garima, Kufri Chipsona, Kufri Frysona Kufri Surya and Kufri Jyoti gave 4.9, 9.2, 19.6, 14.1, 6.0 and 12.6 t/ha higher yield of potato as compared to Kufri Pukhraj. Tuber yield under drip irrigation, maximum yield was obtained from Kufri Frysona (43.5 t/ha) followed by Kufri Chipsona-4 (42.9 t/ha) and Kufri Garima (32.4 t/q/ha) and minimum yield was observed by Kufri Pukhraj (20.4 t/ha) and Kufri Khyati (33.3 t/ha). Percent increase in yield of Kufri Khyati, Kufri Garima, Kufri Chipsona, Kufri Frysona Kufri Surya and Kufri Jyoti was 163, 184, 210, 213, 167 and 169% as compared to Kufri Pukhraj.

Under sprinkler irrigation, maximum number of total

tubers (in thousands/ha) was recorded in Kufri Chipsona (883) followed by Kufri Garima (769) and Kufri Jyoti (887) while minimum number of total tubers was recorded under Kufri Pukhraj (499) and Kufri Garima (595), respectively. Whereas, under drip irrigation, Kufri Frysona (607), Kufri Garima (520), and Kufri Khyati (481) gave higher number of tubers, while Kufri Pukhraj (363) and Kufri Surya (388) in thousand/ha, respectively. The main reason of higher number of tuber in the presence of micro irrigation was the capacity of a genotype to use/ absorb more nutrients per unit from soil i.e. the ability of the root system of a genotype to acquire more nutrients from soil (Trehan, 2009)

The mean maximum temperature during crop season was 27.5°C and the average minimum temperature was 9.7°C. Therefore, potatoes grown here may be suitable for processing. Potatoes grown here can be expected to have higher dry matter and lower reducing sugar content due to high night temperature. Therefore, these potatoes can be used for processing.

Potato cultivars differ in their growth and yield potential; hence there is a differential response to agro climatic conditions and bulking rate even if they belong to same maturity group. Duynisveld *et al.*, (1988) and Sharifi *et al.*,

(2007) have also reported that different cultivars behave different in term of yield and bulking rate. All the varieties gave higher yield as compared to their potential yield as reported by the ICAR-CPRI, Shimla. Kashyap and Panda (2002) also observed significantly higher potato yield under high frequency irrigation. Difference in tuber yield obtained under micro sprinkler and drip irrigation systems was higher than furrow irrigation method. The higher yield in microsprinkler and drip irrigation systems might be due to the fact that frequent watering resulted into higher water potential, thus minimizing fluctuation in soil moisture in effective root zone, which holds promise for increase in crop yield (Hanson *et al.* 1997). The better crop performance under microsprinkler could be attributed to minimum influence of frost, white fly and nutrient leaching. It was observed (visual observation) that whitefly attack was not so severe under microsprinkler regime as compared to drip and furrow irrigated crop. Frequent irrigation with microsprinkler washed the leaf canopy and minimized the whitefly infestation. Apart from this, microsprinkler irrigation might have created better microclimate, which facilitated better photosynthesis, root aeration and plant growth which resulted into higher yield (Dutta and Das, 2001). Findings are in accordance with

Table 1. Growth parameters of different potato cultivars after 55 days of planting under sprinkler and drip irrigation system.

Varieties	Sprinkler irrigation			Drip irrigation		
	Plant height (cm)	No. of branches/ plant	No. of compound leaves/ plant	Plant height (cm)	No. of branches/ plant	No. of compound leaves/ plant
Kufri Khyati	48.1	3.3	24.7	30.1	3.7	26.0
Kufri Garima	37.2	6.1	33.1	26.3	6.2	30.8
Kufri Chipsona-4	70.7	4.9	46.5	51.9	4.3	36.2
Kufri Pukhraj	46.7	3.1	22.8	31.3	3.1	23.3
Kufri Frysona	59.1	3.9	29.5	46.5	4.3	46.5
Kufri Surya	48.7	4.9	31.9	39.8	5.6	35.2
Kufri Jyoti	45.9	2.9	32.1	34.2	4.1	27.9
Mean	50.9	4.2	31.5	37.2	4.5	32.3
SEm $\pm$	3.33	0.27	2.14	1.80	0.22	1.60
CD (p=0.05)	10.2	0.8	6.3	5.0	0.7	4.8

Table 2. Yield and number of tuber obtained in different potato cultivars under sprinkler and drip irrigation system.

Treatment	Sprinkler irrigation			Drip irrigation		
	Yield /plant (g)	Yield (t/ha)	No. of tuber (000/ha.)	Yield /plant (g)	Yield (t/ha)	No. of tuber (000/ha.)
Kufri Khyati	678.4	38.8	673	487.3	33.3	481
Kufri Garima	754.1	43.08	595	474.3	32.5	520
Kufri Chipsona	935.8	53.5	833	626.7	42.9	432
Kufri Pukhraj	593.0	33.9	499	298.2	20.4	363
Kufri Frysona	839.5	48.0	769	636.5	43.5	607
Kufri Surya	697.6	39.9	637	498.6	34.1	388
Kufri Jyoti	813.9	46.5	693	504.7	34.5	462
Mean	758.9	43.4	692	503.8	34.5	465
SEm $\pm$	37.89	2.1	34.54	25.18	1.7	23.48
CD at 5%	113.8	63.7	104	75.6	51.7	70

Table 3. Yield of tubers and number/ plant of different potato varieties under both the irrigation system.

Varieties	Sprinkler irrigation						Drip irrigation					
	Yield under different grades per plant (g)			Number of tuber in different grades			Yield under different grades per plant (g)			Number of tuber in different grades		
	Small (<25 g)	Medium (25-75 g)	Large (>75 g)	Small (<25 g)	Medium (25-75 g)	Large (>75 g)	Small (<25 g)	Medium (25-75 g)	Large (>75 g)	Small (<25 g)	Medium (25-75 g)	Large (>75 g)
<i>Kufri Khyati</i>	37.3	119.0	522.1	3.40	2.16	6.21	37.1	120.2	330.1	1.56	1.72	3.76
<i>Kufri Garima</i>	48.7	131.6	573.8	2.77	2.57	5.08	24.4	150.2	299.7	1.87	2.71	3.03
<i>Kufri Chipsona</i>	59.9	163.3	712.6	2.73	2.53	9.32	66.1	108.6	452.0	3.51	1.73	3.65
<i>Kufri Pukhraj</i>	46.9	144.4	401.8	2.21	2.31	4.22	17.2	95.4	185.6	0.96	2.08	2.26
<i>Kufri Frysona</i>	62.0	255.7	521.8	3.25	3.99	6.21	22.2	105.4	508.9	2.35	2.06	4.46
<i>Kufri Surya</i>	48.8	196.5	452.2	3.15	3.09	4.90	7.9	135.4	355.3	0.46	1.86	3.36
<i>Kufri Jyoti</i>	44.4	152.1	617.4	2.46	2.53	7.13	23.7	170.5	310.5	1.32	2.57	2.87
Mean	49.7	166.1	543.1	2.85	2.74	6.15	28.4	126.5	348.9	1.72	2.10	3.34
SEM $\pm$	2.43	8.37	27.31	0.19	0.17	0.27	1.38	6.27	17.52	0.13	0.13	0.15
CD at 5%	7.5	24.9	81.5	0.43	0.41	0.92	4.3	19.0	52.3	0.26	0.32	0.50

Table 4. Average weight of tubers/plant of different potato varieties under both the irrigation system

Treatments	Sprinkler irrigation			Drip irrigation		
	Average weight of tubers under different grades per plant (g) Under Sprinkler			Average weight of tubers under different grades per plant (g) Under Drip Irrigation		
	Small (<25 g)	Medium (25-75 g)	Large (>75 g)	Small (<25 g)	Medium (25-75 g)	Large (>75 g)
<i>Kufri Khyati</i>	23.73	69.87	87.84	10.99	55.02	84.04
<i>Kufri Garima</i>	13.05	55.49	98.90	17.60	51.15	113.07
<i>Kufri Chipsona</i>	18.83	62.86	123.86	21.94	64.66	76.50
<i>Kufri Pukhraj</i>	17.88	45.93	81.99	21.21	62.46	95.29
<i>Kufri Frysona</i>	9.43	51.12	114.14	19.07	64.05	84.02
<i>Kufri Surya</i>	17.27	72.89	105.89	15.52	63.52	92.29
<i>Kufri Jyoti</i>	17.92	66.44	108.24	18.03	60.12	86.54
Mean	16.49	60.18	104.44	18.43	60.34	81.51
SEM $\pm$	5.12	19.26	35.21	6.45	19.78	27.35
CD at 5%	16.49	60.18	104.44	18.43	60.34	81.51

Holzapfel *et al.* (2000) who reported better soil aeration in root zone of Kiwi crop under microsprinkler irrigation as compared to drip irrigation system, and recorded higher yield. Further, during tuberization (in December) minimum temperature was as low as 512 °C for few days. Microsprinkler irrigation system might have protected the crop from adverse effect of low temperature by sprinkling water droplets on the leaves of the plant, helped in better growth, early maturity and higher potato yield as compared to traditional method. Spieler (1994) also reported that microsprinkler protects crops from adverse climatic conditions which help in better growth and development of plant. Superiority of drip irrigation or sprinkler irrigation over traditional irrigation methods in terms of yield and economics is now well established fact (Narayanamoorthi 1997, Pawar *et al.* 2002). It is imperative to evolve efficient, economical and reliable irrigation management strategies for successful early potato cultivation and to increase productivity and profitability of existing bio-production system for canal irrigated area of arid environment.

From the present study, it can be concluded that there is a good scope for cultivation of potato cultivars like Kufri Chipsona-4 and Kufri Frysona in hot arid region of north-western Rajasthan. These cultivars are agronomically most

efficient in resource poor conditions and had given high yield, better quality tuber and good return. In fact, potato has great potential in the state as the green vegetables are not availability is poor in the arid region of Rajasthan throughout the year. If good quality seed, proper marketing system, sufficient cold storage and irrigation facilities are made available, definitely the prospect of potato will be bright in this region. It is therefore necessary to educate the farmers through front line demonstrations as well as imparting training on good agricultural practices for potato cultivation. Also, western Rajasthan is the most suitable area for the establishment of processing units. This will increase the demand and will further motivate the farmers to grow potatoes in this region.

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Cold arid Ladakh: A natural conservatory of folk apricot cultivars for horticultural use

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Abstract

Traditional knowledge is the essence of social capital, helps in the faster development of science in favour of human kind through a holistic approach. Local culture, spirit, social and ethical norms possessed by local people has often been determining factors for sustainable use, and conservation of biodiversity. In present paper, an effort has been made to converge the information on traditional knowledge generated by the tribes of Ladakh about growing and conservation of folk apricot cultivars for sustainable livelihood. To achieve this objective twenty-three major apricot growing villages of Ladakh from five different eco-geographical regions i.e. Kargil, Khaltai, Dha-Hanu, Leh and Nubra of Ladakh province have been considered. Study revealed that there were forty-three major folk apricot cultivars are grown for commercial and house hold use. The peoples of Ladakh gained location specific life-long experience and indigenous strategy for sustainable biodiversity use and management at individual as well as community level. This has been built up through regular use and attentive observations related to fresh fruit, drying and oil extraction purposes of fruits and kernels. The conserved materials of these folk cultivars are serving the country as *in-situ* field gene banks. Which will be a boon to the development of apricot industry leads to the enhanced livelihood and nutritional security.

Keywords: Traditional knowledge, apricot, *Chulli*, Ladakh, folk cultivars

Introduction

Apricot (*Prunus armeniaca* L.), locally known as '*Chulli*' is one of the sole fruit crops of cold arid areas of Ladakh providing the sustainable livelihood. In Ladakh dried apricot is a valuable commodity, and the value of its production from the Kargil district alone amounts to 20 M Indian rupees per annum (Dar and Wani, 2007; Mir, 2000). Many folk cultivars are cultivated and maintained by farmers in their orchards, backyards or isolated mountainous tracts since ancient world. Most of the trees are of seedling in origin and tend to produce variable quality fruits ranging from very sweet to sub-acidic in taste, yellow to orange/dark red in colour, white to orange pulp colour and sweet to bitter kernels. The available genetic variability also reflects the introduction from neighbouring countries (Zaffer *et al.*, 2004). This variability is very important for further crop improvement programs. But due to lack of proper documentation and management, genetic erosion may cause losing of folk cultivars soon (Dwivedi and Dwivedi, 2004). We know that this region is one of the hotspots for apricot diversity. That is clearly documented in the Vavilov center of origin that apricot was domesticated in the Chinese region including Himalayas and reported that apricot was first cultivated in India during 3000 BC (Huxley, 1992). It is also believed that it had a wide native range including Armenia, Caucasus, the Himalaya,

China, and Japan (Loudon, 1838). In recent findings, it is reported that apricot was originated in the mountains of northern and north-eastern China, with the Dzhungar and Zhalag Mountains of central Asia as a secondary centre of origin (Zeven and DeWet, 1982). Gazette information shows that apricot was the main trading commodity of Ladakh when the Silk Route connecting Leh to China, Tibet and Pakistan was open prior to 1947. British gazetteers Moorcroft and Trebek reported an export of 600 mounds of dried apricot from Leh to Tibet and Tartary in 1825. Some varieties are even known to have come from Yarkhand in China and Tibet (Kaur, 2012). Therefore, cold arid desert of Ladakh is one of the richest sources of variability of apricot, which needs critical attention for documentation and future use of gene pool.

The traditional knowledge especially on natural resource management is crucial for sustainable farming. Traditional knowledge is a cumulative body of knowledge, knowhow, practices and representations maintained and developed by peoples with extended histories of interaction with the natural environment. Such an interaction between modern science and local knowledge can serve the purpose of sustainable agriculture. The value of traditional knowledge has been fully endorsed in the UNESCO's Universal Declaration on Cultural Diversity (UNESCO, 2001). But till date traditional knowledge concerning about folk cultivars of

apricot has not been comprehensively documented, especially from the more remote and inaccessible areas of the high-altitude areas of cold arid Ladakh. It is mostly being maintained and transferred orally from one generation to next. The increasing accessibility of other commercial fruits, combined with the changing life style, leading to the loss of knowledge on traditional varieties in the region (Malik *et al.*, 2010). The concerns of ethnobotanists over such a loss of knowledge have been widely emphasized many times (Brosi *et al.*, 2007; Shanley *et al.*, 2004). But still the systematic collection and characterization of Indian apricot germplasm has not been attempted, and, yet, a few studies have been made to emphasize the genetic variability present (Sofi *et al.*, 2001; Zaffer *et al.*, 2004; Malik *et al.*, 2010). Therefore, we conducted several explorations in Ladakh to survey and collection of folk apricot cultivars present in the high-altitude areas of Ladakh and a documentation of traditional knowledge on horticulturally important traits.

Materials and Methods

Explorations and collection

Five explorations and collections were undertaken in the north-western Himalayas (Jammu and Kashmir). Ladakh is the highest plateau of state of Jammu and Kashmir covering an area about 86,904 square km and located between 32°15'-36° N and 75°15'-80° 15' E. Altitude ranges from 2750 m (Kargil) to 7672 m (Saser Kangri) in Karakoram range. It spans the Himalayan and Karakoram mountain ranges and the

upper Indus River valley. The climate of the cold desert is characterized by the extremes of heat and cold, coupled with excessive dryness, intense solar radiation and rarification of the atmosphere that causes the southerly winds. Air movements are towards the North Pole in southerly currents and offer a slight check on transmission of sunrays that the noon temperature often reaches upto 25° C to 40° C, while the night temperature falls below freezing points. Temperature during winter months reaches to -30° C (Kargil) to -59° C (Drass). Annual average rainfall is only 99 mm. Average relative humidity remains around 40-50% which makes the area totally arid. Soils are poor in most of the essential plant nutrients except potash. Vegetation is very sporadic, mainly concentrated along the river and other minor water sources. Most of the villages are located on isolated hillsides along the water source either near or far from the roadside. The apricot is one of the major fruit crops grown and maintained by each household either in the orchards or backyards. It has a wide range of distribution in different parts of Ladakh with particularly abundance in Sham areas (lower Ladakh) including Hardas, Shilikchey, Khaltsi, Dumkhar, Skurbachan, Achinathang, Dha-Hanu, Biama, Garkone and Upper Ladakh including Saspol, Nimmo, Basgo/Bazgo, Leh, Skuru, Nubra, Sumur, Hunder, Bogdang, Changmer, Turtuk, Garari, Chalunga Post and Thang (Fig. 1).

The explorations were conducted during the years 2000 to 2015 in above apricot growing areas comprising of twenty three villages in collaboration with FRL, DRDO, Leh.

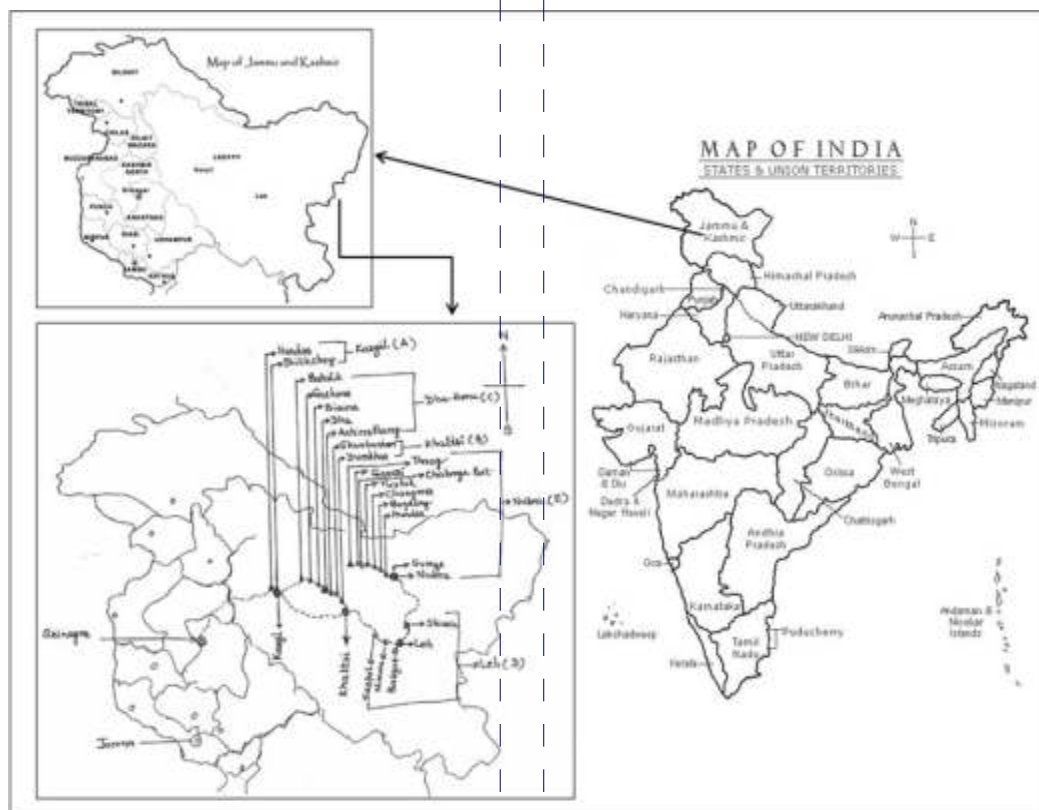


Fig. 1: Location map of the study area in Ladakh, Jammu & Kashmir

During these explorations, collections of folk cultivars of apricot were made based on selective sampling strategy, where samples collected from individual trees conserved by growers. Information about traditional knowledge was collected from apricot growers includes heads of the families, women and communities.

Characterization

Morphological characterization of fruits was carried out on the same day of collection. Descriptors developed for fruit crops (Mahajan *et al.*, 2002) at NBPGR, New Delhi, were uniformly used for recording characterization data of fruit, stone and kernel. Physico-chemical traits were recorded in sixty-three genotypes, wherein, forty three were identified as folk cultivars.

Results and Discussions

Exploration and collection

The exploration work was conducted in the traditional apricot growing regions of Ladakh. Most of the areas were located on high altitudes ranging from 2785 m (Garkone; 34°38'06.8"N, 76°26'01.6"E) to 3480 m (Bazgo; 34°12'49.8"N, 77°17'07.0"E) above mean sea level. The latitude ranged from 34°11'42.4"N, 77°20'06.8"E to 34°50'53.7"N, 76°49'38.4"E. The terrain is mountainous, dried and rocky (Fig. 1).

Traditional use

Sixty-five folk cultivars were collected from selected villages (Table 1 & 2). These were found highly diversified cultivars were conserved in these villages since sanctuaries (Malik *et al.*, 2010). The observations revealed that local farmers are aware about the importance of biodiversity and natural resource management (Singh, 2004; Singh and Nathiben, 2003). Most of the traditional cultivars are as long as the settlements in the Ladakh region. They have been maintained from generation to generation by the nomadic inhabitants of Ladakh.

They were perpetuated by seeds as well as clonal means for expansion in newer areas. The traditional cultivars have been mainly used for fresh consumption followed by drying and oil extraction (Table 1). There were about fourteen traits observed like sweet kernal, table purpose, drying, oil extraction, kernel use, bitter kernelled, suitable for osmotic dehydration, mid-season maturing, late season maturing, natural hybrids, retain colour after drying, tolerant to low temperature, twin kernelled and cultivar with poor self life (Table 1). Some of varieties have been grown with the different folk names with slight changes in their uses (Table 2). Most of the folk cultivars has sweet kernel. However, most of the cultivars were used for fresh consumption followed by drying purpose and oil extraction.

Pomological characteristics and traditional importance of genetic resources

The observations revealed that local farmers were

aware about the importance of biodiversity and natural resource management (Singh and Nathiben, 2003; Singh, 2003; Singh, 2004). They have classified the folk cultivars mainly based on fruit colour, shape and sweetness. Two cultivars '*Rakshey Karpo*' and '*Halman*' were found in most of the locations. Because fruits of '*Rakshey Karpo*' are very attractive, suitable for fresh consumption; kernel is very sweet as almond and stone is white in colour; and '*Halman*' is grown because of its fruit sweetness makes it suitable for drying purpose. Similarly, other folk cultivar like '*Margolam*' had characteristic red fruit colour with larger in size and mainly grown in Garkone and nearby settlements of *Brokpa* tribe. In the *Brokpa* language, these folk cultivars are assigned with specific names like '*Gui*', which means large and flat fruit shape; '*Tilli*' indicates very sweet taste, '*Charrap*' means very juicy and watery and '*Damoma*' means demon shape. The fruits of '*Orjan Chulli*' are characterized by white flesh with milky taste. The folk nomenclature about cultivars are very interesting which sometimes also contains synonyms to cultivars. The name of one cultivar is spoken with different names in different dialect languages. For instance, the name of '*Halman*' is common accepted name in most of the areas particularly in *Baltis* language, but in *Brokpa* language it is also known by '*Shakanda*' (Table 2).

Similarly, other folk cultivar like *Aam Chulli* is named by its mango shape, *Angoor Chulli* bear fruits in clusters like grapes, *Badam Chulli* resembles almond traits, *Bamasuf* retains its natural colour after drying, *Bro Chulli* have good quality oil, *Charrap* fruits are very juicy, *Demoma* fruits are bright red in colour, *Guitilli* fruits are large in size and flat in shape, *Gulzar Aalu* resembles potato taste, *Halman* fruits are very sweet in taste, *Hangol* fruits are sweeter than *Halman* and also retains better colour after drying, *Khantey* fruits are sub-acidic in taste, *Koban* fruits are larger in size, *Mangol* fruits are very juicy, *Mamur Chulli* resembles *Halman* but more juicy, *Narmo* are mostly sweet kernelled, *Rakshey Karpo* nuts are white in colour, *Tokpopa* and *Zen Chulli* are also very attractive in shape, colour and texture.

Genetic diversity among eco-geographical regions of Ladakh

Based on traditional knowledge a total of forty-three folk cultivars identified from twenty three major apricot growing areas of Ladakh (Table 2). These are distributed in five different eco-geographical regions i.e., Kargil (Hardas and Shilikchey), Khaltsi (Khaltsi, Dumkhar and Skurbachan), Dha-Hanu (Achinathang, Dha, Hanu, Biama and Garkone), Leh (Saspol, Nimmo, Bazgo/Basgo and Skuru), and Nubra (Nubra, Sumur, Hunder, Bogdang, Changmer, Garari, Turtuk, Chalunga Post and Thang) of Ladakh.

Kargil eco-geographical region

In this region the major folk cultivars were *Halman*, *Shamber*, *Zenchulli*/ *Papachulli*, *Badamchulli*, *Brochulli*, *Khusta*, *Margolam*, *Nurmo* *Guzmin* and *Shakanda*. This region is producing apricots mainly for fresh consumption. A little quantity of *Halman* is also being used for drying purpose,

But most of the cultivars table purpose.

Khaltsi eco-geographical region

This region also grows table purpose like *Bhomali*, *Khantey*, *Narmo*, *Rakshey Karpo* and *Tokpopa*. Oil extraction is one of the major enterprises in this region using cultivars like *Khantey* etc. Drying type cultivars are generally not grown, but a small quantity of the fruits from *Halman* are utilized for this purpose. *Rakshey Karpo* kernels are used as substitute of almond.

Dha-Hanu eco-geographical region

This area lies along the snow bound river and most of the belt is covered with apricot plantations. These plantations include the folk cultivars like *Aam Chulli*, *Angoor Chulli*, *Charrap*, *Demoma*, *Guitilli*, *Gyalchuma*, *Mangol/Hangoe*, *Mamur Chulli*, *Margolam*, *Orjan Chulli*, *Papa Chulli*, *Rakshey Karpo*, *Rogan*, *Suka* and *Vasu Kangyeb*. In this region home-scale sun drying practices are very common for making dried apricots. Generally, they dry fruits under natural day light on the roof tops of their houses. *Suka* is one of the rare genotypes have sweetest fruits, therefore used for making dried apricots. Oil extraction is another activity, uses bitter apricot kernels.

Leh eco-geographical region

This eco-geographical region is around district head quarter of Leh. The natural plantations of apricots are less mainly in scarcity of water and poor fertility of soil. Therefore, small numbers of cultivars exist. But backyard plantings are in general in peri-urban settlements. The main folk cultivars include *Halman*, *Koban*, *Narmo*, *Rakshey Karpo* and *Tokpopa*. There also dual type cultivars generally grown, but they use it mainly for fresh consumption.

Nubra eco-geographical region

Nubra region is very rich in the apricot germplasm. Large numbers of villages are growing different folk cultivars of *Chulli*. Mostly are located at much higher altitudes as compared to earlier four eco-geographical areas. There apricots are being grown mostly for drying purpose. The important among them are *Bamasuf*, *Chama Chulli*, *Charrap*, *Gulzar Aalu*, *Gurtsi*, *Hangol*, *Hiljing Stachu*, *Karpo Stachu*, *Khantey*, *Khapiyuk*, *Koban/ Kwun*, *Kowan*, *Margolam*, *Narmo*, *Rogan*, *Shahkanda*, *Shakarpara*, *Shambiar*, *Shakashair*, *Shamatipeyan*, *Stachu/ Khokhoos* and *Zen Chulli/ Papa Chulli*.

In all the five regions, most common folk cultivars are *Halman*, *Rakchakarpa*, *Tokpopa*, *Margulam*, *Narmu* and *Khante*. These folk cultivars are the natural hybrids developed by open pollination in this cold arid desert of Ladakh and acclimatized particularly for such conditions. These generally require long chilling period for breaking dormancy and intense sunlight during summer along with dry weather for maturity and colour development. The experiments were also conducted to evaluate these cultivars under Kashmir valley conditions to harness their commercial potential under

Kashmir conditions. But results were found discouraging with poor fruit quality. As the climate of Kashmir valley is different as compared to Ladakh. In Kashmir valley, annual precipitation is about 750 mm is much higher as compared to Ladakh (90 mm), derived partially from the summer monsoon and partially from storms associated with winter low-pressure systems. Snowfall often is accompanied by rain and sleet. Temperatures vary considerably by elevation; the average minimum temperature is in the upper -2 °C in January, and the average maximum is about 31 °C in July. The valley is surrounded by Himalayas on all sides. Spring is the wettest season while autumn is the driest. Therefore, it is concluded that these folk cultivars of apricot are very specific to the existing climatic conditions of Ladakh and should be restricted to such climate conditions.

The production system is mostly organic in nature that is directly influenced by Buddhism which believes in *Ahimsa* (or non-injury means entire abstinence from causing any pain or harm whatsoever to any living creature), prohibits the use of chemicals to control the economic pests like codling moth etc. The fruits of these folk cultivars are usually harvested manually and collect in '*Tsepo*' (basket) and wash them under running water to remove the dusts and then spread on the roof top for their drying under open sunlight. The harvesting period generally starts from July to September. The fruits are dried either as whole fruit (locally known as *Fating*) or seed are separated before drying, and the dried fruit without seed are called '*Chulli Skampo*'. Bitter kernels are used for oil extraction (locally called '*Tseghumar*') is multipurpose oil with a peculiar apricot flavour. Traditionally, the oil was extracted from the semi-roasted kernel by crushing them in a large wooden mortar (locally called as '*Thorn*'), followed by heating and compressing them with few drops of water on a flat stone (locally called as '*Tsigg*').

For the effort of informal *in-situ* indigenous agrobiodiversity conservation, peoples of Ladakh deserves the reward and honour. The agro-biodiversity is rainfed and most of the farmers are economically poor. During the study of exploring the dynamics of traditional knowledge associated with *Chulli* cultivars and its conservation, most felt that the folk cultivars should remain with them for coming generations for their source of livelihood as well as nutritional security. This land should not be allowed to convert into orchards of other fruit cultivar. Majority of them are interested in either expanding or preserving their folk apricot cultivars. Looking to the importance of the *Chulli*, growers are very much interested to see further to identify still better ecotypes from the natural population for further improvement and multiplication.

Traditional knowledge plays an important role in the food security, resource management, and biodiversity conservation. The traditional knowledge generated from many years by the inhabitant of these areas are very useful will surely reduce the time taken to develop the better ecotypes. They have already reached to the point where about forty-three genotypes/folk cultivars are performing better in terms of fruit and nut quality. These forty-three folk cultivars are the land

mark for sustaining the livelihood of this land locked terrain. Plantations under different eco-geographical conditions are facilitating as centre of multi-location trials to see the feasibility of a cultivar. Scientists need to keep an open eye for opportunities to learn from local people, especially given that financial resources and the scientific toolbox are often inadequate in addressing the complex natural and human interactions. Traditional knowledge is the area where there is need to cultivate a bottom-up approach to development building upon the resources and strength of indigenous people, their experiences and diversified knowledge system.

Acknowledgement

Authors express the gratitude to the Indian Army for cooperation, help and logistic support during explorations to Ladakh. Authors also gratefully acknowledge the financial

support provided by National Agriculture Technology Project (ICAR) and Director, Central Institute of Temperate Horticulture, Srinagar as well as Director, Field Research Laboratory, Leh, Ladakh.

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Table 1. Traditional use of folk cultivars of apricot grown in cold arid region of Ladakh

Sl. No.	Traditional use	Folk cultivars
1	Sweet kernel	Aam Chulli, Angoor Chulli, Badam Chulli, Bamasuf, Bhomli, Bro Chulli, Chama Chulli, Charrap, Demoma, Guitilli, Gulzar Aalu, Gurtsi, Gyalchuma, Halman, Halmaan, Hiljing Stachu, Karpo Stachu, Khantey -Hunder, Khapiyuk, Koban (Kwun), Kowan, Mangol (Hangoe), Mamur Chulli, Margolam, Margolam (Amba), Margolam-Garari, Narmo -Dumkhar, Narmo -Thang, Narmo Guzman, Orjain Chulli, Papa Chulli, Rakchey Karpo, Rogan, Shakanda -Shilikchey, Shakanda-Chalunga, Shakanda -Turtuk, Shakanda -Thang, Shakarpara, Shambiar, Shakashair, Shamatipeyan, Stachu (Khokhoos), Suka, Tokpopa -Nimmo, Vasu Kangyeb, Shamber, Yakar, Zen Chulli
2	Table purpose / fresh consumption	Aam Chulli, Angoor Chulli, Badam Chulli, Bamasuf, Bro Chulli, Chama Chulli, Charrap, Demoma, Guitilli, Gurtsi, Halman, Karpo Stachu, Khusta, Koban -Bogdang, Mangol (Hangoe), Mamur Chulli, Margolam, Margolam (Amba), Margolam-Garari, Narmo Guzman, Orjain Chulli, Rakchey Karpo, Rogan, Shakanda-Shilikchey, Shakanda-Turtuk, Shakanda-Thang, Shakarpara, Shambiar, Shakashair, Stachu, Stachu (Khokhoos), Tokpopa -Nimmo, Vasu Kangyeb, Shamber, Yakar,
3	Drying	Bamasuf, Bro Chulli, Chama Chulli, Guitilli, Halman, Halmaan, Hiljing Stachu, Karpo Stachu, Khusta, Koban -Skuru, Mangol (Hangoe), Margolam (Amba), Narmo-Thang, Papa Chulli, Rakchey Karpo, Rogan, Shakanda -Chalunga, Shakanda-Turtuk, Shambiar, Shakashair, Stachu, Stachu (Khokhoos), Suka
4	Oil extraction	Khantey-Hunder, Shakanda-Shilikchey, Shakanda-Thang, Zen Chulli
5	Kernel use	Badam Chulli, Bhomli, Bro Chulli, Hangol
6	Bitter kernel	Khantey-Khaltsi, Koban-Skuru, Koban-Bogdang,
7	Osmotic dehydration	Gyalchuma,
8	Mid Season maturity	Koban (Kwun), Margolam (Amba),
9	Natural hybrids	Gulzar Aalu (Apricot x Plum),
10	Retain colour after drying	Hangol,
11	Tolerant to low temperature	Hangol,
12	Late maturing	Kowan,
13	Twin kernel	Kowan,
14	Poor self life	Shamatipeyan

Table 2. Pomological characteristics and importance of folk apricot cultivars grown in Ladakh region of Jammu and Kashmir

Local cultivars	Place	Altitude	Traditional knowledge	Physico-chemical parameters recorded
Aam Chulli	Achinathang, Khamtsi	3015 m	Large fruits, firm fruits, medium fruit quality, table purpose, mango shape	Fruit weight 25.6 g, TSS 13 ⁰ Brix, kernel sweet
Angoor Chulli	Achinathang, Khamtsi	3015 m	Small fruit size, bearing in clusters, very sweet in taste, juicy, table purpose	Fruit weight 30 g, TSS 28.2 ⁰ Brix, kernel sweet
Badam Chulli	Hardas, Kargil	2800 m	Late maturing, fresh consumption and oil extraction	Fruit weight 17.5 g, TSS 11.5 ⁰ Brix, kernel sweet
Badam Chulli	Shilikchey, Kargil	2790 m	Late maturing, used for oil extraction, kernel	Fruit weight 18.4 g, TSS 12.1 ⁰ Brix, kernel sweet
Bamasuf	Chalunga Post	2930 m	Table and drying purpose, introduced from Pakistan	Fruit weight 16.6 g, TSS 22.8 ⁰ Brix, kernel sweet
Bamasuf	Turtuk	2900 m	Best for drying, retains good colour after drying	Fruit weight 13.4 g, TSS 18 ⁰ Brix, kernel sweet
Bhomli	Dumkhar, Khamtsi	2975 m	Kernel semi-sweet	Fruit weight 18.9 g, TSS 18.4 ⁰ Brix, kernel sweet
Bro Chulli	Shilikchey, Kargil	2790 m	Fruits large in size, late maturing, table purpose, kernel used for oil extraction	Fruit weight 16.4 g, TSS 22.3 ⁰ Brix, kernel sweet
Chama Chulli	Turtuk, Nubra	2900 m	Drying and table purpose	Fruit weight 12.2 g, TSS 13.6 ⁰ Brix, kernel sweet
Charrap	Garkone, Kargil	2785 m	Very large fruits, juicy, sweet, fresh consumption	Fruit weight 35.4 g, TSS 21 ⁰ Brix, kernel sweet
Demoma	Garkone, Kargil	2785 m	Late maturing, red colour, table purpose, sweet kernel	Fruit weight 25.8 g, TSS 21.4 ⁰ Brix, kernel sweet
Guitilli	Garkone, Kargil	2785 m	Bigger fruits, table & drying type, sweet kernel	Fruit weight 25 g, TSS 14.8 ⁰ Brix, kernel sweet
Gulzar Aalu	Turtuk, Nubra	2900 m	Natural hybrid between apricot and plum	Fruit weight 21 g, TSS 11.4 ⁰ Brix, kernel sweet
Gurtsi	Thang, Nubra	2840 m	Table purpose, sweet kernel	Fruit weight 22.4 g, TSS 14.3 ⁰ Brix, kernel sweet
Gyalchuma	Bama, Dha-Hanu	2880 m	Good for osmotic dehydration, sweeter than Tokpopa, sweet kernel	Fruit weight 29.6 g, TSS 22.6 ⁰ Brix, kernel sweet
Halman	Hardas, Kargil	2800 m	Very sweet, medium in size, drying and table purpose	Fruit weight 25.6 g, TSS 25.6 ⁰ Brix, kernel sweet
Halmaan	Nimmoo, Leh	2980 m	Medium fruit size, drying purpose, very sweet	Fruit weight 16.7 g, TSS 34.3 ⁰ Brix, kernel sweet
Hangol	Thang, Nubra	2840 m	Medium fruit size, very sweet, fruits dry on trees, retain color on drying, resistant to low temperature	Fruit weight 19.8 g, TSS 26 ⁰ Brix, kernel sweet
Hiljing Stachu	Thang, Nubra	2840 m	Better than Halman for drying purpose	Fruit weight 19 g, TSS 24 ⁰ Brix, kernel sweet
Karpo Stachu	Turtuk, Nubra	2900 m	Table and drying purpose, sweet kernel	Fruit weight 19 g, TSS 21.3 ⁰ Brix, kernel sweet
Khantey	Hunder, Nubra	3120 m	Round stone and kernel, high oil content	Fruit weight 22.5 g, TSS 12.3 ⁰ Brix, kernel sweet
Khantey	Khamtsi	2975 m	Local landrace, kernel bitter, medium fruit quality	Fruit weight 15.4 g, TSS 12.5 ⁰ Brix, kernel bitter
Khapiyuk	Thang, Nubra	2840 m	Fruits less juicy, pointed tip, sweet kernel	Fruit weight 16 g, TSS 11 ⁰ Brix, kernel sweet
Khusta	Shilikchey, Kargil	2790 m	Medium in size, sweet in taste, table and drying purpose	Fruit weight 18.2 g, TSS 14 ⁰ Brix, kernel sweet

Koban	Skuru, Leh	3110 m	Fruits sweet and juicy, drying type, kernel bitter	Fruit weight 22.4 g, TSS 17.6 ⁰ Brix, kernel sweet
Koban	Bogdang, Nubra	2980 m	Bigger size fruits, juicy, table purpose, sweet kernel	Fruit weight 22 g, TSS 20 ⁰ Brix, kernel sweet
Koban (Kwun)	Chalunga Post, Nubra	2930 m	Fruits large size, sweet in taste, dried whole, sweet kernel, table purpose, mid season maturity	Fruit weight 30 g, TSS 25 ⁰ Brix, kernel sweet
Kowan	Hunder, Nubra	3120 m	Bigger size fruits, twin stone, twin kernel, dried after removal of stone, late maturing	Fruit weight 35.5 g, TSS 12.3 ⁰ Brix, kernel sweet
Mangol (Hangoe)	Dha-Hanu	2840 m	Highly juicy, table and drying purpose, sweet, sweet kernel	Fruit weight 23.1 g, TSS 21.4 ⁰ Brix, kernel sweet
Mamur Chulli	Achinathang, Dha-Hanu	3015 m	Table purpose, taste like Halman but juicier than Halman, kernel sweet	Fruit weight 15 g, TSS 26 ⁰ Brix, kernel sweet
Margolam	Dha, Dha-Hanu	2840 m	Table purpose	Fruit weight 30.5 g, TSS 19.4 ⁰ Brix, kernel sweet
Margolam	Shilikchey, Kargil	2790 m	Table purpose	Fruit weight 19.7 g, TSS 20.7 ⁰ Brix, kernel sweet
Margolam (Amba)	Chalunga Post, Nubra	2930 m	Mid season maturity, table and drying purpose	Fruit weight 26 g, TSS 17.2 ⁰ Brix, kernel sweet
Margolam	Garari, Turtuk	3280 m	Bigger fruit size, table purpose, very juicy	Fruit weight 26 g, TSS 18.6 ⁰ Brix, kernel sweet
Narmo	Dumkhar, Khalsi	2975 m	Good quality traits of fruits	Fruit weight 26.5 g, TSS 18.7 ⁰ Brix, kernel sweet
Narmo	Skuru, Leh	3110 m	Heavy bearing in clusters, dried whole fruits, juicy, sweet kernel, regular in bearing	Fruit weight 19 g, TSS 17.6 ⁰ Brix, kernel sweet
Narmo	Thang, Nubra	2840 m	Very sweet fruits, better than Halman for drying purpose, sweet kernel	Fruit weight 19 g, TSS 25 ⁰ Brix, kernel sweet
Narmo Guzman	Shilikchey, Kargil	2790 m	Table purpose	Fruit weight 8.4 g, TSS 13 ⁰ Brix, kernel sweet
Orjain Chulli	Achinathang, Dha-Hanu	3015 m	Sweet like milk, table purpose, sweet kernel	Fruit weight 13.5 g, TSS 14.5 ⁰ Brix, kernel sweet
Papa Chulli	Achinathang, Dha-Hanu	3015 m	Medium and drying purpose	Fruit weight 13.5 g, TSS 17.4 ⁰ Brix, kernel sweet
Rakchey Karpo	Achinathang, Dha-Hanu	3015 m	Sweet kernel, medium in size, table and drying purpose	Fruit weight 24.5 g, TSS 21.4 ⁰ Brix, kernel sweet
Rakchey Karpo	Dha, Dha-Hanu	2840 m	Sweet kernel, medium in size, table and drying purpose	Fruit weight 25.7 g, TSS 16.6 ⁰ Brix, kernel sweet
Rakshey Karpo	Nimmo, Leh	2980 m	Fruits are large, moderately sweet, sweet kernel	Fruit weight 25.5 g, TSS 26.5 ⁰ Brix, kernel sweet
Rakshey Karpo	Bazgo, Leh	3480 m	Late maturing, medium sweet fruits, table purpose, sweet kernel	Fruit weight 36.8 g, TSS 16.8 ⁰ Brix, kernel sweet
Rogan	Achinathang, Dha-Hanu	3015 m	Medium fruit size, table and drying purpose	Fruit weight 9.5 g, TSS 13.4 ⁰ Brix, kernel sweet
Rogan	Hunder, Nubra	3120 m	Table and drying type, dried as whole, sweet kernel	Fruit weight 22.8 g, TSS 16 ⁰ Brix, kernel sweet
Shakanda	Shilikchey, Kargil	2790 m	Fruits bigger in size, profuse bearing, bearing in bunches, table purpose and kernel used for oil extraction	Fruit weight 16.2 g, TSS 25.3 ⁰ Brix, kernel sweet
Shakanda	Chalunga Post, Nubra	2930 m	Small fruits, drying purpose	Fruit weight 12 g, TSS 22 ⁰ Brix, kernel sweet
Shakanda	Turtuk, Nubra	2900 m	Table and drying type, sweet kernel	Fruit weight 10 g, TSS 14 ⁰ Brix, kernel sweet

Shakanda	Thang, Nubra	2840 m	Fruits bigger in size, profuse bearing, bearing in bunches, table purpose and kernel used for oil extraction	Fruit weight 12.4 g, TSS 18 ⁰ Brix, kernel sweet
Shakarpara	Sumur, Nubra	3250 m	Round fruits, white flesh	Fruit weight 30.6 g, TSS 12 ⁰ Brix, kernel sweet
Shambiar	Turtuk, Nubra	2900 m	Table and drying purpose, juicy, clingstone, mid season maturity	Fruit weight 19.6 g, TSS 15.3 ⁰ Brix, kernel sweet
Shakashair	Thang, Nubra	2840 m	Fruits bigger in size, very juicy and sweet	Fruit weight 33.4 g, TSS 22.3 ⁰ Brix, kernel sweet
Shakashair	Thang, Nubra	2840 m	Drying purpose, sweet kernel	Fruit weight 26.4 g, TSS 20.3 ⁰ Brix, kernel sweet
Shamatipeyan	Thang, Nubra	2840 m	Fruits highly perishable	Fruit weight 17.8 g, TSS 21.4 ⁰ Brix, kernel sweet
Stachu	Chalunga Post, Nubra	2930 m	Table and drying purpose, profuse bearing, red bluish fruit surface, skin thick, slightly acidic in taste, best for drying purpose	Fruit weight 20 g, TSS 18.6 ⁰ Brix, kernel sweet
Stachu (Khokhoos)	Turtuk, Nubra	2900 m	Table and drying purpose, sweet kernel	Fruit weight 15.6 g, TSS 16.6 ⁰ Brix, kernel sweet
Suka	Dha, Dha-Hanu	2840 m	Extremely sweet in taste, orange red in colour, drying purpose	Fruit weight 22 g, TSS 31.2 ⁰ Brix, kernel sweet
Tokpopa	Nimmo, Leh	2980 m	Bigger fruit size, smooth, table purpose, medium sweet	Fruit weight 39.7 g, TSS 15.7 ⁰ Brix, kernel sweet
Tokpopa	Khaltsi	2975 m	Fruits are large, smooth surface, medium sweet	Fruit weight 21.3 g, TSS 12.6 ⁰ Brix, kernel sweet
Vasu Kangyeb	Achinathang, Dha-Hanu	3015 m	Large fruit size, medium fruit quality, very juicy, table purpose	Fruit weight 37.5 g, TSS 17.3 ⁰ Brix, kernel sweet
Shamber	Hardas, Kargil	2800 m	Table purpose, sweet in taste	Fruit weight 9.3 g, TSS 26 ⁰ Brix, kernel sweet
Yakar	Turtuk, Nubra	2900 m	Very juicy, white stone	Fruit weight 20 g, TSS 19 ⁰ Brix, kernel sweet
Zen Chulli	Shilikchey, Kargil	2790 m	Kernel used to extract oil	Fruit weight 23 g, TSS 17.3 ⁰ Brix, kernel sweet

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Thar Karni: A high temperature tolerant variety of ridge gourd for arid region

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(Received: 27.08.2018; Accepted: 12.09.2018)

Abstract

Several local landraces of ridge gourd are spread over a wide range of environments in Rajasthan having specific traits. Evaluated 40 germplasm of ridge gourd under hot arid conditions of western Rajasthan over the years during summer season for different horticultural traits with special reference to high temperature tolerance. Among the evaluated germplasm, selected AHRG-29 (IC-0621468) for high temperature tolerance and purified through inbreeding and identified as variety 'Thar Karni'. Produced female flower on lower nodes (12.00-13.27) having 6.19-6.72 cm long ovary. It is early in harvesting and took 47.83-50.00 days to produce 50% female flowering from sowing. Fruits are cylindrical, 20.19-22.45 cm long with 2.81-2.96 cm diameter weighing 90.18-102.36 g having 10 longitudinal shallow ridges. On an average a single plant produced 21.03 marketable fruits which are free from bitter principle. It showed tolerance to mosaic disease having 7.50% incidence and resistance against melon fruit fly with 17.67% fruit infestation under field conditions. The plants of 'Thar Karni' withstand to high temperature (upto 42°C) with moderate yield potential (151.87 q/ha) which exhibited 31.44% higher yield over Arka Sujath and 37.56% over Pusa Nasdar (check).

Key words: Ridge gourd, Thar Karni, high temperature, fruit yield.

Introduction

Ridge gourd [*Luffa acutangula* (Roxb.) L.] is an important warm season cucurbitaceous vegetable crop grown in different parts of India. Immature fruits are cooked as vegetable and also used in the preparation of chutneys and curries. The fruits are very nutritious and good source of calcium, phosphorus, ascorbic acid, iron and fibre content (Aykroyd, 1963). Being a warm season crop, it has the ability to tolerate hotter conditions, which makes it suitable for widespread cultivation throughout the tropics. However, the climatic conditions of western Rajasthan are altogether different from other parts of India which is characterized by very high potential evapo-transpiration rate, intense solar radiations (320-619/cm²/day), high wind velocity (20 km/hr), high infiltration (9 cm/hr), extremes of temperature (0 to 48°C), low relative humidity, low soil fertility, high soil pH, saline ground water, etc. (More, 2010). Under such harsh climatic conditions cultivation of existing ridge gourd varieties results in very low and poor-quality yield which fetches less return per unit area. Earlier several varieties of ridge gourd has been bred in India and recommended for commercial cultivation in different agroecological zones (Singh *et al.*, 2009). Among the varieties 'Pusa Nasdar' has been widely cultivated by the farmers but the productivity is very low in hot arid regions due to extremities of temperature

during summer season. The average productivity of ridge gourd in Rajasthan is only 38.98 q/ha (Anonymous, 2016-17).

Ridge gourd being monoecious in sex form showed high degree of cross pollination and therefore, possess wide range of variability in vegetative, flowering and fruit characteristics (Chandra, 1995). Considerable variability exists in quantitative traits and tolerance to high temperature among germplasm of ridge gourd (Choudhary and Kumar, 2011). Several local landraces of ridge gourd are also spread over a wide range of environments in Rajasthan (Choudhary *et al.*, 2014). The existence of wide genetic diversity in ridge gourd in hot arid region provides ample scope to screen and develop trait specific genotypes adapted to high temperature regimes. Keeping in view, the need of vegetable growers of arid region it was felt to identify stable and superior genotype of ridge gourd having high temperature tolerant to fulfill the need of farmers of hot arid region. Therefore, a systematic breeding programme was initiated with the objective to develop high temperature tolerant variety of ridge gourd adapted to hot arid conditions.

Materials and Methods

The study material comprised of five genetically different inbred lines of ridge gourd along with two released varieties viz., Arka Sujath and Pusa Nasdar (check). 'Thar

'Karni' originated from an open pollinated local landrace (AHRG-29; IC-0621468) collected from farmer's field. The collected germplasm was screened during summer season over the years for horticultural attributes with special reference to high temperature tolerance. Among the population of AHRG-29, identified and selected phenotypically superior plants based on horticultural attributes with special reference to high temperature and biotic stress tolerance. The selected plants were self pollinated and harvested the seed separately. Homogenized the selected progeny through self pollination exercising single plant selection and evaluated over the years during summer seasons of 2012 to 2014.

The experiments were carried out at Research Farm of Central Institute for Arid Horticulture, Bikaner, Rajasthan (India) located at 28°N latitude, 73°18'E longitude at an altitude of 234.84 m above sea level during summer season of 2012 to 2014 in randomized block design with three replications. The soil of experimental field was loamy sand with a pH of 8.7, EC 0.20 dS m⁻¹ and organic carbon 0.07 per cent. The spacing maintained between rows was 2.0 m and between plants 50 cm. The experiments were raised on drip irrigation system in second fortnight of February. Fertilization, irrigation, other cultural practices and need based plant protections measures were followed as recommended for commercial production. The mean monthly minimum and maximum temperature was recorded from sowing to last harvest of the crop (February-June) which varied from 5.84°C in February, 2012 to 43.64 °C in June, 2014 (Fig. 1.)

The observations were recorded on five randomly selected plants from each replication for flowering, yield and yield contributing traits. Among flowering traits, the observation were recorded on node at which 1st female flower appeared, ovary length (cm) and days to produce 50% female flower were recorded. Among yield and its components, fruit length (cm), fruit diameter (cm), fruit weight (g), number of marketable fruits/ plant and fruit yield (q/ ha) were assessed. Screening against mosaic disease and infestation of melon fruit fly (*Bactrocera cucurbitae*) was done under filed conditions during summer season of 2013 and 2014. The categorized of genotypes for fruit infestation of melon fruit fly was done following the rating system given by Nath 1966) as: immune (no damage), highly resistant (1-10%), resistant (11-20%), moderately resistant (21-50%), susceptible (51-75%) and highly susceptible (76-100%). (Data on disease incidence of mosaic symptoms were recorded during growth period of the crop. The reaction for resistance due to mosaic disease was categorized following disease rating scale suggested by Singh *et al.* (2007) with some modifications as immune (0% symptom), tolerant (0.1-10% symptoms), moderately resistant (10.1-25% symptoms), susceptible (25.1-50% symptoms) and highly susceptible (>50% symptoms). The recorded data were statistically analysed using the INDOSTAT statistical package (Indostat Services, Hyderabad).

Results and Discussion

The results showed highly significant differences among seven genotypes of ridge gourd for flowering, yield

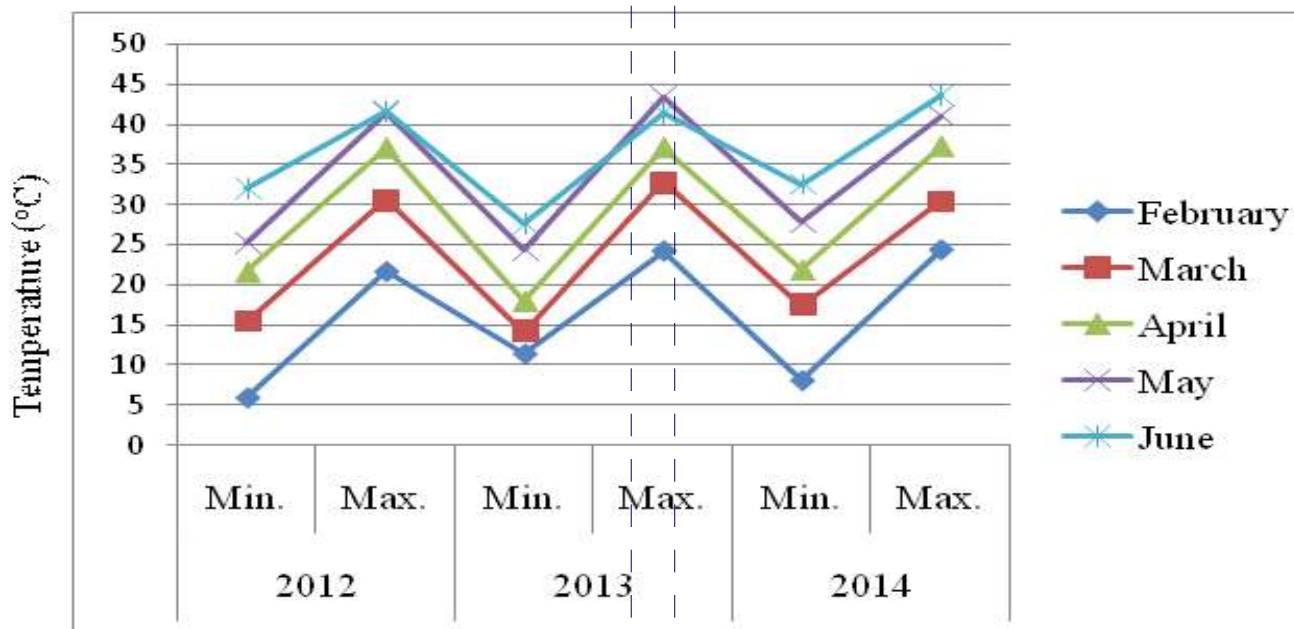


Fig. 1: Mean monthly minimum and maximum temperature

and yield contributing characteristics. The results presented in Table 1 indicated that 'Thar Karni' produced female flower on lower nodes (12.00-13.27) in 47.83-50.00 days after sowing. The length of ovary (6.19-6.72 cm) was found to be significantly superior over all genotypes and check (5.04-5.47 cm). The new variety was found to be superior to other popular varieties in terms of yield attributing traits (Table 2) such as fruit length (20.19-22.45 cm) and number of marketable fruits/plant (19.67-22.40). Whereas, it was comparable to other popular varieties in terms of fruit diameter (2.81-2.96 cm) and fruit weight (90.18-102.36 g). Among the evaluated entries 'Thar Karni' was found to be able to withstand high temperature which set fruits upto 42°C during April-May under hot arid conditions of Rajasthan. Based on 03 years average (2012, 2013 and 2014), the variety 'Thar Karni' recorded fruit yield of 151.87 q/ ha which is 31.44% higher over Arka Sujath and 37.56% over check i.e. Pusa Nasdar (Table 3). Earlier, Choudhary and Kumar (2011), Choudhary *et al.* (2014) and Varalakshmi and Krishnamurthy (2017) reported significant variation among fruit traits in ridge gourd.

The data presented in Table 4 indicated that 'Thar Karni' showed tolerance to mosaic disease with 7.50% incidence under field conditions during summer season of 2013 and 2014. Whereas, rest all genotypes including Pusa Nasdar (check) depicted moderately resistant against mosaic disease. Fruit infestation by melon fruit fly in 'Thar Karni' ranged from 17.70% in 2013 to 17.65% in 2014 under field conditions and categorized as resistant (Table 5) which is at par with Pusa Nasdar (18.27%). The resistance against melon fruit fly impart due to presence of high tannin content (8.93 g/ 100 g), flavonoid content (2.24 mg/ 100 g), phenol content (69.27 mg/ g), ascorbic acid content (483.71 mg/ 10 g), fibre content (1.49 g/ 100 g) and low level of free amino acid (3.81 mg/ g) on dry weight basis in Thar Karni (AHRG-29) variety of ridge gourd as reported by Haldhar *et al.* (2015). Based on the performance and superiority over check, AHRG-29 has been identified as variety 'Thar Karni' by the Institute's Variety Identification Committee in 2015. Being tolerant to high temperature, it would fulfil the requirement of ridge gourd growers in arid and semi-arid regions.

Table 1. Flowering traits of ridge gourd genotypes during summer seasons

Entries	Node at which 1 st female flower appeared			Ovary length (cm)			Days to produce 50% female flower		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
Thar Karni	13.27	12.67	12.00	6.26	6.19	6.72	47.83	48.67	50.00
AHRG-30	13.47	15.00	14.13	5.37	4.77	4.64	53.00	52.00	56.50
AHRG-31	17.76	18.90	17.27	4.21	4.87	4.58	52.17	51.50	52.67
AHRG-33	14.93	13.53	15.47	4.67	4.83	5.07	49.00	50.00	54.00
AHRG-47	20.27	17.80	18.13	5.20	5.94	5.60	55.17	55.33	55.67
Arka Sujath	15.87	14.17	13.47	4.87	5.10	5.20	49.00	53.33	54.00
Pusa Nasdar (C)	15.20	15.27	15.43	5.04	5.23	5.47	50.50	53.50	54.50
SEm±	1.24	1.00	1.06	0.37	0.30	0.41	1.49	1.29	1.17
CD at 5%	3.83	3.08	3.27	1.13	0.93	1.25	4.59	3.96	3.61
CV (%)	13.63	11.31	12.15	12.54	9.94	13.22	5.06	4.28	3.77

Table 2. Yield contributing traits of ridge gourd genotypes during summer seasons

Entries	Fruit length (cm)			Fruit diameter (cm)			Fruit weight (g)			No. of marketable fruits/plant		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Thar Karni	21.07	20.19	22.45	2.96	2.81	2.85	102.36	90.18	94.69	21.03	22.40	19.67
AHRG-30	24.40	24.21	23.29	3.57	2.52	2.91	94.94	77.75	81.53	17.73	15.47	16.73
AHRG-31	20.80	17.81	19.43	3.60	3.30	4.02	75.73	69.29	75.16	17.33	18.33	18.43
AHRG-33	22.79	20.98	21.15	3.70	3.19	3.09	95.40	84.26	98.86	18.47	17.73	17.07
AHRG-47	20.53	18.04	18.11	3.63	2.70	2.98	92.30	72.31	91.27	19.10	15.53	14.13
Arka Sujath	18.86	19.43	19.45	4.20	3.80	3.46	104.98	94.40	105.35	15.63	15.60	14.33
Pusa Nasdar (C)	21.10	19.93	20.26	3.34	2.84	3.22	95.54	92.11	97.93	15.07	15.23	13.20
SEm±	1.01	1.21	0.97	0.21	0.18	0.22	4.86	4.40	5.26	1.10	1.07	1.78
CD at 5%	3.10	3.72	2.98	0.65	0.55	0.69	14.96	13.55	16.22	3.40	3.31	3.63
CV (%)	8.16	10.42	8.13	10.31	10.29	12.12	8.90	9.19	9.90	10.76	10.83	12.57

Table 3. Fruit yield of ridge gourd genotypes during summer seasons

Entries	Fruit yield (q/ ha)			
	2012	2013	2014	Average
Thar Karni	148.35	156.38	150.88	151.87
AHRG-30	98.44	102.43	106.16	102.34
AHRG-31	88.88	96.41	100.88	95.39
AHRG-33	111.99	106.58	111.15	109.91
AHRG-47	108.24	94.20	103.61	102.02
Arka Sujath	117.32	111.47	117.53	115.44
Pusa Nasdar (C)	114.88	103.80	112.52	110.40
SEm+	8.83	8.13	9.38	-
CD at 5%	27.20	25.05	28.90	-
CV (%)	13.58	12.78	14.17	-
% increase over Arka Sujath	26.45	40.29	28.38	31.44
% increase over Pusa Nasdar (C)	29.13	50.66	34.09	37.56

Table 4. Incidence of mosaic disease in ridge gourd genotypes

Entries	% incidence of mosaic disease during summer seasons*			Category
	2013	2014	Pooled	
Thar Karni	5.00 (12.87)	10.00 (18.27)	7.50 (15.82)	Tolerant (T)
AHRG-30	20.00 (26.52)	11.67 (19.89)	15.83 (23.42)	Moderately resistant (MR)
AHRG-31	25.00 (29.96)	12.50 (20.58)	18.75 (25.60)	MR
AHRG-33	25.00 (29.85)	20.00 (26.53)	22.50 (28.29)	MR
AHRG-47	25.00 (29.90)	20.00 (26.51)	22.50 (28.26)	MR
Arka Sujath	10.00 (18.40)	12.50 (20.60)	11.25 (19.57)	MR
Pusa Nasdar (C)	16.67 (23.83)	5.00 (12.52)	10.83 (19.16)	MR
SEm+	1.65	1.72	0.99	-
CD at 5%	5.15	5.37	3.07	-
CV (%)	11.70	14.42	7.47	-

*Values in parentheses are angular-transformed

Table 5. Per cent fruit infestation by melon fruit fly in ridge gourd

Entries	Fruit infestation (%) during summer seasons*			Category
	2013	2014	Pooled	
Thar Karni	17.70 (24.85)	17.65 (24.81)	17.67 (24.83)	Resistant (R)
AHRG-30	55.70 (48.26)	55.63 (48.22)	55.67 (48.24)	Susceptible (S)
AHRG-31	79.80 (63.55)	79.63 (63.40)	79.72 (63.47)	Highly susceptible (HS)
AHRG-33	67.73 (55.37)	67.77 (55.39)	67.75 (55.38)	S
AHRG-47	77.83 (62.21)	77.67 (62.05)	77.75 (62.13)	HS
Arka Sujath	29.93 (33.15)	30.23 (33.34)	30.08 (33.25)	Moderately susceptible (MR)
Pusa Nasdar (C)	18.30 (25.31)	18.23 (25.26)	18.27 (25.29)	R
SEm+	2.06	1.92	1.99	-
CD at 5%	6.42	5.99	6.20	-
CV (%)	7.99	7.46	7.72	-

*Values in parentheses are angular-transformed.

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Evaluation of male date palm (*Phoenix dactylifera* L.) for pollen grain production under arid conditions

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(Received: 17.07.2018; Accepted: 01.09.2018)

Abstract

In date palm cultivation, pollen grains play an important role for fruit set, maturity, fruit yield and quality. It is a dioecious plant and pollination is essential for proper fruit set. The farmers of the arid region are facing problem of pollen grains due to lack of sufficient number and superior type of male plants. Further, it was observed that due to climatic conditions, since last 2-3 years emergence of spathe is late in males than female palm. The objective of the study was to identify superior genotype of male date palm for pollen production. Four elite male palms grown at Date palm experimental block, CIAH farm were evaluated during the year 2016-17 for emergence, number of spathes, size of spathe and pollens yield/spathe under hot arid environment. The amount of pollen produced per spathe varied among male palms. The size of spathe was also differed significantly from one male to another male palm. The pollen production ranged from 17.2 g to 25.0 g per spathe. The study revealed that CIAH/DP/M-03 male plant produced highest amount of pollen grains (643g/tree) followed by CIAH/DP/M-01 (578g/tree) under arid conditions.

Key words: Date palm, male, spathes, pollen grains, pollination, fruit set,

Introduction

Date palm (*Phoenix dactylifera* L. Family-Arecaceae) also known as *Khajoor*, *Kharek* is an ancient fruit tree of semi-arid and arid regions of the world. It grows well under poor desertic soils due to its hardy plant characteristics and deep root system. Date palm is dioecious and cross pollinated crop. It requires dry hot climate for growth and development of fruits (Zaid, 1999). It can be grown at such places where adequate irrigation facility is available besides other climatic requirements (Chandra *et al.*, 1992). Its delicious fruits at *doka* (khalal) stage are eaten as fresh and also used for preparation of several value added products (Singh *et al.*, 2004). Moreover, all plant parts of date palm are useful since its history of cultivation (Chao and Krueger, 2007) in several ways to make handicraft items. Its seed kernel is used for animals and fish feed.

The extremely dry hot areas comprising Jaisalmer, Barmer, Bikaner and Jodhpur in Rajasthan, Bhatinda, Fazlika, Abohar in Punjab, Sirsa, Hisar, Mahendergarh, Bhiwani in Haryana and Kachchh region in Gujarat are the potential areas for date palm cultivation in India. In Rajasthan, earlier area of date palm cultivation was about 50- 60 hectare, now 850 ha area is under cultivation by planting of imported tissue culture plants in districts of Jaisalmer, Barmer, Jodhpur, Churu, Sri Ganga nagar, Hanumangarh and Bikaner by Rajasthan Horticulture Development Society. The naturally grown date palm seedling is available in coastal areas of Gujarat as grove in depressions, on riverbank, *nala* and boundary of field/farms (Singh *et al.*, 2004; Murlidharan *et al.*, 2008). These seedling populations include female and male plants. The estimated

area under date palm cultivation is 18847 ha. with production 173997.66 MT during the year 2017 in Kachchh region, Gujarat (Bhuj, Anjar, Khedoi, Mundra, Mandavi and Jamnagar).

The male date palm is also important like female plants for production of pollen grains as well as avenue tree. Looking to its potential, new date palm plantation has done in arid region of Rajasthan, Gujarat and other parts of the country. Being dioecious nature, male and female flowers borne on tree separately. Male and female plants are identifying only at flowering stage and about 5% male plant is required for pollination. However, availability of pollen grains is one of the emerging constraints in date palm cultivation area due to lack of sufficient male trees. Identification of elite male and further multiplication is essential to meet out present pollen demand and conservation of pollen is also desirable. About 10- 20g pollen grains are normally required for pollination of a full grown tree. Keeping in view, the present study was undertaken to identify suitable date palm male tree for early flowering and high pollen grains yield under hot arid conditions.

Material and Methods

The study was carried out on different 4 elite type male palms at CIAH, Bikaner for pollen production potential. The historical and morphological back ground of male tree under taken for study is given. The date palm seeds procured from Iran, Iraq, Mundra (Gujarat), Bikaner (Rajasthan) were sown in nursery to raise saplings. The saplings were planted in the field for evaluation. In general the 50:50 sex ratio of male and female palm have been reported in seedlings. The full

grown tree between age of 10-12 were taken for study. These plants were maintained with common cultural practices. Looking to the importance of the male tree, it was studied for pollen production during 2016-17. The observations on emergence of spathe, time taken for opening of spathe, size of spathe, pollen grains yield per spathe as well as per tree was recorded. The number of spathe emerged per tree was counted and observations on size (length x width) were observed of three spathes. For pollen yield, spathes were cut down at opening time and kept on paper under shade condition for drying. The weight of dried pollen was measured and data was analysed statistically.

Results and Discussion

Data on spathe emergence, opening and days taken for flowering in male palm in relation to pollen grains yield is given in table 1 and 2.

Variability in male date palm: The natural seedling population of date palm is available in coastal belt of Kachchh region of Gujarat in India and pollen grains are collected from male plants by farmers for pollination (Singh *et al.*, 2004). In other parts of country, seedling population is very less. At CIAH, Bikaner, 4 genotypes were marked elite tree in field repository collected from different available sources (Table 1). The seedlings of date palm were evaluated for spathe size, days taken for opening of spathes and pollen production. The variation in spathe size, days taken for opening of spathes was observed in male seedlings. The variation in days taken for opening of spathes ranged from 18-29 days. The opening of spathe also depends on climatic conditions of the region. Similar findings have also reported by Shaheen (2004).

Based on varietal performance under Indian

conditions, the varieties have been recommended for cultivation for different regions. It has been noted that frequency of pollination and fruit set differed from variety to variety. In case of Medjool pollination is easy and required less pollen for better fruit set. The problem of fruit set and fruit drop also observed in tissue culture plantations according to feedback information of the growers in western Rajasthan. It may possibly be due to flowers opening time, receptivity of stigma, viability and germination of pollen grains besides environmental factors.

Spathe emergence and opening: Flowering takes place from January to March months depending upon agro-climatic conditions of the region and varieties. It is dioecious in nature and the identification of sex (male or female) of seedling palm trees is possible only after the trees start flowering and thus there remains equal possibility of male and female sex of seedling palm trees. In North India, flowering starts after winter season *i. e.* with the start of spring season. Flowering is preceded by spathe initiation. The spathe initiation is governed by various factors such as cultivar, place of cultivation, temperature, management practices and other climatic conditions prior to spathe initiation. The floral characteristics in male date palm have studied by Mohammad *et al.* (2009) and reported their effect on fruiting. Under Bikaner conditions, spathe emergence starts from last week of January and completed at the end of February and beginning of March. It has been observed since last two- three years that prolonged winter delays 10-15 days the spathe emergence. The spathe initiation commenced early in male then female plants. However, the duration of emergence of spathe and flowering varied in different varieties. A palm tree usually bears 2-14 spathe/tree depend on age of plant and cultural practices

Table 1. Evaluation of male date palm genotypes under hot arid conditions

S.N	Male date palm genotype	Age of tree (years)	Date of spathe emergence	Date of opening of spathes	Days taken for opening
1	CIAH/DP/M-01	13	11.1.17	10.2.17	29
2.	CIAH/DP/M- 02	10	12.2.17.	04.3.17	19
3.	CIAH/DP/M -03	12	06 .2.17	01.3.17	23
4.	CIAH/DP/M -04	12	10.2.17	28.2.17	18

Table 2. Evaluation of male date palm genotypes for pollen production.

S. No.	Male date palm genotype	Length of spathe (cm)	Width of spathe (cm)	No of spathe /plant	Weight of pollen/ spathe (g)	Pollen grains yield /plant (g)
1	CIAH/DP/M- 01	45.00	16.60	27.20	21.00	578.6.0
2.	CIAH/D/PM -02	36.60	15.62	18.60	20.20	443.00
3.	CIAH/DP/M -03	34.80	15.60	25.00	25.00	643.60
4.	CIAH/DP/M-04	41.00	19.00	22.00	17.20	379.80
SEm+		0.77	0.56	0.44	0.38	3.36
CD at 5%		2.34	1.71	1.35	1.15	10.18

employed.

Production of Pollens: The production of pollen grains greatly varied from one plant to another male plant and varieties. It also depend on age of tree and number of spathe emerged out. The size of spathe also influenced the amount of pollen grains. It has been observed on farmer's field in western Rajasthan that Ghanami male produced more pollen grains in comparison to Al Ain City (Madsari) male variety. The data on spathe size, number of spathe per plant and yield of pollen grains varied significantly among male genotypes studied (Table-2). The number of spathe per plants was significantly higher in CIAH/DP/M-01 followed by CIAH/DP/M-03. The significantly higher yield of pollens per plant was recorded in CIAH/DP/M-03 (643g/tree). The morphological variation in male palm has observed which may possibly due to plants originated from seeds. The morphological differences in male palms were observed during evaluation of pollen grains germination, viability and chemical composition by Aly (2018). The variation of number of spathe /plant and production of pollen per spathe varied from 17-25g. The finding is similar with the results obtained by Shaheen (2004) in male date palm plants.

Pollination and storage of pollens: Pollination in female palm trees is done manually as it is a dioecious plant and for that strands of freshly opened male inflorescence is cut from the tree. Male strands kept on female palm inverted for pollination. It is necessary to tie the pollinated inflorescence with up knot to hold male strand in pollination. Another method of pollinating female clusters consists of dusting of pollens on it within 2 days of anthesis. It should be done in morning hours for obtaining better fruit set. If pollens are in short supply, it may be mixed with talc powder. Few Farmers covers the female spathe after doing pollination with brown paper bags for better fruit set. Fruit set depends on viability and germination of pollen grains. Pollen can be stored at under refrigerated conditions at 4 °C and deep freez (-20 °C) for next season use (Ateeyeh, 2012). Due to environmental factors, some time spathe in male palm opens late than female and problem arise about availability of pollen for pollination in time. The pollen grains can be stored under proper storage temperature conditions to maintain its viability for pollination. The difference in viability of pollen stored under different temperature was observed by Maryam *et al*, (2015). It can be concluded that elite male should planted in proper ratio for

pollination and better fruiting in date palm. Surplus pollen grains may be stored under refrigerator or deep freeze conditions for next season use. The variation in male palm is due to the fact that the majority of male date palms are originated from seeds. An elite male palm (CIAH/DP/M-03) was found superior in respect of pollen production than other genotypes. The viability of pollen grains should also be tested before the use for pollination. The study reveals that elite male should be identified and multiplied to meet out pollen grains requirement.

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Study on changes of nutritional quality of different *karonda* (*Carissa carandas*) processed products during storage

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(Received: 13.02.2017; Accepted: 23.04.2018)

Abstract

Karonda is an important crop indigenous to India which is used in alternative medicine, health foods and herbal products. It has good potential in processed forms but little information is available on changes of nutritional quality of different karonda processed products during storage. Therefore, the present investigation was carried out to study the changes of nutritional quality of different karonda processed products during storage. Four products were made from karonda viz., jelly, jam, candy and squash, stored for 120 days and analyzed biochemically. The four months storage study revealed that across all the products the total soluble solids, acidity, reducing sugar, total sugar and browning was found to increased significantly from the initial mean values of 67.5 °Brix, 0.35%, 25.9%, 61.7% and 0.38 O.D. of fresh products to the final value of 74.2 °Brix, 2.11%, 31.8%, 63.3% and 0.44 O.D. at the end of storage, respectively. While, the non reducing sugar, ascorbic acid, moisture content and anthocyanin content of various karonda products were decreased significantly from the initial mean values of 33.6%, 3.53 mg/100g, 4.86%, and 2.39 mg/100g of fresh products to the final value of 29.4%, 1.76 mg/100g, 1.83%, and 0.99 mg/100g at the end of storage, respectively. Across all the products, an increasing trend in bacterial and fungal count was recorded up to 120 days of storage as compared to fresh products. Minimum bacterial (1.84×10^5 cfu/g) and fungal count (2.09×10^4 cfu/g) was obtained in fresh products and it was increased to 7.37×10^5 cfu/g bacteria and 9.78×10^4 cfu/g fungi in 120 days of storage.

Key words: Karonda, nutritional quality, processed products, storage

Introduction

Karonda (*Carissa carandas* L.) is an underutilized indigenous fruit crop of India, thrives well throughout tropics and sub-tropics of the world and arid and semi-arid areas of the country. It can also flourish well on problematic soils, particularly on highly saline and alkaline soils. Fruit is slightly sour and astringent in taste, therefore, it is not popular as dessert fruit but it is rich source of essential vitamins and minerals required for adequate human health. It is rich source of iron and vitamin C and therefore, very useful for curing anemia and has antiascorbutic properties. The ripe fruit have antioxidant properties and reported to be useful in bilious (Watt, 1972), cough, diabetes, leprosy, anemia and intestinal worming (Vasu, 1986).

Besides its nutritional and medicinal importance, the karonda fruit has good potential of processing and has potential for export as fresh fruits and processed products such as preserve jam, candy, juices, pickles etc (Chandra and Jindal, 2001). Karonda becomes ready for harvesting from mid November to first week of January. Since, it is a perishable commodity, it needs quick disposal. The post harvest losses in karonda vary from 30-40 %. Huge harvest of the produce during peak harvesting season creates glut and the growers are

compelled to sale their produce at low prices which reduces the markets value of the fruit. Hence, value addition through processing would be the only effective tool for economic utilization of karonda. Besides, being acidic in nature karonda is not consumed as fresh and not popular as table fruit. Since, karonda is a seasonal fruit, its preservation in different products is necessary to avoid its spoilage and to make its availability round the year (Parvathi and Anby, 1997). Both unripe and ripe fruits are processed into a number of value added products.

The storage of fresh karonda fruits for longer time is not quite feasible. Therefore, storage in the form of processed products is more feasible. Also, longer shelf life of value added products of karonda (candy, squash, jelly and jam) is important from consumers and marketing point of view. Little attempts have been made to study the shelf life of processed products of karonda fruit. Keeping these points in view, the present investigation was undertaken to study the storage stability, non-enzymatic browning, anthocyanin content and microbial growth in processed products of karonda.

Materials and Methods

The present investigation was conducted at the Post-

harvest Technology Laboratory, Department of Horticulture and Food Processing, Uttar Pradesh, Saharanpur, India, during June to November, 2007 and 2008. Healthy and matured karonda fruits of two genotypes viz., 'White with Pink blush' and 'Green with Purple blush' were used in experiments. The data of the experiment was statistically analyzed using randomized block design with three replications. In case of two treatments, sample means were compared using the 't' test (Chandel, 1991). One kilogram mature fruits each of 'Pink with White blush' and 'Green with Purple blush' genotypes were taken for assessing the biochemical analysis. For biochemical analysis, fruit pulp from both genotypes was taken for estimating various parameters like total soluble solids (TSS) (°Brix), acidity (%), ascorbic acid (mg/100 g), moisture content (%), reducing sugar (%), non-reducing sugar (%), total sugar (%) and anthocyanin (mg/100 g). TSS was determined by hand refractometer. The acidity was measured by using standard solutions of pH 4.0 and 7.0 as reference to calibrate. The ascorbic acid content of karonda pulp was estimated by visual titration method (Freed, 1966) and the moisture content was determined according to AOAC (1970) method. Reducing sugar, non-reducing sugar and total sugars were estimated by volumetric method (Gauri Shankar, 1999). Total anthocyanins were determined by the procedure of Fuleki and Francis, 1968.

Four products were made from karonda viz., candy, squash, jelly and jam. Different processed products were prepared by standardized recipes. Glass bottles were used as packaging material for storage of jelly, jam, candy and squash for different periods. Karonda products were stored for 120 days at ambient temperature and the biochemical and microbial analysis was done at each month interval. Both bacterial as well as fungal counts were done at each storage periods. Serial dilutions of the processed products were made using sterilized buffer medium. Products (Jelly, Jam, Candy and Squash) were diluted to four dilutions 10^1 , 10^2 , 10^3 and 10^4 for bacterial and three dilutions 10^1 , 10^2 and 10^3 for fungi. A sample of 1.0 ml from each dilution was transferred into sterilized Petri-plates containing 20 ml solidified media and spread uniformly over the entire surface with the help of sterilized bent glass rod. The petri plates were allowed to dry at least for 15 minutes prior to inversion of Petri plates in B. O. D.

for incubation at 30°C for 24 hours. After 24 hours of incubation, the population of bacteria and fungus were counted and it was expressed as colony forming unit (cfu) per g of sample as per following formula-

Organism c.f.u/g of sample = No. Of colonies (Avg. of 3 replicates)/ Amount paired x dilution

Result and Discussion

Biochemical analysis of karonda fruits

Studies on biochemical characters of karonda genotypes showed a significant range of variability in TSS, moisture, reducing sugar, total sugar and anthocyanin content (Table 1). Green with Purple blush genotype was recorded higher TSS (7.27 °Brix), acidity (3.67%), ascorbic acid (14.23 mg/100 g), reducing sugar (4.86%), non-reducing sugar (1.81%), total sugar (6.49%) and anthocyanin content (6.85 mg/100 g) than Pink with White Blush genotype which contains 6.26 °Brix TSS, 3.32% acidity, 12.26 mg/100g ascorbic acid, 4.02% reducing sugar, 1.51% non-reducing sugar, 5.36% total sugars and 2.47 mg/100 g anthocyanin. Pink with White Blush genotype was recorded highest moisture (77.52 %) than Green with Purple genotype containing 70.52 % moisture. The differences in chemical characters of fruits in present investigation may be due to the differences in locations, fruit maturity and genotypes (Singh *et al.*, 2006).

Storage stability of processed products of karonda

Total Soluble Solids (TSS)

The data (Table 2) indicate that TSS of candy, squash, jelly and jam increased slightly during storage. The TSS content in the original fruit was found to be 6-7 °Brix and the moisture content in fresh fruit was 70-80%. However, the average TSS content of the processed products (candy, squash, jelly and jam) during storage was found to be increased from 67.4 °Brix of fresh to 74.2 °Brix at 120 days of storage. Maximum mean TSS content of all the four products (74.2 °Brix) was recorded at 120 days of storage period and it was

Table 1. Biochemical character of karonda genotypes (mean of 2 years)

Genotypes	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100 g)	Moisture Content (%)	Reducing Sugar (%)	Non-Reducing sugar (%)	Total Sugar (%)	Anthocyanin (mg/100 g)
Green with Purple Blush	7.27	3.67	14.23	70.52	4.86	1.82	6.49	6.85
Pink with White Blush	6.26	3.32	12.26	77.52	4.02	1.51	5.36	2.47
Mean	6.77	3.5	13.25	74.02	4.44	1.67	5.93	4.66
Observed value of t	14.82	1.74	4.01	14.82	4.91	2.53	4.13	9.13
Table value of t at 5%	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03
Result	S	NS	NS	S	S	NS	S	S

10.0% higher over initial (0 days) mean TSS content of the products (67.4 °Brix). Hydrolysis of polysaccharides of processed products of fruits during storage may be possible reason for increase in TSS. Dhawan and Gupta (1996) also reported a significant increase in TSS in storage, which might be due to the conversion of some of the insoluble fraction into soluble fraction.

Acidity

The results indicate that titrable acidity of various karonda products increased significantly during storage (Table 3). On comparing the acidity of different products with the fresh fruit, it was found that there was general loss in acidity due to processing. On the basis of mean values, at the end of storage period the maximum acidity was recorded in jelly (3.74%) and the minimum in squash (1.34%) which was 1000 and 415.3%, respectively higher over their initial acidity. Maximum mean acidity of all the four products (2.11) was recorded at 120 days of storage period and it was 502.8% higher over initial mean acidity of the products (0.35%). Degradation of pectin substances have been reported for increased acidity in fruit products (Conn and Stumpf, 1976). The significant interaction between different karonda products and storage periods was recorded with respect to acidity.

Ascorbic Acid

The results (Table 4) indicate that ascorbic acid content of various karonda products decreased significantly during storage. In general the processing of the fruits through various recipes employed for preparation of karonda products (candy, squash, jelly and jam) resulted in remarkable loss of ascorbic acid content from a value of 12 to 14 mg/100 g of fresh fruit to an average value of 3.53 mg/100 g of fresh products. The final products obtained after 120 days of storage were found to contain ascorbic acid ranging from 3.31 to 0.22 mg/100 g. Similarly, the average ascorbic acid content diminished from 3.53 to 1.76 mg/100 g amongst various products. The maximum initial ascorbic acid content was recorded in candy (4.32 mg/100 g) followed by jam (4.25 mg/100 g), squash (2.89 mg/100 g) and jelly (2.68 mg/100 g). On the basis of mean values, at the end of storage period the maximum ascorbic acid was recorded in candy (3.31 mg/100

g) and the minimum in jelly (0.88 mg/100 g) which was 30.5 and 204.5%, respectively reduced over their initial ascorbic acid content. Minimum mean ascorbic acid content of all the four products (1.76 mg/100 g) was recorded at 120 days of storage period and it was 100.6% lower over initial mean ascorbic acid of the products (3.53 mg/100 g). The significant interaction between different karonda products and storage periods was recorded with respect to ascorbic acid content. Reduction in ascorbic acid content could be due to oxidation by trapped oxygen in container which resulted in formation of dehydro- ascorbic acid. Present findings are similar to those of Maciel *et al.* (1999) in acerola jelly and Singh and Singh (1994) in litchi squash.

Moisture content

The results (Table 5) indicate that moisture content of various karonda products decreased significantly during storage. In general, the processing of the fruits through various recipes employed for preparation of karonda products (candy, squash, jelly and jam) resulted in remarkable loss of moisture content from 70-80% of fresh fruit to an average value of 4.86% of fresh products. The maximum initial moisture content was recorded in squash (9.67%) followed by jam (4.33%), jelly (3.25%) and candy (2.41%). On the basis of mean values, at the end of storage period the maximum moisture was recorded in squash (4.22%) and the minimum in jam (0.82%) which was 129.1 and 428.0%, respectively reduced over their initial moisture content. Minimum mean moisture content of all the four products (1.83%) was recorded at 120 days of storage period and it was 165.5% lower over initial mean moisture content of the products (4.86%). After 120 days of storage period the moisture content in candy, squash, jelly and jam was reduced by 104.2, 129.1, 198.1 and 428.0%, respectively over their initial (0 days storage) moisture content. The interaction between products and storage periods was non-significant in terms of moisture content. This decrease in moisture content of the products prepared by various methods was mainly due to evaporation of moisture. Similar findings were also reported by Dhawan and Gupta (1996) in guava jelly and Maciel *et al.* (1999) in acerola jelly.

Table 2. Changes in TSS (°Brix) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					Mean
	0 Day	30 Days	60 Days	90 Days	120 Days	
Candy	76.9	81.9	83.9	86.9	90.9	84.1
Squash	50.0	51.1	51.5	52.0	53.0	51.5
Jelly	69.0	69.7	70.4	71.0	73.0	70.6
Jam	73.9	75.9	77.2	78.9	79.9	77.1
Mean	67.5	69.6	70.8	72.2	74.2	
	A	B	A x B			
S.Ed.	1.12	1.15	2.33			
CD at 5%	2.3	2.3	NS			

Table 3. Changes in acidity (%) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	0.56	0.63	0.65	1.54	1.65	1.01
Squash	0.24	0.51	1.25	1.26	1.34	0.92
Jelly	0.34	2.15	3.42	3.61	3.74	2.65
Jam	0.26	0.62	1.62	1.64	1.70	1.17
Mean	0.35	0.98	1.74	2.01	2.11	
	A	B	A x B			
S.Ed.	0.092	0.091	0.191			
CD at 5%	0.19	0.18	0.38			

Table 4. Changes in ascorbic acid (mg/100 g) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	4.32	4.20	3.71	3.63	3.31	3.83
Squash	2.89	2.54	1.45	1.13	0.22	1.65
Jelly	2.68	2.16	1.89	1.10	0.88	1.74
Jam	4.25	3.70	3.21	3.17	2.61	3.39
Mean	3.53	3.15	2.57	2.26	1.76	
	A	B	A x B			
S.Ed.	0.063	0.081	0.146			
CD at 5%	0.13	0.16	0.29			

Table 5. Changes in moisture content (%) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	2.41	1.85	1.58	1.35	1.18	1.67
Squash	9.67	5.93	5.02	4.82	4.22	5.93
Jelly	3.25	2.78	2.11	1.45	1.09	2.16
Jam	4.33	2.47	1.81	0.98	0.82	2.08
Mean	4.86	3.26	2.63	2.15	1.83	
	A	B	A x B			
S.Ed.	0.523	0.542	1.120			
CD at 5%	1.05	1.09	NS			

Reducing sugar

The results (Table 6) indicate that reducing sugar content of various karonda products increased significantly during storage. In general the processing of the karonda resulted in increase of reducing sugar content from 3-4% of fresh fruit to an average value of 25.9% of fresh products. Data further reveals a gradual increase in reducing sugar content in all the products stored for 0, 30, 60, 90, and 120 days. Mean values of different products at different storage periods were found varied from initially 25.9% to 31.8% at after 120 days. Similarly, mean values of different products (candy, squash, jelly and jam) varied from 9.26% in squash to 40.5% in jam. The maximum reducing sugar content at initial and 120 days of storage period was recorded in jam followed by jelly, candy and squash. After 120 days of storage period the reducing sugar content in candy, squash, jelly and jam was found increased by 18.7, 74.0, 19.7 and 17.9%, respectively over their initial (0 days storage) reducing sugar content. The increase in reducing sugars of products could be due to inversion of non-reducing sugars into reducing sugars.

Similar trend of sugars content was also recorded in date palm jelly (Ali *et al.*, 1990) and pomegranate juice (Waskar and Deshmukh, 1995).

Non-reducing sugar

The non-reducing sugar content of various karonda products decreased significantly during storage (Table 7). In general the processing of karonda resulted in increase of reducing sugar content from 1.3-1.6% of fresh fruit to an average value of 33.64% of fresh products. Data further reveals a gradual reduction in non-reducing sugar content in all the products stored for 0, 30, 60, 90, and 120 days. Mean values of different products at different storage periods were found varied from initial 33.64% to 29.40% at 120 days. Similarly, mean values of different products (candy, squash, jelly and jam) varied from 25.27% in jelly to 41.04% in candy. The maximum non-reducing sugar content at initial and 120 days of storage period was recorded in candy followed by squash, jam and jelly. After 120 days of storage period the non-reducing sugar content in candy, squash, jelly and jam

was decreased by 4.87, 9.55, 28.6 and 23.7%, respectively over their initial (0 days storage) non-reducing sugar content. The decrease in non-reducing sugars of products could be due to inversion of non-reducing sugars into reducing sugars. Similar trend of different sugars content was also recorded in date palm jelly (Ali *et al.*, 1990) and pomegranate juice (Waskar and Deshmukh, 1995).

Total sugar

Total sugar content of various karonda products increased significantly during storage (Table 8). In general the processing of karonda resulted in increase of total sugar content from 5-6% of fresh fruit to an average value of 61.7% of fresh products. Mean values of different products at different storage periods were found varied from initial 61.70% to 63.27% at 120 days. Similarly, mean values of different products (candy, squash, jelly and jam) varied from 44.57% in squash to 70.14% in candy. The maximum total sugar content at initial was recorded in jam followed by candy, jelly and squash while at 120 days of storage period the maximum total sugar content was recorded in candy, jam, jelly and squash which were increased by 3.94, 4.57, 0.85 and 1.48%, respectively over their initial (0 days storage) total sugar content.

Anthocyanin content

The anthocyanin content of various karonda products decreased significantly during storage (Table 9). The processing of the fruits in to processed products resulted in remarkable loss of anthocyanin content from 2 to 7 mg/100 g of fresh fruit to an average of 2.34 mg/100 g of fresh products. The maximum initial anthocyanin content was recorded in candy (4.82 mg/100 g) followed by jam (2.91 mg/100 g), jelly (1.16 mg/100 g) and squash (0.67mg/100 g). While at the end of storage period (120 days), the maximum anthocyanin was recorded in candy (2.39 mg/100 g) followed by jam (1.06 mg/100 g), squash (0.35 mg/100 g) and jelly (0.15 mg/100 g) which were decreased by 101.6, 91.4, 673.3 and 174.5%, respectively over their initial anthocyanin content (0 days storage). Minimum mean anthocyanin content of all the four products (0.99 mg/100 g) was recorded at 120 days of storage period and it was 141.4% lower over initial mean anthocyanin of the products (2.39 mg/100 g). Statistical analysis revealed that the interaction of products and storage periods were

significant with respect to anthocyanin content. It was both the degradation of anthocyanin and formation of hydroxymethyl-furfural was responsible for loss of anthocyanin in sour cheery and blackberry juices during storage (Louvric, 1965).

Nonenzymatic browning in products

An increasing trend in browning was recorded up to 120 days of storage as compared to fresh products (Table 10). The browning of various products (candy, squash, jelly and jam) in different storage periods were significant and the interaction between products and storage periods were also found significant. Minimum mean browning of 0.38 O.D. was observed in freshly prepared products and browning was increased to 0.44 O.D. in 120 days of storage period. At 120 days of storage period the highest browning was observed in candy (0.78 O.D.) followed by jam (0.64 O.D.), jelly (0.21 O.D.) and squash (0.12 O.D.). Similar results were reported during storage by Singh and Singh (1994) in squash of litchi and Ashraf (1987) in jamun jelly. The browning in product develops due to decline in ascorbic acid content of the product (Stadman, 1948). Production of 5-hydroxymethyl; 2-furfuraldehyde in fruit juices from sugar, particularly ketones by heating during processing and caused browning with the reaction of amino compounds and sugars (Diemair and Jury, 1965).

Microbial analysis

Bacterial count

In various products of karonda during different storage periods significant variation in bacterial count was observed (Table 11). An increasing trend in bacterial count was recorded up to 120 days of storage as compared to fresh products. Minimum bacterial count of 1.84×10^5 cfu/g was obtained in fresh products and it was increased to 7.37×10^5 cfu/g in 120 days of storage. The highest bacterial count was obtained in jelly (6.24×10^5 cfu/g) followed by jam (5.61×10^5 cfu/g of sample), squash (3.04×10^5 cfu/g of sample) and candy (1.90×10^5 cfu/g of sample). Interaction between products (candy, squash, jelly and jam) and storage periods (0, 30, 60, 90 and 120 days) was also found significant. The study shows that the sugar used as a protecting agent caused microbial growth in various karonda products. Microbial growth was increased due to improper sanitation practices. Similar

Table 6. Changes in reducing sugar (%) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	25.0	25.9	26.7	27.8	29.6	27.0
Squash	6.8	8.2	8.7	10.8	11.8	9.3
Jelly	34.5	36.3	36.7	38.6	41.3	37.5
Jam	37.6	38.5	40.0	42.1	44.4	40.5
Mean	25.9	27.2	28.0	29.8	31.8	
	A	B	A x B			
S.Ed.	0.44	0.48	1.04			
CD at 5%	0.9	1.0	NS			

Table 7. Changes in non-reducing sugar (%) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	42.0	41.7	41.1	40.4	40.0	41.0
Squash	34.6	33.5	33.3	33.0	31.6	33.2
Jelly	28.1	26.9	24.9	24.6	21.8	25.3
Jam	29.9	28.6	27.5	25.8	24.1	27.2
Mean	33.6	32.7	31.6	31.0	29.4	
	A	B	A x B			
S.Ed.	0.55	0.57	1.19			
CD at 5%	1.1	1.14	NS			

Table 8. Changes in total sugar (%) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	69.0	69.7	69.9	70.3	71.7	70.1
Squash	43.5	43.8	44.1	45.9	45.5	44.6
Jelly	64.7	63.7	65.4	65.4	65.3	64.9
Jam	69.6	69.2	69.6	70.0	70.6	69.8
Mean	61.7	61.6	62.2	62.9	63.3	
	A	B	A x B			
S.Ed.	0.74	0.82	1.64			
CD at 5%	1.5	1.7	NS			

Table 9. Changes in anthocyanin (mg/100 g) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	4.82	4.41	4.23	3.39	2.39	3.85
Squash	0.67	0.56	0.46	0.44	0.35	0.5
Jelly	1.16	0.54	0.36	0.26	0.15	0.49
Jam	2.91	2.7	2.45	2.28	1.06	2.28
Mean	2.39	2.05	1.88	1.59	0.99	
	A	B	A x B			
S.Ed.	0.175	0.132	0.343			
CD at 5%	0.35	0.27	0.69			

Table 10. Non-enzymatic browning (O.D.) in karonda products during storage (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	0.72	0.73	0.76	0.77	0.78	0.75
Squash	0.05	0.07	0.08	0.10	0.12	0.08
Jelly	0.14	0.16	0.20	0.20	0.21	0.18
Jam	0.60	0.62	0.63	0.63	0.64	0.62
Mean	0.38	0.40	0.42	0.43	0.44	
	A	B	A x B			
S.Ed.	0.002	0.002	0.003			
CD at 5%	0.004	0.01	0.01			

findings were reported Kanekar *et al.* (1992) in mango jam. Bacterial count was found to be higher in different karonda products as compared to fungal count.

Fungal count

In various products of karonda during different storage periods significant variation in fungal count was observed (Table 12). An increasing trend in fungal count was recorded up to 120 days of storage as compared to fresh products. Minimum fungal count of 2.09×10^4 cfu/g was obtained in fresh products and it was increased to 9.78×10^4 cfu/g in 120 days of storage. The highest fungal count was obtained in jam (7.49×10^4 cfu/g) followed by jelly (6.85×10^4 cfu/g of sample), squash (4.80×10^4 cfu/g of sample) and candy (2.66×10^4 cfu/g of sample). Data also showed that

significantly highest fungal count was observed in jam stored for 120 days (7.49×10^4 cfu/g) and the lowest in fresh candy (1.13×10^4 cfu/g).

The results of present investigation can be concluded that after four months storage the total soluble solids, acidity, reducing sugar, total sugar and browning was found to increased significantly from the initial mean values across all the products. While, the non reducing sugar, ascorbic acid, moisture content and anthocyanin content of various karonda products were decreased significantly from the initial mean values at the end of storage. Across all the products, an increasing trend in bacterial and fungal count was recorded up to 120 days of storage as compared to fresh products.

Table 11. Changes in bacterial count (per ml/g of sample) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	0.82×10^5	1.12×10^5	1.32×10^5	2.52×10^5	3.72×10^5	1.90×10^5
Squash	0.99×10^5	1.78×10^5	2.58×10^5	4.68×10^5	5.18×10^5	3.04×10^5
Jelly	3.23×10^5	3.53×10^5	5.06×10^5	8.03×10^5	11.33×10^5	6.24×10^5
Jam	2.35×10^5	2.45×10^5	6.15×10^5	7.85×10^5	9.25×10^5	5.61×10^5
Mean	1.84×10^5	2.22×10^5	3.77×10^5	5.77×10^5	7.37×10^5	
	A	B	A x B			
S.Ed.	0.071	0.074	0.142			
CD at 5%	0.14	0.15	0.29			

Table 12. Changes in fungal count (per ml/g of sample) during storage of karonda products (mean of 2 years)

Products (A)	Storage period (B)					
	0 Day	30 Days	60 Days	90 Days	120 Days	Mean
Candy	1.13×10^4	1.33×10^4	2.33×10^4	3.92×10^4	4.63×10^4	2.66×10^4
Squash	2.02×10^4	3.82×10^4	4.72×10^4	6.02×10^4	7.42×10^4	4.80×10^4
Jelly	1.85×10^4	2.45×10^4	6.06×10^4	9.85×10^4	14.05×10^4	6.85×10^4
Jam	3.36×10^4	4.05×10^4	7.95×10^4	9.05×10^4	13.05×10^4	7.49×10^4
Mean	2.09×10^4	2.91×10^4	5.26×10^4	7.21×10^4	9.78×10^4	
	A	B	A x B			
S.Ed.	0.068	0.058	0.132			
CD at 5%	0.14	0.12	NS			

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Antixenotic and allelochemical resistance traits of ber (*Ziziphus mauritiana*) against stone weevil (*Aubeus himalayanus*) in hot arid region of India

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(Received: 10.04.2018, Accepted: 16.07.2018)

Abstract

Plants possess different antixenotic and allelochemical properties, which resultantly induce in them different mechanisms of resistance. The ber varieties/ genotypes Kali, Katha, Illaichi and Tikadi were found to be resistant; Akharota, Dandan, Gola, Goma Kirti, Sanaur-1, Seb, Umran and ZG-3 moderately resistant; Badami, Banarasi Karaka, Gularvasi, Jogia, Kaithli, Mundia, Reshmi, Sanaur-3, Thar Bhuhhraj, Thar Sevika and Thornless susceptible and Banarsi Pebandi, Chhuhara, Sanaur-2, Sanaur-4 and Sanaur-5 highly susceptible varieties/ genotypes against stone weevil. The fruit infestation ranged from 8.80 to 49.44 % on retained fruits and 13.31 to 73.77% on dropped fruits. Tannins, phenols, alkaloids and flavonoids contents had significant negative correlations ($P = 0.01$) with the percentage fruit infestation on retained fruits and the fallen fruits. The pulp: stone ratio was having significant positive correlations ($P = 0.01$) with percent fruit infestation on retained and the dropped fruits. Two principal components (PCs) were extracted with eigen value =1.0, after varimax rotation with Kaiser normalization procedure which converged in three iterations. The extraction communalities for all the variables tested were = 0.5 indicating that the variables were well represented by the extracted PCs which together explained a cumulative variation of 90.75 %. PC1 explained 70.74 % of the variation while PC2 explained 20.01 % of variation. PC1 had the loadings for flavonoid content (0.91), tannins content (0.71), total alkaloid (0.93) and phenols content (0.95). Pulp: stone ratio of different varieties/ genotypes of ber (0.96) were loaded in PC2.

Key words: Ber, antixenotics, allelochemicals, stone weevil, resistance.

Introduction

The ber, *Ziziphus mauritiana* is native to Province of Yunnan in southern China to Afghanistan, Malaysia and Queensland, Australia (Morton, 1987). It is native of South and Central Asia, found throughout the arid and semi-arid tracts. It is cultivated to some extent throughout its natural range on commercial scale and has received much horticultural attention in India (Morton, 1987). *Z. mauritiana* is a gregarious spiny shrub or a small tree, ends of branches curved or drooping. Branches and branchlets armed with short stipular spines. The plant is a vigorous grower and has a rapidly-developing tap root. The richness of the pulp in nutritive compounds has been widely recognised. Nonetheless, there are no definitive values for pulp composition. However ber is richer source of protein, phosphorus, calcium, carotene and vitamin C (Bakhshi and Singh, 1974). The crop is gaining popularity among the growers because of its adaptability to adverse climatic conditions and good returns of yield. The crop is suffered great losses due to insect-pests and diseases (Singh, 2008) and more than 130 species of insect-pests were found to attach the crops in India. Balikai (2009) reported a total of 22 insect and non-

insect species and likewise, Kavitha and Savithri (2002) documented about 23 insect species on ber. In addition to these, the ber stone weevil, *Aubeus himalayanus* Voss (Coleoptera: Curculionidae) appeared to be an emerging pest reported from various region of India (Karuppaiah *et al.*, 2010; Balikai *et al.*, 2013, Haldhar *et al.*, 2012; Haldhar *et al.*, 2013d; Haldhar *et al.*, 2016). The stone weevil is an emerging threat for ber production in India especially in Northern India.

Plants having antibiosis characters such as flavonoids, phenols, tannins, alkaloids *etc.* may cause reduced insect survival, prolonged development time, decreased size and reduced fitness of new generation (Gogi *et al.*, 2010; Haldhar *et al.*, 2013a). Hence such mechanisms of plant resistance have been effectively and widely used for managing insect-pests in fields of horticultural crops (War *et al.*, 2012; Haldhar *et al.*, 2015a; Haldhar *et al.*, 2015b, Haldhar *et al.*, 2017, Haldhar *et al.*, 2018). Direct defenses are mediated by plant characteristics that affect the herbivore's biology such as mechanical protection on the surface of the plants (*e.g.*, hairs, trichomes, thorns, spines and thicker leaves) that either kill or retard the development of the herbivores (Hanley *et al.*, 2007). Identification of ber genotypes/ varieties resistant to stone

weevil had not yet been initiated owing to inadequate information on the sources of plant traits and understanding of the effects of crop variability. The present investigation was undertaken to identify various antixenotics (biophysical structures) and allelochemicals (biochemical compounds) traits of *Z. mauritiana* cultivars associated with resistance to stone weevil infestation under field conditions.

Materials and methods

Survey was conducted at different places of Rajasthan, Maharashtra, Haryana, Delhi, Punjab and different varieties/ genotypes of *Z. mauritiana* were collected. During the survey, trees were selected randomly on the basis of tree spread and height, leaf and fruit characters. In each location three cutting with bud from a single tree were collected, labeled and brought to CIAH farm. The seed of wild ber, *Z. rotundifolia* were used for raising the seedling in the nursery. The collected scion buds were used for shield budding on wild ber seedling rootstocks. Three budded seedlings of each place were planted with a spacing of 6 x 6 m in the field gene bank of ICAR-CIAH farm for establishment. Twenty nine varieties/ genotypes of ber, *Z. mauritiana* were finally selected for conservation, evaluation and resistance study at the field gene bank at experimental farm of ICAR-Central Institute for Arid Horticulture, Bikaner (at 28°06'45.0"N 73°20'52.4"E and altitude of 234.84 m above sea level). All the recommended agronomic practices (e.g. weeding, fertilization, hoeing, etc.) were performed equally in each experimental plant. Twenty fruit were randomly selected in each of 3 replicates and average incidence was calculated as the per cent of fruit infested with *A. himalayanus* during 2015-16 and 2016-17. Based on Kaiser Normalization method, the resistance category was mentioned as immune (no damage), highly resistant (1-10%), resistant (11-20%), moderately resistant (21-50%), susceptible (51-75%) and highly susceptible (76-100%) of all varieties/ genotypes of Indian ber against *A. himalayanus* infestation. Two fresh fruits of each variety/ genotype from each replication were selected, cut into small pieces and dried. For the estimation of biochemicals, the procedures used for each biochemical were flavonoids, phenols, tannins and alkaloid content and the analysis were also determined on the basis of these procedures (Haldhar *et al.*, 2018). Ten marketable fresh fruits of each of the twenty-nine ber cultivars were used to record data on the morphological traits (pulp: stone ratio, fruit surface and stone hardness). The data on percentage fruit infestation, biochemical fruit traits and principal component analysis were analyzed by one-way ANOVA using SPSS 16 software (O'Connor, 2000). The means of significant parameters among tested genotypes were compared using Tukey's honestly significant difference (HSD) tests for paired comparisons at a probability level of 5%.

Result and Discussion

The twenty nine ber varieties/ genotypes were taken for resistance study against stone weevil. The significant differences were found in percentage fruit infestation in

retained and dropped fruits among the tested varieties/ genotypes during study. The varieties/ genotypes Kali, Katha, Illaichi and Tikadi were found to be resistant; Akharota, Dandan, Gola, Goma Kirti, Sanaur-1, Seb, Umran and ZG-3 moderately resistant; Badami, Banarsi Karaka, Gularvasi, Jogia, Kaithli, Mundia, Reshmi, Sanaur-3, Thar Bhubhraj, Thar Sevika and Thornless susceptible and Banarsi Pebandi, Chhuhara, Sanaur-2, Sanaur-4 and Sanaur-5 highly susceptible varieties/ genotypes against stone weevil at ICAR-CIAH, Bikaner. The fruit infestation ranged from 8.80 to 49.44 % on retained fruits and 13.31 to 73.77% on dropped fruits during 2015-16. The per cent fruit infestation was found highest in Sanaur-2 (49.44 % in retained fruit and 73.77 % in dropped fruits) and the lowest in Tikadi (8.80 % in retained fruits and 13.31 % in dropped fruits) followed by Katha (9.07 % in retained fruits and 13.71 % in dropped fruits) during 2015-16 (Table 1). The per cent infestation was recorded highest in Sanaur-2 (49.88 % in retained fruits and 74.16 % in dropped fruits) followed by Sanaur-5 (49.07 % in retained fruits and 72.14 % in dropped fruits) during 2016-17 while minimum per cent infestation was found in Tikadi (9.02 % in retained fruits and 13.57 % in dropped fruits) followed by Katha (9.26 % in retained fruits and 14.04 % in dropped fruits). The fruit infestation was ranged from 9.02 to 49.88 % in retained fruit and 13.57 to 74.16 % in dropped fruits and significantly lowers in resistant varieties/ genotypes and higher in susceptible varieties/ genotypes (Table 2). Plant-arthropod interactions are thought to be of utmost importance for understanding the dynamics of ecological communities (Sarmiento *et al.*, 2011; Han *et al.*, 2016; Haldhar *et al.*, 2018). Plant defense strategies against insect herbivores may involve the synthesis of a plethora of biologically active compounds (allelochemicals), which are phylogenetically conserved in specific plant families or genera (Mithofer and Boland, 2012). Plants frequently display genetic variation within and between population for traits that influence the preference of insects on their hosts that is resistance traits (Johnson and Agrawal, 2005; Haldhar *et al.*, 2013c; Haldhar *et al.*, 2017). Numerous studies have shown that varieties/ genotypes of the same crop species could significantly differ in their resistance to insect-pests (Dhillon *et al.* 2005; Sarfraz *et al.* 2006; Gogi *et al.* 2010, Haldhar *et al.*, 2013a, Haldhar *et al.*, 2013b, Cartea *et al.*, 2014; Haldhar *et al.*, 2015a) and it is effected by biochemical traits of plants. Similar our findings also incorporated with Gogi *et al.* (2010) and Haldhar *et al.* (2015b) that studied and observed the lower fruit infestation and larval densities on resistant varieties/ genotypes of bitter gourd and ridge gourd than on their susceptible varieties/ genotypes.

Tannins, phenols, total alkaloid and flavonoid contents ranged from 123.61 to 222.06 mg/100g, 42.95 to 90.33 mg/100g, 0.52 to 1.48 % and 9.32 to 24.42 mg/100g, respectively with values significantly higher in resistant varieties/ genotypes and lower in susceptible varieties/ genotypes (Table 3). Tannins, phenols, alkaloids and flavonoid contents had significant negative correlations ($P = 0.01$) with the percentage fruit infestation on plant fruits and the fallen fruits (Table 5). The antixenotic fruit traits like fruit surface,

stone hardness and pulp: stone ratio was observed for different varieties/ genotypes of ber. The pulp: stone ratio ranged from 2.12 to 27.13 and was significantly high in susceptible and low in resistance varieties/ genotypes. The highest pulp: stone ratio was found in variety Mundia and least in variety Tikadi. Most of the resistant varieties were having extremely hardy stones and in susceptible varieties the stones were slightly hard (Table 4). The pulp: stone ratio was having significant positive correlations ($P = 0.01$) with percent fruit infestation on retained and the dropped fruits (Table 5). Isoflavonoids isolated from the wild relatives of chickpea acted as antifeedant against *H. armigera* at 100 ppm. Judaicin and maackiain were also found to be deterrent to *S. littoralis* and *S. frugiperda*, respectively (Simmonds and Stevenson, 2001). Flavonoids played a central role in various facets of plant life especially in plant-environment interactions. These defended plants against various biotic and abiotic stresses including UV radiations, pathogens and insect-pests (Treutter, 2006). Tannins had a strong deleterious effect on phytophagous insects and affected the insect growth and development by binding to the proteins, reduced nutrient absorption efficiency and caused midgut lesions (Barbehenn and Peter Constabel, 2011). Phenols acted as a defensive mechanism not only against herbivores but also against microorganisms and competing plants. Qualitative and quantitative alterations in phenols and elevation in activities of oxidative enzyme in response to insect attack was a general phenomenon (Barakat *et al.*, 2010; War *et al.*, 2011; 2015c). Phenols also played an important role in cyclic reduction of reactive oxygen species (ROS) such as superoxide anion and hydroxide radicals, H_2O_2 and singlet oxygen, which in turn activated a cascade of reactions leading to the activation of defensive enzymes (Maffei *et al.*, 2007). Plant structural traits such as leaf surface wax, thorns or trichomes, cell wall thickness and lignifications formed the first physical barrier to feeding by the insect (Agrawal *et al.*, 2009). In these findings, biophysical traits were also found significantly different among tested genotypes (Gogi *et al.*, 2010). The first line of plant defense against insect-pests is the erection of a physical barrier either through the formation of a waxy cuticle (Hanley *et al.*, 2007) and/ or the development of spines, setae and trichomes (Sharma *et al.*, 2009). Chamarthi *et al.* (2011) reported that leaf glossiness, plumule and leaf sheath pigmentation were responsible for shoot fly *A. soccata* resistance in sorghum, *S. bicolor*.

Based upon the above morphological and biochemical characters individually, it was impossible to group the entities as variables were not in agreement to each other. Hence, principal component analysis was performed to achieve parsimony and reduce the dimensionality by extracting the smallest number of components that accounted for most of the variation in the original multivariate data. Taking into consideration five parameters viz., flavonoid content, total alkaloid, tannin content, phenol content and

pulp: stone ratio principal component analysis (PCA) was performed. Two principal components (PCs) were extracted with Eigen value =1.0, after varimax rotation with Kaiser Normalization procedure which converged in three iterations. The extraction communalities for all the variables tested were = 0.5 indicating that the variables were well represented by the extracted PCs which together explained a cumulative variation of 90.75 %. PC1 explained 70.74 % of the variation while PC2 explained 20.01 % of variation. PC1 had the loadings for flavonoid content (0.91), tannins content (0.71), total alkaloid (0.93) and phenols content (0.95). Pulp: stone ratio of different varieties of ber (0.96) were loaded in PC2 (Table 6 & Figure 1). According to Gogi *et al.* (2010) maximum variation in fruit infestation was explained by tannin and flavanol contents whereas, rest of the biochemical fruit traits explained <0.2% variation in the fruit infestation. Haldhar *et al.* (2015a) found that two principal components (PCs) were extracted explaining cumulative variation of 90% in melon fruit fly infestation and length of ovary pubescence, rind thickness, flavonoid content, ascorbic acid, free amino acid, tannins content, and phenols content were the reliable variables for characterization of resistance. Prasad *et al.* (2015) observed two principal components (PCs) were extracted explaining cumulative variation of 76.2%. Seed weight, grain hardness, oviposition, adult emergence, median development period and grain weight loss were the reliable variables for characterization of resistance to *S. oryzae*. The sorghum lines EC 24, EC 22, PEC 8, PEC 7, EP 78, EP 57, AKR 354 were classified as resistant to *S. Oryzae*.

Thus, from the foregoing account, it could be argued that reduction in stone weevil infestations on resistant varieties/ genotypes could be due to antibiosis (allelochemicals) and phenotypics (biophysical). Ber varieties/ genotypes Kali, Katha, Illaichi and Tikadi were classified as resistant to stone weevil and these could be used in future breeding programme as resistant sources. Certain biochemical traits (e.g. flavonoid, tannins, phenols content and total alkaloid) and biophysical traits (e.g. stone hardness, fruit surface and pulp: stone ration) were linked to resistance of ber against *A. himalayanus* and therefore, could be used as marker traits in plant breeding programmes to select resistant varieties/ genotypes.

Acknowledgments

The authors are thankful to Director, ICAR-Central Institute for Arid Horticulture, Bikaner, India, for providing facilities and advice required for experimentation and to R. Swaminathan, Professor, Department of Entomology, MPUAT, Udaipur, India and Majeet Singh, Professor, SKRAU, Bikaner, India for critical discussion and suggestions.

Table 1. Per cent fruit infestation of stone weevil, *Aubeus himalayanus* on different varieties/ genotypes of ber during 2015-16

S. No.	Genotypes	Per cent fruit infestation		Resistance category
		Retained fruits	Dropped fruits	
1.	Akharota	22.63 (28.39)	34.01 (35.66)	MR
2.	Badami	36.27 (36.99)	53.78 (47.15)	S
3.	Banarsi Karaka	25.95 (30.53)	35.09 (36.31)	S
4.	Banarsi Pebandi	45.71 (42.52)	62.60 (52.28)	HS
5.	Chhuhara	43.50 (41.25)	60.43 (51.00)	HS
6.	Dandan	27.39 (31.53)	38.03 (38.06)	MR
7.	Gola	14.41 (22.29)	27.82 (31.82)	MR
8.	Goma Kirti	16.27 (23.73)	30.21 (33.32)	MR
9.	Gularvasi	36.76 (37.31)	57.42 (49.25)	S
10.	Illaichi	9.76 (18.19)	15.49 (23.16)	R
11.	Jogia	36.50 (37.15)	58.57 (49.92)	S
12.	Kaithli	34.31 (35.84)	56.12 (48.50)	S
13.	Kali	10.46 (18.86)	14.79 (22.61)	R
14.	Katha	9.07 (17.52)	13.71 (21.67)	R
15.	Mundia	32.21 (34.56)	49.41 (44.64)	S
16.	Reshmi	31.71 (34.25)	47.64 (43.62)	S
17.	Sandura No. 1	22.63 (28.39)	32.94 (34.98)	HR
18.	Sanaur-1	24.70 (29.79)	29.16 (32.58)	MR
19.	Sanaur-2	49.44 (44.66)	73.77 (59.26)	HS
20.	Sanaur-3	42.84 (40.87)	55.08 (47.90)	S
21.	Sanaur-4	46.01 (42.69)	66.48 (54.72)	HS
22.	Sanur-5	48.89 (44.34)	71.58 (57.78)	HS
23.	Seb	18.72 (25.62)	30.07 (33.24)	MR
24.	Thar Bhubhraj	41.58 (40.14)	60.02 (50.84)	S
25.	Thar Sevika	36.68 (37.26)	54.80 (47.75)	S
26.	Thornless	46.85 (43.18)	63.92 (53.12)	S
27.	Tikadi	8.80 (17.25)	13.31 (21.38)	R
28.	Umrans	17.80 (24.94)	25.63 (30.40)	MR
29.	ZG-3	19.01 (25.76)	28.53 (32.27)	MR
SEm±		0.93	1.21	
LSD (P = 0.05)		2.63	3.43	

*Values in parenthesis are angular-transformed

Value following different letter down the column are R - resistant, MR- moderately resistant, S - susceptible and HS-Highly susceptible

Table 2. Per cent fruit infestation of stone weevil, *Aubeus himalayanus* on different varieties/ genotypes of ber during 2016-17

S. No.	Genotypes	Per cent fruit infestation		Resistance category
		Retained fruits	Dropped fruits	
1.	Akharota	22.38 (28.22)	34.49 (35.94)	MR
2.	Badami	36.66 (37.22)	54.47 (47.55)	S
3.	Banarsi Karaka	26.28 (30.73)	35.54 (36.57)	S
4.	Banarsi Pebandi	46.23 (42.82)	63.08 (52.57)	HS
5.	Chhuhara	44.05 (41.57)	60.92 (51.29)	HS
6.	Dandan	27.78 (31.79)	38.40 (38.27)	MR
7.	Gola	14.72 (22.54)	28.10 (31.99)	MR
8.	Goma Kirti	16.58 (23.98)	30.48 (33.49)	MR
9.	Gularvasi	37.17 (37.55)	57.66 (49.39)	S
10.	Illaichi	10.09 (18.5)	15.66 (23.29)	R
11.	Jogia	36.90 (37.39)	58.99 (50.16)	S

12.	Kaithli	34.88 (36.18)	56.44 (48.68)	S
13.	Kali	10.84 (19.19)	15.10 (22.86)	R
14.	Katha	9.26 (17.7)	14.04 (21.95)	R
15.	Mundia	32.91 (34.98)	49.58 (44.74)	S
16.	Reshmi	32.29 (34.61)	47.74 (43.68)	S
17.	Sandura No. 1	23.33 (28.86)	33.20 (35.14)	HR
18.	Sanaur-1	25.14 (30.07)	29.81 (33.01)	MR
19.	Sanaur-2	49.88 (44.91)	74.16 (59.51)	HS
20.	Sanaur-3	43.14 (41.04)	55.25 (48.00)	S
21.	Sanaur-4	46.57 (43.01)	66.82 (54.93)	HS
22.	Sanaur-5	49.07 (44.44)	72.14 (58.14)	HS
23.	Seb	18.80 (25.68)	30.42 (33.46)	MR
24.	Thar Bhubhraj	41.99 (40.37)	60.63 (51.20)	S
25.	Thar Sevika	36.90 (37.39)	55.20 (47.99)	S
26.	Thornless	47.08 (43.31)	64.25 (53.32)	S
27.	Tikadi	9.02 (17.45)	13.57 (21.60)	R
28.	Umran	17.84 (24.97)	25.84 (30.54)	MR
29.	ZG-3	19.20 (25.89)	28.87 (32.49)	MR
SEm+		1.08	1.22	
LSD (P = 0.05)		3.07	3.47	

*Values in parenthesis are angular-transformed

Value following different letter down the column are R - resistant, MR- moderately resistant, S- susceptible and HS -Highly susceptible

Table 3. Biochemical (allelochemical) fruit traits of different varieties/ genotypes of ber

S. No.	Varieties/ genotypes	Flavonoid content (mg/100g)*	Tannins content (mg/100g)	Phenols content (mg/100g)	Total alkaloid content (%)
1.	Akharota	16.32	179.60 (13.43)	77.73 (8.84)	1.14
2.	Badami	13.29	140.07 (11.88)	55.42 (7.49)	0.62
3.	Banarsi Karaka	15.72	171.60 (13.12)	77.13 (8.82)	1.23
4.	Banarsi Pebandi	10.99	128.99 (11.39)	48.24 (7.01)	0.61
5.	Chhuhara	12.28	122.92 (11.12)	44.22 (6.72)	0.52
6.	Dandan	19.47	159.41 (12.66)	70.71 (8.46)	1.04
7.	Gola	18.36	170.90 (13.11)	79.47 (8.96)	1.15
8.	Goma Kirti	20.35	175.67 (13.28)	77.64 (8.86)	0.93
9.	Gularvasi	15.48	136.42 (11.71)	57.66 (7.66)	0.65
10.	Illaichi	23.65	215.97 (14.72)	87.83 (9.42)	1.36
11.	Jogia	12.86	123.61 (11.15)	58.32 (7.70)	0.64
12.	Kaithli	15.02	137.23 (11.75)	61.40 (7.90)	0.57
13.	Kali	21.74	197.38 (14.07)	80.26 (9.01)	1.44
14.	Katha	24.42	198.14 (14.09)	85.71 (9.29)	1.48
15.	Mundia	12.36	145.96 (12.11)	53.70 (7.40)	0.80
16.	Reshmi	14.40	152.94 (12.40)	56.59 (7.59)	0.67
17.	Sandura No. 1	16.29	154.10 (12.44)	65.54 (8.16)	1.13
18.	Sanaur-1	16.35	160.80 (12.71)	63.95 (8.06)	1.11
19.	Sanaur-2	11.61	115.03 (10.76)	42.95 (6.63)	0.52
20.	Sanaur-3	14.02	144.88 (12.06)	52.28 (7.30)	0.68
21.	Sanaur-4	9.32	123.85 (11.15)	48.81 (7.06)	0.54
22.	Sanaur-5	11.32	116.03 (10.80)	43.58 (6.68)	0.40
23.	Seb	20.28	176.77 (13.32)	76.44 (8.79)	0.99
24.	Thar Bhubhraj	13.03	158.40 (12.62)	53.16 (7.36)	0.67

25.	Thar Sevika	14.10	162.24 (12.76)	56.94 (7.61)	0.71
26.	Thornless	11.35	222.06 (14.93)	45.75 (6.83)	0.54
27.	Tikadi	23.75	200.67 (14.20)	90.33 (9.55)	1.53
28.	Umrans	16.35	169.50 (13.05)	63.97 (8.06)	1.17
29.	ZG-3	18.00	171.74 (13.13)	67.51 (8.27)	1.22
SEm±		0.66	0.36	0.22	0.05
LSD (P = 0.05)		1.88	1.03	0.61	0.14

* Analysis taken on dry weight basis of ber stone

Table 4. Morphological (antixenotic) fruit traits of different varieties/ genotypes of ber

S. No.	Varieties/ genotypes	Pulp: stone ration	Stone hardness	Fruit surface
1.	Akharota	9.46	Medium	Plain
2.	Badami	5.43	Slightly	Ridge
3.	Banarsi Karaka	26.88	Highly	Ridge
4.	Banarsi Pebandi	18.30	Medium	Ridge
5.	Chhuhara	19.42	Slightly	Plain
6.	Dandan	9.51	Highly	Plain
7.	Gola	10.13	Extremely	Plain
8.	Goma Kirti	14.24	Highly	Ridge
9.	Gularvasi	19.83	Medium	Ridge
10.	Illaichi	7.56	Extremely	Ridge
11.	Jogia	12.06	Medium	Ridge
12.	Kaithli	16.64	Medium	Ridge
13.	Kali	6.70	Extremely	Ridge
14.	Katha	6.99	Extremely	Ridge & Wart
15.	Mundia	27.13	Medium	Ridge
16.	Reshmi	11.73	Medium	Ridge
17.	Sandura No. 1	7.31	Highly	Ridge & Wart
18.	Sanaur-1	9.07	Medium	Wart
19.	Sanaur-2	12.91	Slightly	Ridge & Wart
20.	Sanaur-3	15.01	Medium	Ridge
21.	Sanaur-4	15.34	Slightly	Ridge
22.	Sanaur-5	18.31	Slightly	Ridge
23.	Seb	14.25	Extremely	Plain
24.	Thar Bhubhraj	10.78	Slightly	Ridge
25.	Thar Sevika	12.26	Slightly	Ridge
26.	Thornless	10.50	Medium	Ridge
27.	Tikadi	2.12	Highly	Plain
28.	Umrans	6.85	Highly	Ridge
29.	ZG-3	9.77	Medium	Ridge & Wart
SEm±		0.73		
LSD (P = 0.05)		2.06		

Table 5. Correlation coefficient (r) between per cent infestation on retained fruits and dropped fruits along with different allelochemical and antixenotic fruit traits of ber varieties/ genotypes

	Per cent infestation on plant fruit	Per cent infestation on fallen fruit	Phenols content (mg/100g)	Tannins content (mg/100g)	Flavonoid content (mg/100g)*	Total alkaloid content (%)
Per cent infestation on fallen fruit	0.983**					
Phenols content (mg/100g)	-0.947**	-0.928**				
Tannins content (mg/100g)	-0.705**	-0.741**	0.716**			

Flavonoid content (mg/100g)*	-0.924**	-0.916**	0.931**	0.716**		
Total alkaloid content (%)	-0.935**	-0.966**	0.910**	0.726**	0.875**	
Pulp: stone ratio	0.479**	0.496**	-0.421*	-0.481**	-0.504**	-0.474**

**Significant at P = 0.01 (two-tailed)

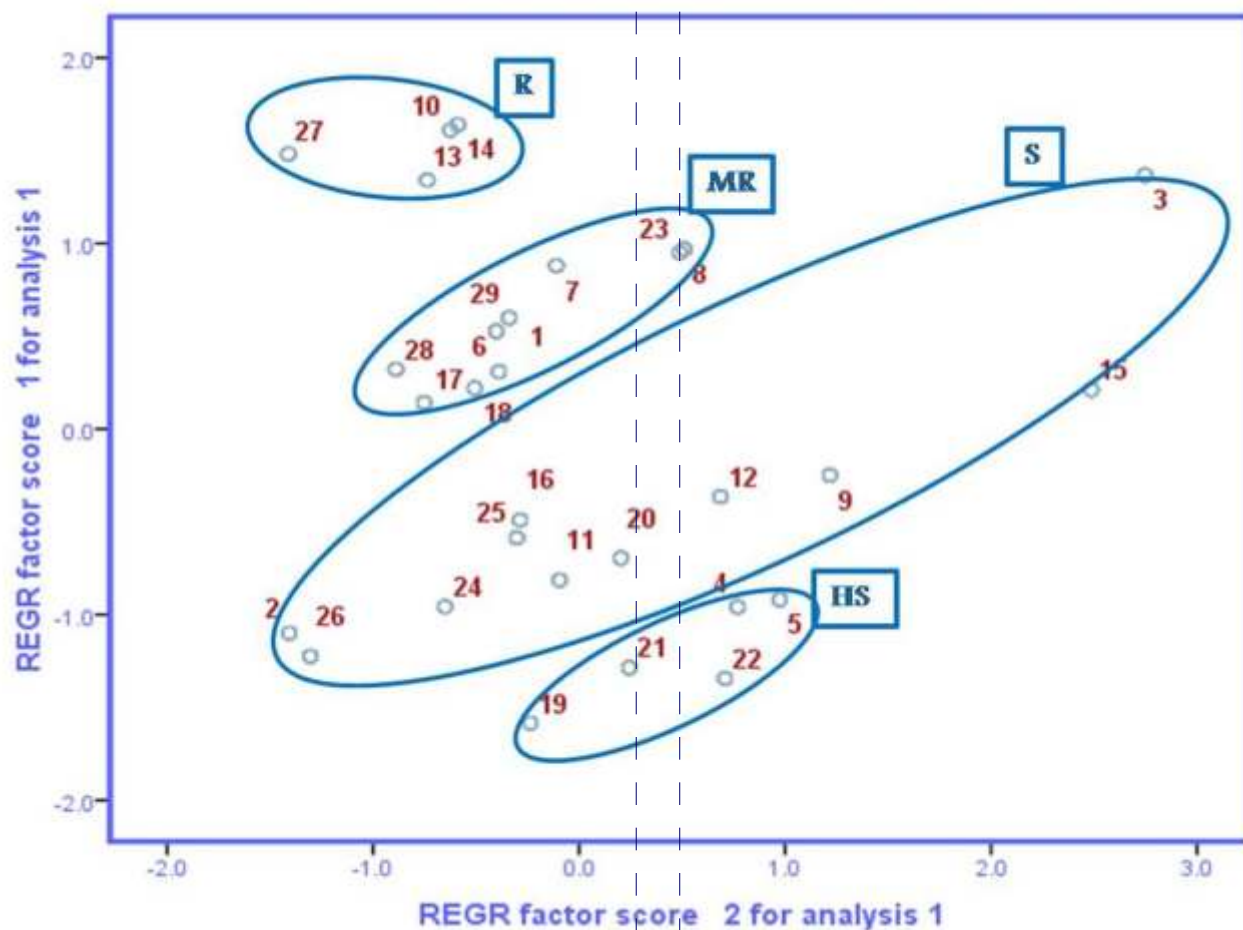
* Significant at P = 0.05 (two-tailed)

Table 6. Component loadings of parameters for resistance against stone weevil, *Aubeus himalayanus* in ber fruits

S. No.	Parameters	Principal components	
		1	2
1	Per cent infestation on plant fruit	-0.95	0.24
2	Percent infestation on fallen fruit	-0.95	0.27
3	Phenols content (mg/100g)	0.95	-0.19
4	Tannins content (mg/100g)	0.71	-0.40
5	Flavonoid content (mg/100g)*	0.91	-0.29
6	Total alkaloid content (%)	0.93	-0.25
7	Pulp: stone ration	-0.24	0.96

Rotation Method: Principal Component Analysis with Varimax with Kaiser Normalization.

Rotation converged in 3 iterations

Fig. 1: Plot of PC1 and PC2 showing clusters of ber genotypes showing resistance to stone weevil, *Aubeus himalayanus*

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Collection, evaluation and improvement of some underutilized fruits in hot Indian desert

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(Received: 28.05.2018; Accepted: 26.07.2018)

Abstract

Underutilized crops have the immense potential to provide social, nutritional and environmental benefits to global community at large and local poor inhabitants in particular. Many underutilized species in arid zone are known for their edible fruits or as vegetables viz. *kair* (*Capparis decidua*), *lasora* (*Cordia myxa*), *jhar ber* (*Ziziphus nummularia*), *pilu* (*Salvadora oleoides*), *khejri* (*Prosopis cineraria*), *phalsa* (*Grewia subinaequalis*), *bael* (*Aegle marmelos*), *karonda* (*Carissa carandas*), *fig* (*Ficus carica*) and *tahiti lime* (*Citrus latifolia*) etc. However, intensive work on germplasm collection, evaluation and improvement was done on *lasora*, *karonda* and *khejri* which resulted in identification of some high yielding genotypes in these crops. In case of *lasora*, 13 germplasm accessions were collected and evaluated from which four high yielding accessions viz. CAZRI-G2025, CAZRI-G2021, CAZRI-G2012 and CAZRI-G2011 were found promising. Among the 8 accessions collected and evaluated in *karonda*, the accessions, CZK-2011, CZK-2022 and CZK-2031 have shown high yield potential. Seven germplasm collections of budded *khejri* including the variety *Thar Shobha* were evaluated for pod quality and yield. The highest pod yield was recorded in CAZRI-Kh-1 (13.2 kg/plant) followed by CAZRI-Kh-2 (11.6 kg/plant) in seventh year.

Key words: Underutilized fruits, evaluation, improvement, selection, *lasora*, *karonda*, *khejri*.

Introduction

Underutilized crops have the potential to provide great social and nutritional benefits to the rural poor as well as the global community at large, and it is increasingly recommended that they are identified, researched and promoted in much the same ways and levels of resourcing as the world's main staple food plants. Under-utilized crops are defined as species with under-exploited potential for contributing to food security, health (nutritional/medicinal), income generation and environmental services. Though, Indian desert is considered very harsh climatically for growing of fruit crops but there are several underutilized fruit species mostly indigenous ones which can be grown successfully either as rainfed or with supplemental irrigation water wherever it is available. The potential underutilized species for arid regions are *kair* (*Capparis decidua*), *lasora* (*Cordia myxa*), *jhar ber* (*Ziziphus nummularia*), *pilu* (*Salvadora oleoides*), *khejri* (*Prosopis cineraria*), *phalsa* (*Grewia subinaequalis*), *bael* (*Aegle marmelos*), *karonda* (*Carissa carandas*), *fig* (*Ficus carica*) and *tahiti lime* (*Citrus latifolia*) etc. *Cordia myxa* L., locally called *gonda*/ *lasora*/ *lehsua* belongs to family Boraginaceae and is found grown all over India except high hills. It is resistant to drought and hence quite widespread in arid and semi arid regions of north India. Being a multipurpose plant, it has long been associated with health, nutrition and other diversified uses. The immature fruits of *gonda* are used as vegetable, pickled with raw mango and can be dehydrated for use in off season. *Karonda* (*Carissa*

carandas) is another underutilized fruit crop with high nutraceutical value besides its suitability in biofencing. It belongs to family Apocynaceae which thrives well through out tropical and sub tropical climate including arid regions. The presence of vitamin C and anthocyanin enhances the antioxidant properties of *karonda* fruit (Sawant and Godghate, 2013). The fruit is used for preparation of jelly, pickle, beverage and preserve. Some improved varieties developed recently are Pant Manohar, Pant Sudarshan and Pant Suvarna.

Khejri (*Prosopis cineraria* L. Druce) is an important component of arid farming system and plays significant role in the economy of the farming community of the Indian desert. Belonging to sub family mimosoidae of fabaceae (leguminosae) family, the tree is found growing in arid and semi-arid parts of Rajasthan, Gujarat, Haryana, Punjab, Delhi and some parts of southern India. The trees of *khejri* grow well in climatic constraints of arid zone. Because of its multiple economic value and suitability in agroforestry systems, it is conserved in arable land where its population is regulated by the farmer (Saxena, 1977). One collection of *Tahiti lime* was also evaluated for its performance in arid climate with supplemental irrigation and it emerged a suitable species with larger and seedless fruit. Looking to the commercial and ecological significance of these multipurpose species, the work on their collection, evaluation and improvement were started during 2000-2001 and still continuing and progress is being reported in this paper.

Materials and methods

Twelve germplasm accessions of *lasora* were collected in the form of seeds or bud wood depending upon the season during 2000-2008 from different parts Rajasthan and Gujarat. The seeds were first raised in the nursery while the bud woods were budded on to the seedling rootstock of the same species in the nursery. Six months old seedling/budded plants were transplanted in the field at 6x6 m spacing at Horticulture field, ICAR-Central Arid Zone Research Institute, Jodhpur for evaluation. In case of karonda, ripened fruits of seven accessions were collected from different parts of Rajasthan while seedlings of Pant Manohar variety were obtained from G.B. Pant University of Agriculture and Technology Pantnagar (Utarakhand) during 2000-2005. The seeds from ripened fruits were first sown in nursery beds after treating them with fungicides. One-year-old seedlings were transplanted in the field at 4x4m spacing. Ten-year-old plants were evaluated for vegetative growth, flowering, and fruiting, and fruit morphological characters, fruit colour and fruit yield. Twenty mature fruits were harvested randomly from each accession to record observation on physico-chemical parameters. Fruit size (length and girth) was measured with the help of digital vernier caliper while weight was taken by digital top pan balance. The total soluble solids (TSS) were determined with Erma Hand Refractometer (0-32°Brix). The titratable acidity (%) and ascorbic acid content were determined by AOAC methods. Ten fruits from each accession were weighed and volume estimated by water displacement

method. Fruit yield from were recorded every year from 7th year onwards. In case of *khejri*, six accessions and a released variety were evaluated during 2006-2015. One-year-old seedlings were transplanted in the field at 5x5m spacing in 2006. These seedlings were budded *in situ* with budwood collected from six germplasm accessions from different parts of Jodhpur district based on pod characteristics. Bud woods of variety Thar Shobha were collected from Central Institute for Arid Horticulture, Bikaner and the same was also budded *in situ* on the seedling rootstocks along with collected accessions. Uniform cultural practices were followed for maintenance of the plants of all the three species. The data on vegetative growth, fruiting, fruit yield and fruit morpho-physiological parameters were recorded as per standard methods. In case of Tahiti lime rooted layers were obtained from a private nursery of Pushkar, Ajmer (Rajasthan) and were planted in the field at 4x4m spacing and its performance with respect to fruit yield and fruit physico-chemical parameters recorded.

Results and Discussion

Germplasm collection and evaluation: The germplasm collection of different underutilized fruit crops (Table 1) were made from different parts of India over a period of 10 years. The collected germplasm has been evaluated and still being maintained in field gene bank. The results of germplasm evaluation in respect of different crops is discussed separately.

Table 1. Germplasm collection of underutilized fruits of arid region

Species	No. of accessions	Source
<i>Lasora</i> (<i>Cordia myxa</i>)	13	Rajasthan(Jodhpur, Pali,Ajmer,Chittor) and Gujarat(Bhuj)
Karonda (<i>Carissa carandas</i>)	8	Rajasthan(Jodhpur, Udaipur,Ajmer) and Uttarakhnad(Pantnagar)
<i>Khejri</i> (<i>Prosopis cineraria</i>)	7	Jodhpur and Bikaner
Tahiti lime (<i>Citrus latifolia</i>)	1	Ajmer

Lasora

Thirteen germplasm accessions were evaluated for its growth, fruiting behaviour and fruit characteristics. On the basis of their performance over the years it was noted that there was not much variation in different accessions with respect to vegetative growth such as plant height and canopy area but significant variation was recorded in fruit yield per plant and fruit characteristics (Table 2). Mean bunch weight was highest (137.4g) in accession No. G 2021 while lowest bunch weight of 28.65 g was recorded in accession No. G2014. The No. of fruits per bunch ranged from 4.62 g (G 2014) to 14.80 g (G 2021). Similarly, mean fruit weight varied from 5.81 g to 10.5 g in different accessions. The stone pulp ratio was maximum (1:6.5) in accession No. G 2025 and minimum (1:5) in accession No. G 2013. Fruit yield of selected genotypes are given in Table 2. Based on continuous high fruit yield

accession Nos.G2025, G2061, G2012, G2021, G2022, G2062 and G2011 were selected for further evaluation. The selected genotypes were multiplied by vegetative means (budding) to maintain their clonal purity. Based on consistent higher yield, the accession nos. CAZRI-G2011, CAZRI-G2012, CAZRI-G2021 and CAZRI-G2025 (Fig.1) have been found promising. Budded plants these genotypes have also been planted at one farmer's field to validate their superiority at outstations. All the four genotypes began fruiting in third year with a range of 5-15 kg per plant under limited supplementary irrigation.

The fact that the *lasora* has been traditionally propagated by seeds generating variation in plant population due to segregation. Higher variability from seed propagated progeny were recorded in respect fruit yield per plant while narrow range of variations in fruit size, shape cluster weight,



Fig. 1: Fruits of high yielding improved genotypes of lasora

Table 2. Fruit morphological characteristics and yield of 13 accessions of lasora

S.N	Accessions	Mean bunch weight (g)	No. of fruits per bunch	Mean fruit weight (g)	Pulp: stone ratio	Fruit yield ⁻¹ (kg plant ⁻¹)
1.	CAZRI-G2011	60	8.2	8.0	6.0	22.85
2.	CAZRI-G2012	62.0	10.0	7.8	5.6	27.9
3.	CAZRI-G2013	110.0	7.6	9.5	5.2	8.5
4.	CAZRI-G2014	28.65	4.62	7.91	6.0	10.5
5.	CAZRI-G2021	137.40	14.80	9.0	6.0	59.5
6.	CAZRI-G2022	57.40	8.40	5.81	5.0	13.2
7.	CAZRI-G2023	58.63	8.90	7.63	6.0	14.0
8.	CAZRI-G2025	61.5	14.0	10.5	6.5	98.2
9.	CAZRI-G2026	60.0	10.0	8.5	5.6	12.0
10.	CAZRI-G-2051	75.6	9.5	7.2	6.2	9.5
11.	CAZRI-G-2061	45.2	6.5	6.8	5.1	26.0
12.	CAZRI-G-2062	66.2	7.5	7.2	4.5	31.0
13.	CAZRI-G-2063	42.6	6.2	5.8	5.2	21.0
CD(P=0.05)		15.27	5.21	2.61	1.42	15.76

number of fruits per cluster, fruit weight and pulp: stone ratio (Meghwal *et al.*, 2015). Samadia (2007) surveyed the *lasora* core variability sites in Rajasthan and reported the variability in tree height, canopy volume and fruit and seed morphological characters. He also observed two types of leaves in *lasora* i.e. large and small size. The large leaf types produce big fruited *gonda*, while smaller leaf types produce smaller fruits of wild types with no commercial value. In germplasm collection at CAZRI also both the types of

germplasm are being maintained. Moreover, we have used small fruited types as rootstock for commercial big fruited types, since the former is considered more drought hardy and seed germination percent is also higher (Meghwal, 2007). Further, the evaluation of different rootstocks also revealed better performance on small fruited *gonda* rootstock in regards to higher fruit yield and longer graft compatibility (Meghwal *et al.*, 2014).

Karonda

Eight germplasm (Fig. 2) including a released variety i.e. Pant Manohar were evaluated for their performance in arid region. Great deal of variation was recorded in plant height, canopy area, growth habit, precocity, morpho-physico-chemical characteristics of fruits and fruit yield (Table 3&4). The data on plant height did not show significant differences among the accessions, while canopy area and fruit yield recorded significant variation. The fruit yield of accession No. CZK2011 was exceptionally very high during all the years. The mean fruit yield of this accessions found highest (33.98 kg plant⁻¹) followed by CZK 2031(24.28 kg plant⁻¹) and CZK 2022(24.03 kg plant⁻¹). The physico-chemical characteristics of fruits of different accessions also showed significant variations (Table 3).

Rich diversity in physico-chemical characteristics of the fruits of different accessions indicate the presence of genetic diversity in karonda accessions maintained at field

gene Bank in CAZRI. Variations in the germplasm of karonda with regard to physico-chemical characters and fruit yield corroborates the earlier findings from Punjab (Bal, 2003) and high degree of genotypic and phenotypic variability reported from Maharashtra by Sawant *et al.* (2003). Based on long term performance of the germplasm for fruit yield and other desirable attributes, the accession Nos.CZK2011, CZK2022 and CZK2031 may be recommended for dual purpose (bio-fencing and fruits) in arid zone.

Khejri

Wide variation exists in the natural stands of *khejri* due to occurrence of cross pollination and prevailing seed propagation. From the Horticultural quality point of view, the variability in pod quality traits is most important. Pareek (2002) observed diversity in pod characteristic such as taste (flat, bitter, acrid and sweet), tenderness (hard, semi hard, less tender, tender), fiber content (fibrous, less fibrous and

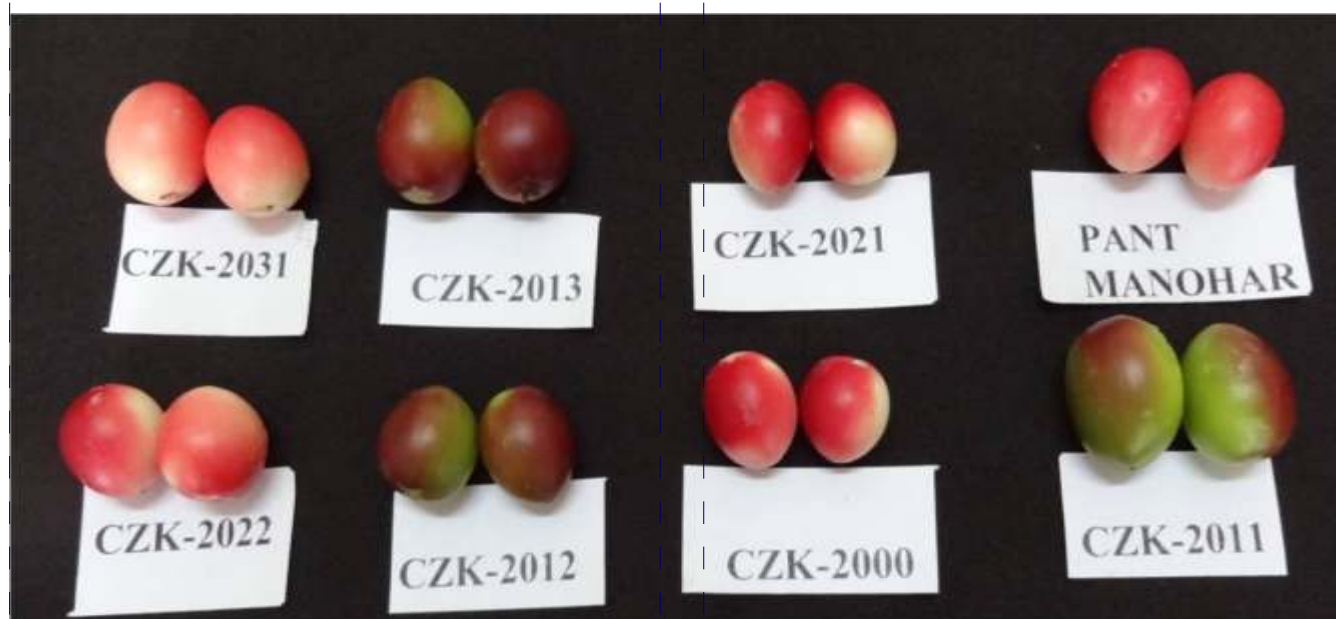


Fig. 2: Fruits of genotypes of Karonda

Table 3. Vegetative growth and fruit yield of karonda accessions (7th year, onwards)

Genotype	Plant height(m)	Canopy area(m ²)	Fruit yield (kg plant ⁻¹)				Mean yield (kg plant ⁻¹)
			2012	2013	2014	2015	
CZK2000	2.47	11.84	16.50	17.2	18.5	20.1	18.80
CZK2011	3.06	10.45	22.60	31.5	40.6	41.2	33.98
CZK2012	2.51	4.86	13.00	12.1	15.3	18.8	14.80
CZK2013	2.90	9.62	15.20	17.0	19.8	22.5	18.63
CZK2021	2.56	6.73	14.52	16.3	17.8	18.5	16.78
CZK2022	2.38	5.14	20.2	22.4	24.8	28.7	24.03
CZK2031	2.45	6.76	18.20	21.6	25.1	32.2	24.28
Pant Manohar	2.62	6.92	16.80	18.3	20.2	23.5	19.70
Mean	2.62	7.79	17.13	19.55	22.76	25.69	
CD(p=0.05)	NS	2.14	3.27	3.71	4.60	4.45	

fibres), colour (green, light green), pod length, thickness, seed number, seed size, protein content and mineral constituents. Among these traits, sweet taste, longer, thin, tender pods green in colour, and less fibrous ones are the desirable traits for culinary purpose. The trees having desirable pod characteristics may be identified from the natural population. Seven germplasm accessions of khejri including variety Thar Shobha were evaluated for pod characteristics. Significant variation was recorded for pod characteristics (Table 5). The bunch weight ranged from 6.2 (Thar Shobha) to 16.26 (CAZRI-Kh-3), while number of fruits per bunch varied from 4.5 to 19.6. Similar variations were also recorded for mean pod weight, mean pod length, pod girth, number of seeds per pod and dry matter content. The variation for pod characteristics is quite obvious as the germplasm has been collected from natural population multiplied by seeds.

The variation in pod characteristics of *khejri* validates the earlier reports of recorded variability from natural population of *khejri* in arid regions of Rajasthan (Vishal nath *et al.*, 2000).

Tahiti lime (*Citrus latifolia*)

Evaluation of large fruited lime germplasm indicated that it is a fast growing, precocious bearer and cold hardy. The plant growth was very luxuriant during favourable period i.e. from July to March but it could not tolerate hot weather during April to June which resulted into leaf burning, sun scorching and shrinkage of fruits (Anon 2006). Mean fruit yield after 5 years of planting ranged from 15-20 kg per plant depending upon the weather condition during flowering and fruiting. Its flowering and fruiting can be synchronized by crop regulation in such a way that fruit harvesting is completed by end of the March to avoid heat injury to the fruits. Physico-chemical

Table 4. Physico-chemical characteristics of fruits of *Carissa carandas*

Accession No.	Fruit size(mm)		fruit weight (g)	Fruit volume (cc)	No. of seeds/fruit	TSS ($^{\circ}$ Brix)	Acidity	Dry matter (%)	Vitamin C (mg 100 $^{-1}$ g)
	Length	girth							
CZK2000	17.37	14.32	2.60	1.95	3.5	9.2	2.90	13.56	34.32
CZK2011	21.79	16.35	3.74	3.8	6.3	9.4	2.82	12.85	35.88
CZK2012	23.05	18.29	2.96	3.2	3.6	9.5	2.92	13.19	24.96
CZK2013	23.52	19.22	4.86	4.3	6.1	8.5	2.84	12.31	43.68
CZK2021	19.29	16.05	2.76	3.1	6.6	8.0	2.75	13.83	31.2
CZK2022	22.47	19.14	4.18	4.5	4.9	8.5	2.14	12.77	31.2
CZK2031	22.66	19.57	5.01	4.7	5.4	8.7	2.95	12.96	37.4
Pant Manohar	21.52	17.15	3.34	3.4	3.5	9.0	2.90	13.00	31.2
CD (5%)	0.77	0.68	0.30	0.17	0.21	0.18	0.17	0.22	0.48

Table 5. Pod characteristics and yield of budded khejri germplasm

Acc. No./variety	Bunch weight (g)	No. of pods per bunch	Mean weight (g)	Mean length (cm)	Pod girth (mm)	No. of seeds per pod	Dry matter (%)	Mean pod yield (kg plant $^{-1}$)
CAZRI-Kh-1	13.22	19.6	0.99	12.94	2.9	9.81	13.58	13.2
CAZRI-Kh-2	10.88	13.0	1.13	11.53	3.08	9.2	12.35	11.6
CAZRI-Kh-3	16.26	9.0	1.58	13.36	3.11	14.40	20.85	10.5
CAZRI-Kh-4	12.50	6.2	3.10	12.6	4.8	11.2	22.82	8.6
CAZRI-Kh-5	5.8	6.3	2.1	8.5	2.8	10.2	17.2	7.5
CAZRI-Kh-6	18.05	10.0	2.26	12.04	4.03	12.0	25.68	9.2
Thar Shobha	6.2	4.5	2.5	16.16	2.5	14.05	19.06	7.8
CD(P=0.05)	4.27	6.21	1.2	4.2	2.1	3.24	5.12	2.5

characteristic of the fruits are as follows:

No. of fruits per cluster	: 3-5
Average fruit weight	: 75 g (range 60-90 g)
Rind thickness	: 2.5 mm
Juice percent	: 56.45
TSS	: 7%
Acidity	: 5.76%
Seedlessness	: 100%

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An adoption of improved varieties of kachri (*Cucumis melo* var. *callosus*) in hot arid region of Rajasthan: An impact assessment

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Abstract

The present study was conducted in all 12 districts of hot arid region of Rajasthan during last 10 years (2007 -2017). These districts were purposively selected for the study as the farmers of these district have adopted the improved variety (AHK-119) of kachri and was grown extensively during kharif/summer season of the year. An extensive study was conducted to assess the impact of adoption of this improved variety and it was found that the average production of the improved variety was 89 q/ha while that of local variety (local check) was 64.0 q/ha. This illustrate that average production of improved variety of kachri (AHK-119) was 39.06 % higher than the production of local one. Per hectare net return from the improved variety of kachri (AHK-119) was 107.35 % higher than the net return achieved from the local variety of kachri. The total area under cultivation of improved variety AHK-119 of kachri in entire hot arid region of Rajasthan was 1277 ha in 2007 which increased to 3865 ha in the year 2017. The gross return from the improved variety of kachri (AHK-119) in entire hot arid region of the Rajasthan was 17.50 corers in 2007 which increased to 52.97 crores in 2017. Likewise the net return from the improved variety of kachri (AHK-119) in entire hot arid region of Rajasthan was 12.88 crores in 2007 which increased to 38.98 corers in 2017 i.e. increased three times in 2017 in comparison to the year 2007. There were observed several progressive farmers who multiplied/produced the seed of improved variety of kachri (AHK-119) under the scientific guidance of the scientist of the Institute (ICAR-CIAH, Bikaner) and sold it @ Rs. 2000 3000 or more per kg to other needy farmers/clients to earn money.

Key words: Adoption, production, improved variety, kachri, impact assessment, hot arid region.

Introduction

The hot arid regions of the India are spread over 32 million ha (0.32 million Sq.Km.) in the state of Rajasthan (61%), Gujarat (20%), Andhra Pradesh (7%), Punjab (5%), Haryana (4%), Karanataka (3%), and Maharashtra(0.4%) which are characterized by hostile agro-climatic conditions and fragile eco-system. As reveals that out of total geographical hot arid area of the country (India), more than 60 % area falls under the state of Rajasthan which spread over arid 12 districts viz., Jaisalmer, Barmer, Bikaner, Churu, Sikar, Jhunjhunu, Naguar, Jodhpur, Pali, Jalor, Sriganganagar, Hanumangarh of the state. In general, the hot arid region of Rajasthan receives very low rainfall, varies from 100 mm annu⁻¹ in north-western district of Jaisalmer to 450 mm per annum in the eastern boundaries of arid district of Rajasthan. The potential evapo-transpiration varies from 2063 mm in Jaisalmer to 1503 mm in Sikar districts of Rajasthan. The rainfall is very erratic and often experienced prolong drought. The ground water table is very deep and often brackish in nature. The extremes of temperature having severe winter during December-January with temperature as low as -4° C and very hot summer during May-June with temperature as high as 48-50 °C is another important characteristic of the hot arid region of Rajasthan. The solar radiation is very high (from 400 Cal cm⁻¹ day⁻¹ in winter to 625 Cal in summer). The wind

velocity in June is very high which leads to heavy wind erosion and formation of sand dunes. Some time strong sand storms of very high speed (60 -70 km h⁻¹) with huge amount of sand particles also occurs. The soils are coarse textured with low silt, clay and humus content and water holding capacity is very low and infiltration rate is very high. The soil fertility is very poor having low organic carbon (0.02-0.06%). Soil salinity, calcareousness and gypsiferous nature of soil add another dimension to these constraints in adoption and production any crops in hot arid regions (Dhadar and Saroj, 2004). Thus, the hot arid region of Rajasthan is full of challenges, threats and constraints which inhabit advancement of the crop production and farming system. However, the hot arid region has been blessed with some of the strength also which disclose the rays of hope and scope of advancement of horticultural development in the region. Aamong such strength, the availability of potential bio-diversity/genetic resources, existence of promising germplasm and drought hardy species of cucurbitaceous vegetables, etc., are the major strengths which can play vital role in horticultural development in these regions. The cucurbitaceous vegetables are the largest group of vegetables among all vegetables grown in hot arid region of Rajasthan. There were various potential and unique cucurbitaceous vegetables which were grown traditionally and used/consumed widely by the dwellers of the region in

various ways using their own traditional knowledge and methods. Among them, kachri is the most favourite and accepted vegetable among the local people of the arid region of Rajasthan. It is highly drought hardy cucurbitaceous vegetable of the region which is grown there from ancient time. *Kachri*, belongs to the family- *Cucurbitaceae*, genus- *Cucumis*, species- *melo* and var. *callosus/agrestis*. it is mainly grown during the rainy season under the mixed cropping system at large scale or as sole crop at small scale. Some of the farmers who had irrigation facilities grew the *kachri* as sole crop during the summer season also. *Kachri* is the most liked traditional vegetable in hot arid regions where it was utilized/ consumed by > 90 % people as fresh for vegetable purpose and in the forms of various traditionally value added products.

Development of the variety: Considering immense socio-economic importance and industrial potentiality of kachri, ICAR-Central Institute for Arid Horticulture, Bikaner addressed the improvement and scientific cultivation of *Kachri* (*Cucumis melo* var. *callosus* Rott. Cong). The Institute initiated the systematic exploration and research work on improvement of kachri. In 1994, intensive crop specific surveys and explorations were undertaken in hot arid and semi-arid regions of the country and a large number of germplasm (land races, local types and semi-cultivated) of kachri were collected, documented, conserved and potential among the same were evaluated. After an extensive evaluation and hard work, the Institute developed and released a unique improved variety of kachri in 1998 and named as "AHK 119" and disseminated to farmers fields.

The farmers realized the potentiality and beneficial features of this variety (AHK-119) like very early variety, can grown twice in a year (kharif & summer season) with limited water/ soil moisture, high yielding, best suitable in existing harsh climatic conditions, uniform shape, size and colour of the fruits, very good taste and aroma, suitable to prepare the value added products, has long shelf life, high market demand, comparatively high return/ha, etc. and started to grow it on their fields at large commercial scale. The graph of high demand of seeds of this variety hiked year to year. The area and production of the variety increased very fast year to year and continue to increase with increasing rate among large number of farmers. However, it was not crystal clear picture and actual position of adoption/spread, production, productivity, economic return and other impacts of adoption of this improved variety of kachri "AHK-119". Keeping these facts in mind, an intensive impact study was conducted in hot arid regions of Rajasthan with the objective "to assess the impact of adoption of improved variety (AHK-119) of kachri in hot arid region of Rajasthan".

Methodology

The present study was conducted in all 12 districts of hot arid region of Rajasthan during last 10 years (2007 -2017). These districts were purposely selected for the study as the farmers of these districts have adopted the improved variety (AHK-119) of kachri and are growing extensively during each

kharif/summer season of the year. The data and information were collected from multifarious sources/ techniques with the help of semi-structured interview schedule as per objective of the study. The major sources/techniques used to collect the data and information for the study were :

- ✓ Bench mark surveys.
- ✓ Data/information recorded under front line demonstrations on farmer's fields.
- ✓ Interviewing and group discussion with farmers/clients.
- ✓ Discussion and information collected from farmers during different training programmes.
- ✓ Discussion and feed backs recorded from several farmers during the display of technological exhibitions in different farmers' fair and other occasions. .
- ✓ Information/data collected from the line departments and NGOs.
- ✓ Information/data collection from the field workers and secondary sources.
- ✓ Collection of data/information from KVKs of the hot arid region of Rajasthan.
- ✓ Individual online/telephonic discussion and feed backs of the farmers/clients and agencies.
- ✓ Collection of information from seed producing and supplying agencies.
- ✓ Discussion and feed backs from progressive farmers of the in hot arid region of Rajasthan.
- ✓ Collection of information/data from local vegetable markets/mandies, etc.

Thus, the data/information about the adoption, production and spread of the cultivation of improved variety of kachri "AHK-119" were collected extensively from multifarious sources to assess the impact of adoption and production cultivation spread of this improved variety of kachri.. The data and information so collected were compiled, estimated, analyzed and tabulated using the appropriate statistical tools and techniques to draw the inferences/conclusion of the present study. The outcomes/results of the study are being disclosed and cited in details as follows.

Results and discussion

Results and discussions of the outcomes of the study are cited under different heads and subheads as follows.

Comparative economic and yield potential of improved variety (AHK-119) of kachri

A comparative study was carried out to show the production and yield potential of improved variety of kachri over local one. During the study, 100 farmers were selected in each group viz. growing AHK 119 and local kachri. The data/information were collected from both the categories of the farmers and comparison was made between the gross and net return achieved/ha from the improved variety as well as and local variety (local check) of the kachri. It was found that the average production of improved variety of kachri (AHK-119) was 89 q/ha while that of local variety (local check) was 64.0 q/ha only showing there by that average production of

improved variety of kachri (AHK-119) was 39.06 % higher over then local one. The average gross return and net return achieved from the improved variety of kachri (AHK-119) were 137060 and 100860, respectively while the average gross return and net return achieved from the production of local variety (farmers practices) of kachri were 77440 and 48640, respectively (Table 1 and Figure 1). This illustrates that net return achieved from the improved variety of kachri (AHK-119) was 107.35 % higher over the net return achieved from the local variety (local check) of kachri. Similar kind of findings were reported by Balai, *et. al.* (2013).

Adoption and spread in area under the improved variety (AHK-119).

The Institute released the improved variety of kachri (AHK-119) and initiated the work on dissemination and

popularization of the same among the farmers to adopt it. A large number of farmers realized the potentiality and benefits of this variety. Initially, a few farmers adopted and started its cultivation. The popularity of the variety increased very fast among the farming community and demand hiked within 3-4 years of its releasing. The area and production of this variety is continuously increasing year by year. In past, the farmers of the hot arid region of Rajasthan adopted AHK-119 very speedily at large scale and it was calculated that the spread over about 4000 ha area within a few years with large production. The yearly calculation/estimation of the status of spread in area and production of improved variety of kachri (AHK-119) and local one are given in Table 2.

The data in table 2 reveals that the total area under cultivation improved variety (AHK-119) of kachri in entire hot arid region of Rajasthan was 1277 ha in 2007 which

Table 1. Comparative average cost of cultivation, gross and net return (round figures) from production of improved variety (AHK-119) and local variety of kachri.

Particulars/operations	Average cost cultivation involved growing the improved variety (AHK-119) of kachri by 100 farmers (Rs./ha)	Average cost of cultivation in growing the local variety of kachri by 100 farmers (Rs./ha)
Land Preparation	6000	4600
Seed	1600	1500
Fertilizer	7200	4000
Irrigation	2000	1500
Agro Chemicals (including pesticides)	2400	1200
Other labour charges (including harvesting and transportation)	17000	16000
Total cost of cultivation	36200	28800
Kachri production (q/ha)	89	64
Selling price of kachari (Rs/q)*	1540	1210
Gross return from kachari/ha*	137060	77440
Net return from kachari/ha*	100860	48640

*The return/income includes both from fresh as well some value added products of kachri.

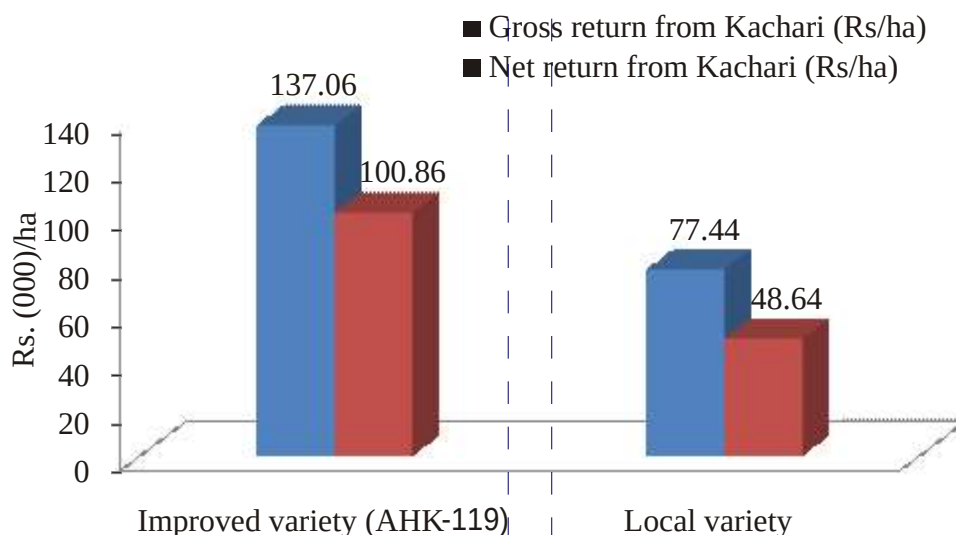


Fig 1: Difference in gross and net returns ('000Rs./ha) from production of improved variety (AHK-119) and local variety of kachri.

increased to 3865 ha in the year 2017. In case of different district of the hot arid region of Rajasthan, maximum area of improved variety of kachri was under in Bikaner district followed by Nagaur district which increased from 630 to 1720 ha in Bikaner district and from 348 to 1081 in Nagaur districts during the year 2007 to 2017, respectively. The other district where the improved variety of kachri is grown on more than 100 ha of land in 2017 were Jodhpur, Barmer, Sikar and Jhunjhunu. However, the area under this improved variety of kachri was observed fluctuated year to year which might be due to uncertainty in climatic conditions in hot arid region and other factors like erratic and low rainfall, high temperature, frequently occurrence drought and strong sand storms, scarcity of water, low availability of seeds, attack of pests and

diseases, low supply of electricity and canal water, etc.

Gross and net return from the improved variety (AHK-119) of kachri in entire hot arid region of Rajasthan.

On the basis of information/data collected during the study, year wise gross and net return earned from the improved variety (AHK-119) of kachri in entire hot arid region of Rajasthan were analyzed and statistically calculated. The results revealed (Table 3) that the gross return from the improved variety of kachri (AHK-119) in entire hot arid region of the Rajasthan was 17.50 crores in 2007 which increased to 52.97 corers in 2017 i.e. three times increase in last ten years. Likewise the net return from the improved variety in entire hot arid region of Rajasthan was 12.88 corers in 2007 which

Table 2. Year wise area under improved varieties of kachri (AHK-119) in different districts of the hot arid region of Rajasthan (Area in ha.*)

Districts	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Barmer	32	35	36	105	62	92	78	122	103	122	145
Bikaner	630	707	472	1280	1087	1465	1292	1480	1405	1505	1720
Churu	32	23	29	58	52	62	65	80	72	84	96
Sriganganagar	10	10	9	36	28	33	31	35	28	35	41
Hanumangarh	11	10	11	28	25	31	26	36	30	34	46
Jaisalmer	19	18	18	52	68	78	51	68	52	72	86
Jalore	17	21	24	64	59	71	54	71	62	83	85
Jhunjhunu	40	18	20	55	64	74	61	89	78	89	137
Jodhpur	50	37	36	104	94	131	112	152	141	152	181
Nagaur	348	230	267	688	572	774	695	1035	902	925	1081
Pali	39	16	20	42	68	79	52	89	74	92	110
Sikar	48	25	25	78	74	95	80	108	110	122	137
Total area under AHK-119 in hot arid region of Rajasthan	1277	1152	967	2590	2253	2985	2597	3365	3057	3315	3865
% area of the country (India) under AHK-119 in hot arid region of Rajasthan.	62.11	67.17	64.96	64.29	79.25	87.41	87.11	74.69	79.77	85.48	63.44

* Kharif + summer season

Table 3. Year wise total area (ha), production ('000'tons), gross and net income (in Corers) from improved variety of kachri (AHK-119) in hot arid regions of Rajasthan.

Years	Area*	Production	Gross return	Net return
2007	1277	11.37	17.50	12.88
2008	1152	10.25	15.79	11.62
2009	967	8.61	13.25	9.75
2010	2590	23.05	35.50	26.12
2011	2253	20.05	30.88	22.72
2012	2985	26.57	40.91	30.11
2013	2597	23.11	35.59	26.19
2014	3365	29.95	46.12	33.94
2015	3057	27.21	41.90	30.83
2016	3315	29.50	45.44	33.44
2017	3865	34.40	52.97	38.98

* Kharif + summer season both

increased to 38.98 crores in 2017. It implies that the net return of the improved variety of kachri (AHK-119) in entire hot arid region of Rajasthan increased three times in this period. It is also worth to mention here that contribution of the improved variety kachri (AHK-119) in total net return achieved from kachri crops (improved + local) in entire hot arid region of Rajasthan was > 60 % in the year of 2007 which increased > 80 % during the year 2017. Similar findings with respect to net return per hectare and cost benefit ratio were also reported by Jatav, *et. al*, (2016a, 2016b).

Development of seed chain of improved variety of kachri (AHK-119) and income generation.

The area and production of the improved variety of kachri (AHK-119) increased rapidly in hot arid region of Rajasthan. The major reason behind fast increasing in area and production in the region was development of seed production chain of the variety among the farmers. Initially, the farmers purchased the seeds of improved variety of kachri (AHK-119) from the Institute (ICAR-CIAH, Bikaner) and multiplied the same on their own fields under the technical guidance of scientists of the Institute and used it to grow on their own fields in next season/year or sold out the surplus seed to their fellow farmers/ shopkeepers to earn money. Several progressive farmers who multiplied /produced the seed of improved variety of kachri (AHK-119) on their own level each upto extent of 10 30 kg/season under the scientific guidance of the experts and sold it (@ Rs. 2000 3000 or more per kg) to other needy farmers/clients to earn money. As the demand of seeds of this improved variety (AHK-119) is very high among the farmers of the hot arid regions, hence, several progressive farmers have made their profession to multiply/produce seeds of this variety to earn in considerable amount of money. The trend of such multiplication of the seeds of improved variety of kachri (AHK-119) is increasing year to year which is encouraging more and more spread of this variety in hot arid region of Rajasthan. These finding are in the line of the findings reported by Meena *et. al*. 2016 in their study.

Constraints in adoption and production of improved variety (AHK-119) of kachri at large scale in hot arid region of Rajasthan.

Despite the apparent need and advantages associated with adoption and production of improved variety (AHK-119) of kachri at large scale in hot arid region of Rajasthan, the farmers were not much success in adoption and production/growing of the improved variety of kachri on their fields in harsh climatic conditions of the region. They had to face various “problems/ constraints” which led to low/ non adoption of these crops at large scale in hot arid climatic conditions of the hot arid region of the Western Rajasthan. Major general constraints observed during the study which hinder the adoption and production of improved variety of kachri at large scale in hot arid regions of western Rajasthan India were as follows.

(I) Ecological constraints.

The major observed ecological constraints which

affect the large adoption and production of improved variety of kachri at large scale in hot arid region of Rajasthan were as follows.

- Acute shortage of water
- Poor and erratic rainfall
- Occurrence of drought and famine very frequently.
- Very deep and salty/brackish ground water
- Extremes of temperature during summer (upto 50°C)
- Perpetuation of high hot winds and sand storms
- Shifting of sand and sand dunes
- High evapo-transpiration and low relative humidity
- Poor soil with low water retention capacity.

(ii) Socio-psychological constraints.

During the study there were observed various socio-psychological and cognitive constraints also which led to low or non adoption and production/growing the improved variety of kachri at large scale in hot arid regions of Rajasthan which were as follows.

- Lack of awareness, interest and knowledge
- Deep faith in traditional cropping system
- Lack of reciprocal technical interactions between scientists and farmers.
- Lack of technical - social institutions
- Predominance of myths and misunderstandings
- Illiteracy and heterophilic population
- Fear of crop failure
- Dissonance about the success of crops/technologies
- Lackadaisicalness in farmers and lack of inspirations/motivations.

(iii) Techno-economic constraints.

Techno-economic constraints which were responsible in low or non adoption and production of improved variety of kachri at large scale in hot arid region were as below.

- Low/non accessibility of seeds of improved variety of at local level as per desire.
- Non availability technical guidance and reliable inputs at local level.
- Lack of awareness and knowledge improved production technologies of kachri
- Lack of local markets/*mandies* to sell the produces/products of kachri.
- Poverty, scare resources and low risk bearing capacity of the farmers.
- Perishable nature of the produces / products.
- No standard technologies for value addition of fruits of kachri .
- Lack of subsidy/credit facilities to support to the farmers.
- The commercial production front of kachri is lagging behind
- No security and support against crop failure and low

income
Monopoly of brokers in selling/purchasing produces/products.

(iv) Constraints related to essential infrastructural facilities.

There were observed some infrastructural constraints also which were considered responsible for low adoption of the improved variety of kachri in hot arid region were as follows.

- Lack of reliable sources of technical information and inputs.
- Poor extension and communication system
- Lack of the specific facilities for farmers' trainings and skill development.
- Poor networking on modern/improved production technologies of kachri.
- Lack of safe storage / preservation facilities.
- Limited and irregular supply of electricity
- Unfamiliar and long distance of research and extension institutions.
- Absence of regulated local markets and transportation facilities.

From the foregoing account, it can be argued that if quality seed of AHK-119, scientific method of cultivation, proper marketing system, sufficient storage, post harvest management and value addition techniques/facilities are made available, definitely the prospect of production of this variety will be bright in hot arid regions of the country. For further boost up of the adoption and production of improved variety of kachri at large commercial scale in regions, the farmers should be encouraged and facilitated to grow it on more and more areas. The wider publicity and popularity of the improved

variety (AHK-119) of kachri should be ensured among the farmers/clients through organizing different extension programmes and activities. There were observed some constraints also which impede the fast adoption and spread of this variety in hot arid region. These constraints should be eradicated through creating proper strategic plan and scientific management practices.

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Effect of rootstocks on growth, yield and fruit quality attributes of sweet orange (*Citrus sinensis*) cv. Sathgudi

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(Received : 22.07.2018, Accepted : 21.09.2018)

Abstract

The plant growth, yield and fruit quality attributes of 'Sathgudi' sweet orange (*Citrus sinensis* (L.) Osbeck) on four rootstocks were evaluated under semi-arid conditions of central Gujarat at Central Horticultural Experiment Station (ICAR-CIAH, Bikaner), Godhra during the year 2016-2017 and 2017-2018. Results showed that various rootstocks had significant effect on growth, yield, fruit weight and quality of Sathgudi sweet orange. The highest plant height (1.50 m), root stock girth (17.20 cm), scion girth (16.30 cm), plant spread (1.40 m & 1.35 m) and tree volume (1.48 m³) were observed with Rangpur lime rootstock closely followed by rough lemon. The fruit weight and yield were also affected by different rootstocks. Trees on 'Carrizzo' citrange had lower fruit weight and yield than those budded on to the other rootstocks. Significantly, the maximum fruit weight (170.20 g), yield (8.5 kg/plant), juice percent (42.12 %), TSS (12.0 °Brix), TSS and acid ratio (8.95), total sugar (5.70%) and vitamin C (58.90 mg/100g) were found in Sathgudi trees budded on to Rangpur lime.

Key words: Orange, rootstock, growth, yield, quality

Introduction

Sweet orange cv. Sathgudi is successfully cultivated in the semi-arid tracts of the Indian subcontinent. It is popular amongst growers in semi-arid regions of country owing to its higher yield potential and consumer's preference. India's citrus production has reached to approximately 12.75 mt in 2017 from an area of 1.06 mha out of which sweet orange contribution in production is 3.48 mt from an area of 0.209 mha. (Anon., 2017). Various kinds of rootstocks used in citrus production played substantial role in the development of the citrus industry in the world (Yildiz *et al.*, 2013). Rootstock is used beneficially for solving both limiting and restricting factors of citrus production (soil, climate and pests, etc.) and conditioning the market demands on productivity, short juvenility period and high-fruit quality. Further, factors like cultivar characteristics, rootstocks employed, growing conditions orchard management, type of flowers and the fruit drops can affect citrus cultivars yield and quality attributes (Demirkeser *et al.*, 2003, Parameshwar *et al.*, 2018). The use of particular type of rootstock can influence different aspects of tree growth and development, including yield, fruit quality and tolerance to stress caused by biotic and abiotic factors (Filho *et al.*, 2007). The main rootstock in India for citrus production is rough lemon or Jatti khatti (*Citrus jambhiri* Lush.) which can be considered as an ideal rootstock for all set of agro-climatic conditions (Kumar *et al.*, 2017). It is now well known fact that the genotypic differences of rootstocks may modify growth, yield and fruit quality attributes. The present study was aimed to assess the effect of different rootstocks on sweet orange cv. Sathgudi tree growth, yield and quality under

semi-arid conditions of central Gujarat.

Materials and Methods

The present work was carried out during 2016-2017 and 2017-2018 at Central Horticultural Experiment Station (ICAR-CIAH), Vejalpur, Godhra. Plant materials for the experiment consisted of sweet orange cultivar budded on four rootstocks, viz., rough lemon (*Citrus jambhiri* Lush.), Rangpur lime (*Citrus limonia* [L.] Osb.), Carrizo citrange (*Citrus sinensis* [L.] Osb. × *Poncirus trifoliata* [L.] Raf.) and Cleopatra mandarin (*Citrus resnyi* Hort. ex Tan.). The budded plants were planted during the year 2012. The experiment was laid out in Randomized Block Design with 4 treatments and 5 replications. Plant growth in terms of plant height (m), root stock girth (cm), scion girth (cm), plant spread (m) and tree volume (m³) were recorded. Plant height was determined by measuring the distance from the ground to the top of the plant with the help of measuring tape. Plant spread in North-South and East-West directions was recorded with the help of measuring tape and tree volume (V) was determined as per formula suggested by Roose *et al.*, (1986) and recorded in cubic meter. Scion girth was taken at fixed height 10 cm above the graft union and root stock girth at 10 cm below the graft union. The positions were marked with paint for taking observations. All plants were given the uniform cultural practices. The data on fruit yield (kg/tree) and physico-chemical characters were recorded using standard procedures. From each treatment, fruits were randomly selected from all the directions for recording the data and brought to the laboratory of Central Horticultural Experiment Station,

Vejalpur, Panchmahal (Godhra), Gujarat. TSS of fruits was measured with the help of hand refractrometer while titratable acidity, ascorbic acid, and total sugars were determined by AOAC (1990) methods. The data were statistically analyzed as per method of Gomez and Gomez (1984).

Results and discussion

Different rootstocks significantly influenced the various growth parameters of Sathgudi sweet orange (Table 1). Sathgudi on Rangpur lime rootstock produced vigorous plant with the maximum plant height (1.50 m), root stock girth (17.20 cm), scion girth (16.30 cm) plant spread in E-W (1.40 m) and N-S directions (1.35 m) and tree volume (1.48 m³) followed by rough lemon (1.35 m, 16.32 cm, 15.60 cm, E-W 1.30 m, N-S 1.28 m and 1.18 m³) for these parameters. The minimum plant height (1.10 m), root stock girth (14.20 cm), scion girth (14.0 cm) plant spread in E-W (1.13 m) and N-S directions (1.0 m) and tree volume (0.65 m³) were recorded on Cleopatra mandarin rootstock. The findings of the present study clearly demonstrated the differential growth response of the rootstocks on the scion variety which might be due to the inherent genetic potential of the rootstocks. Results of the study showed that Rangpur lime followed by rough lemon showed its superiority in terms of plant height, spread tree volume of Sathgudi sweet orange over other rootstocks, thus indicating their well adapted nature to soil conditions with efficient root system that might have resulted in higher accumulation of nutrients (Kumar *et al.*, 2017). Variation in growth parameters of sweet orange due to use of various rootstocks have also been reported earlier by Yildiz *et al.* (2013) and Ghosh *et al.* (2012).

Significantly, the maximum fruit weight (170.20 g), fruit yield (8.5 kg/plant) and juice content (42.12 %) were observed with Rangpur lime rootstock followed by Rough lemon (160.50 g, 7.20 kg/plant and 38.0 % respectively). While the minimum fruit weight (152.10 g), yield per tree (5.20 kg) and juice content (36.0 %) were found with Cleopatra mandarin (Table 2). Degree of yield expression of a scion cultivar, budded on specific rootstock is considered as one of the indicators for rootstock-scion combination for a particular agro-climatic condition. Higher yield along with other yield attributing characters of sweet orange on Rangpur lime rootstock was reported by Mustafa and Reddy (1990) under Bangalore and Ghosh *et al.* (2012) under West Bengal conditions. Grace *et al.* (2005) recorded maximum weight, size and Juice percentage in Sathgudi sweet orange fruits on Rangpur lime rootstock in Tirupati (Andhra Pradesh) conditions. Further, fruit chemical quality characters were also significantly affected by various rootstocks used (Table 2). In respect of chemical quality parameters of fruit, significant improvements have been observed in TSS (12.0 °Brix), TSS acid ratio (8.95), total sugar (5.70%) and vitamin C (58.90 mg/100g) in Sathgudi trees budded on to Rangpur lime while the minimum TSS (11.0 °Brix), acidity (1.44 %), TSS acid ratio (7.63), total sugar (5.10%) and vitamin C (48.10 mg/100g) were recorded in Sathgudi orange on Cleopatra mandarin. These results are in agreement with Ghosh *et al.* (2012) and Grace *et al.* (2005).

In conclusion, Rangpur lime may be adopted as Rootstock for sweet orange cv. Sathgudi under the semi arid conditions of central Gujarat to increase yield with improved fruit quality attributes.

Table 1. Effect of rootstocks on growth, yield and fruit quality attributes of sweet orange cv. Sathgudi

Treatments	Plant height (m)	Root sock girth (cm)	Scion girth (cm)	Plant spread		Tree volume (m ³)
				E-W (m)	N-S (m)	
Rangpur lime	1.50	17.20	16.30	1.40	1.35	1.48
Rough lemon	1.35	16.32	15.60	1.30	1.28	1.18
Cleopatra mandarin	1.20	16.00	15.50	1.15	1.10	0.80
Carizzo Citrange	1.10	14.20	14.00	1.13	1.00	0.65
CD(P=0.05)	0.11	0.09	0.10	0.12	0.11	0.27

Table 2. Effect of rootstocks on fruit yield and fruit quality attributes of sweet orange cv. Sathgudi

Treatments	Yield (kg/plant)	Fruit weight (g)	Juice (%)	TSS (°Brix)	Acidity (%)	TSS and acid ratio	Total sugar (%)	Vitamin C (mg/100g)
Rangpur lime	8.50	170.20	42.12	12.00	1.34	8.95	5.70	58.90
Rough lemon	7.20	160.50	38.00	11.20	1.42	7.88	5.50	51.20
Cleopatra mandarin	6.20	155.15	37.12	11.10	1.43	7.76	5.40	50.12
Carizzo Citrange	5.20	152.10	36.00	11.00	1.44	7.63	5.10	48.10
CD(P=0.05)	0.98	2.31	1.11	0.13	0.03	0.07	0.12	0.48

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Effect of potassium and zinc on growth, yield and quality of garlic (*Allium sativum* L.)

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(Received: 24.07.2018; Accepted: 3.09.2018)

Abstract

A field experiment was conducted during *Rabi* season 2017-18 at the Research Farm, College of Horticulture, Mandsaur (M.P.) to study the response of potassium and zinc on growth, yield and quality of garlic. The experiment was laid out in factorial RBD design with three replications including four levels of potassium (0, 25, 50 and 75 kg K₂O/ha) and three levels of zinc (0, 5 and 10 kg Zn/ha). Results showed that application of K₃Z₂ (75 Kg K₂O/ha + 10 Kg Zn/ha) significantly increased the plant height, number of leaves per plant, fresh weight of plant (g), dry weight of plant (g) fresh weight of bulb (32.4g), dry weight of bulb (10.22 g), polar diameter of bulb (4.73 cm), equatorial diameter of bulb (4.72 cm), bulb yield (146.7 q/ha), volatile oil content in bulb (0.40%) and non-significant effect showed in TSS content in bulb (42.51 °Brix). Therefore, the application of 75 Kg K₂O/ha and 10 Kg Zn/ha gave maximum growth, yield and quality attributes and of garlic.

Keywords: Garlic, potassium, zinc, growth, volatile oil

Introduction

Garlic (*Allium sativum* L.) is one of the important spice crop belong to family Alliaceae. The bulb is tunicate and is composed of disc-like stem, thin dry scales, which are the bases of the foliage leaves and smaller bulbs or cloves. The cloves are enclosed by the dry outer scales having cloves consist of a protective cylindrical sheath, a single thickened storage leaf sheath and small central bud (Farooqi *et al.*, 2004). Potassium plays an important role in maintenance of cell water potential because it regulates opening and closing of stomata (Sinha, 1978), Biebl (1958) reported that potassium facilitates water uptake by plants from the soil solution is regulate by several factors including soil texture, moisture conditions, pH, aeration and temperature (Mengel and Kirkby, 1980).

Zinc is essential component and activator of many enzymes involved in auxin biosynthesis and photosynthesis (Romheld and Marscher, 1991) and their act as an important role in plant growth and yield of garlic. Zinc is most deficient among all the micronutrients in Indian soils condition. In many parts of India, zinc as a plant nutrient now stands third in importance next to nitrogen and phosphorus (Takkar and Randhawa, 1980). It plays an important role as a constituent of alcohol dehydrogenase and carbonic anhydrase in both microorganisms and higher plants. It helps the utilization of phosphorus and nitrogen in plants (Singh *et al.*, 2002).

Materials and Methods

The experiment was laid out at the "Research Field of the Department of Plantation, Spices, Medicinal and Aromatic Crops", College of Horticulture, Mandsaur, RVSKVV,

Gwalior, (M.P.) during *Rabi* season of 2017-18. Mandsaur is situated in Malwa Plateau in western part of Madhya Pradesh at North latitude of 23.45° to 24.13° and 74.44° to 75.18° East longitudes and an altitude of 435.02 meters above mean sea level. The soil of the experimental field was light black loamy in texture with low nitrogen (192 kg/ha), low phosphorus (7.6 kg/ha), medium potassium (145.0 kg/ha) soil having (pH 8.36) and EC (0.18 dS/m). The field experiment comprising 12 treatment combinations with the three replications was laid out in factorial randomized block design with two factors. The experiment consisted of four levels of potassium (0, 25, 50 and 75 kg K₂O/ha) and three levels of zinc (0, 5 and 10 kg Zn/ha). The crop variety G-282 were sown in spacing 15x10 cm with seed rate of 500 kg/ha. Uniform dose of nitrogen (150 kg/ha) through urea and phosphorus (60 kg/ha), through single super phosphate, potash and zinc nutrient were applied according to the treatment. Data were recorded for various growth, yield and quality parameters and statistically analyzed using the method of analysis of variance as described by Panse and Sukhatme (1985).

Results and Discussion

Effect of Potassium on growth attributes

Maximum plant height (30.84, 50.50, 71.13, 73.23 cm) at 30, 60, 90 and 120 DAS, number of leaves (3.87, 6.58, 8.71, 9.49) per plant at 30, 60, 90 and 120 DAS, fresh weight (2.72, 8.55, 28.57, 67.00 g) of plant (g) at 30, 60, 90 and 120 DAS, dry weight (0.53, 2.61, 7.08, 30.14, 28.13 g) of plant (g) at 30, 60, 90, 120 DAS and at harvest were recorded under application of potassium K₃ (75 kg K₂O ha⁻¹) followed by K₂

(50 kg K₂O ha⁻¹) and lowest in K₀ (0 kg K₂O ha⁻¹) at all the growth stages. It may be attributed to the fact that application of potassium improved not only availability of potassium but other nutrients also which are considered vitally important for growth and development of plants. The similar results have also been reported by Magray *et al.* (2017), Ismail *et al.* (2014), Arisha *et al.* (2017), Sayed *et al.* (2012), Sakarvadia *et al.* (2009) in garlic and Aftab *et al.* (2017) in onion.

Effect of Potassium on Yield attributes

Maximum fresh weight (28.5 g) of bulb, dry weight (9.57 g) of bulb, polar diameter (4.72 cm), equatorial diameter (4.42 cm) and bulb yield (139.3 q/ha) were recorded under application of potassium in K₃ (75 kg K₂O ha⁻¹) followed by K₂ (50 kg K₂O ha⁻¹) and lowest in K₀ (0 kg K₂O ha⁻¹) at all the stages of yield attributes. The similar results have also been reported by Sayed *et al.* (2012), Magray *et al.* (2017), Ismail *et al.* (2014), Arisha *et al.* (2017), Sakarvadia *et al.* (2009) in garlic and Aftab *et al.* (2017) in onion.

Effect of Potassium on quality attributes

Maximum TSS (41.63 °Brix) content and oil content (0.33 %) were recorded under application of potassium levels in K₃ (75 kg K₂O ha⁻¹) followed by K₂ (50 kg K₂O ha⁻¹) and lowest in K₀ (0 kg K₂O ha⁻¹). These may be due to potassium is essential for production of oil and fats. Similar results were also reported by Sayed *et al.* (2012), Arisha *et al.* (2017), Ismail *et al.* (2014) in garlic and Desuki *et al.* (2006) and Verma and Singh (2012) in onion.

Potassium plays an important role in maintenance of cell water potential because it regulates opening and closing of stomata (Sinha, 1978). Biebl, 1958 reported that potassium facilitates water uptake by roots and reduces transpiration loss in plant.

Effect of zinc on growth attributes

Maximum plant height (30.44, 50.73, 71.22, 72.60cm) at 30, 60, 90 and 120 DAS, number of leaves (3.82,

6.48, 8.50, 9.34) per plant at 30, 60, 90 and 120 DAS, fresh weight (2.50, 7.65, 28.34, 64.46) of plant (g) at 30, 60, 90 and 120 DAS, dry weight (0.53, 2.65, 6.27, 26.91, 27.28) of plant (g) 30, 60, 90, 120 DAS and at harvest, were recorded under application of zinc Z₂ (10 kg Zn ha⁻¹) followed by Z₁ (5 kg Zn ha⁻¹) and lowest in Z₀ (0 kg Zn ha⁻¹) at all the growth stages. It might be due to better growth and development of plant parts in terms of plant height, no. of leaves. Application of zinc might have increased the availability and steady supply of nutrients for plant metabolism and photosynthetic activity resulting into optimum growth and development of the crop. In addition, zinc is important in the synthesis of tryptophan, a component of some proteins and a compound needed for production of growth hormones (auxins) like Indol-Acetic Acid. Such improvement under increased availability of zinc in rhizosphere might have resulted in greater uptake by the plant consequently leading to a favourable effect on various processes of plant".

The similar results have also been reported by Rohidas *et al.* (2010), Chanchan *et al.* (2014), Islam *et al.* (2012), Sakarvadia *et al.* (2009) in garlic and Manna *et al.* (2014) in onion.

Effect of Zinc on Yield and yield attributes

Maximum fresh weight (28.8 g) of bulb, dry weight (9.32 g) of bulb, polar diameter (4.51 cm), equatorial diameter (4.31 cm) and bulb yield (136.7 q/ha) were recorded under application of zinc Z₂ (10 kg Zn ha⁻¹) followed by Z₁ (5 kg Zn ha⁻¹) and lowest in Z₀ (0 kg Zn ha⁻¹) at all the stages of yield attributes. Similar results were also reported by Chanchan *et al.* (2014), Rohidas *et al.* (2010), Islam *et al.* (2012), Nasreen *et al.* (2009) In garlic and Manna *et al.* (2014) and Trivedi and Dhumal (2013) in onion.

Effect of Zinc on quality attributes

Maximum TSS content (38.25 °Brix) in bulb and volatile oil content (0.32 %) in bulb were recorded under application of zinc Z₂ (10 kg Zn ha⁻¹) followed by Z₁ (5 kg Zn

Table 1. Effect of potassium and zinc on growth and yield of garlic

Treat.	Plant height (cm)				No of leaves per plant				Fresh weight of plant (g)				Dry weight of plant (g)				
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Potassium																	
K ₀	26.16	47.77	65.76	66.58	3.32	5.06	7.37	8.00	2.03	4.41	22.93	53.01	0.42	1.35	4.49	18.46	22.13
K ₁	29.90	49.52	67.91	67.52	3.49	6.44	7.66	8.42	2.24	6.34	25.40	58.66	0.47	2.68	5.69	24.95	24.97
K ₂	30.32	50.27	69.84	69.57	3.50	6.57	8.33	8.82	2.39	6.86	25.62	63.76	0.48	2.42	6.42	27.63	26.59
K ₃	30.84	50.50	71.13	73.23	3.87	6.58	8.71	9.49	2.72	8.55	28.57	67.00	0.53	2.61	7.08	30.14	28.13
SEm±	0.36	0.42	0.72	1.52	0.09	0.10	0.15	0.18	0.12	0.32	0.61	1.11	0.02	0.07	0.10	0.31	0.37
CDat 5%	1.06	1.23	2.11	4.46	0.26	0.28	0.43	0.54	0.34	0.95	1.78	3.27	0.05	0.22	0.30	0.92	1.09
Zinc																	
Z ₀	28.05	47.41	64.06	64.63	3.31	5.66	7.48	7.82	2.00	5.08	22.31	53.27	0.41	1.81	5.54	23.74	22.73
Z ₁	29.43	50.41	70.71	70.45	3.51	6.35	8.07	8.89	2.53	6.89	26.24	64.09	0.49	2.34	5.95	25.24	26.36
Z ₂	30.44	50.73	71.22	72.60	3.82	6.48	8.50	9.34	2.50	7.65	28.34	64.46	0.53	2.65	6.27	26.91	27.28
SEm±	0.31	0.36	0.62	1.32	0.08	0.08	0.13	0.16	0.10	0.28	0.53	0.96	0.02	0.06	0.09	0.27	0.32
CD at 5%	0.91	1.07	1.82	3.86	0.22	0.24	0.37	0.47	0.30	0.82	1.54	2.83	0.05	0.19	0.26	0.80	0.94

Table 2. Effect of potassium and on growth, yield and quality of garlic

Tret.	Fresh weight of bulb (g)	Dry weight of bulb (g)	Polar diameter(cm)	Equatorial diameter (cm)	Bulb yield (q ha ⁻¹)	TSS content (°Brix)	Volatile oil content (%)
Potassium							
K ₀	23.3	8.40	3.94	3.63	114.6	33.28	0.22
K ₁	26.7	8.66	4.33	4.10	131.1	36.20	0.26
K ₂	27.0	9.12	4.50	4.36	134.8	38.83	0.31
K ₃	28.5	9.57	4.72	4.42	139.3	41.63	0.33
SEm±	0.58	0.07	0.05	0.06	0.52	0.18	0.01
CD at 5%	1.70	0.20	0.14	0.17	1.53	0.54	0.02
Zinc							
Z ₀	23.1	8.49	4.19	3.96	118.7	36.64	0.23
Z ₁	27.2	9.00	4.43	4.11	133.3	37.57	0.29
Z ₂	28.8	9.32	4.51	4.31	136.7	38.25	0.32
SEm±	0.50	0.06	0.04	0.05	0.45	0.16	0.01
CD at 5%	1.47	0.17	0.12	0.15	1.33	0.47	0.02

Table 3. Combined effect of potassium and zinc on growth parameter of garlic.

Treatment	Plant height (cm)				No of leaves per plant				Fresh weight of plant (g)			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
K ₀ Z ₀	23.17	46.50	63.33	62.90	3.07	5.00	7.07	7.50	1.76	3.91	21.97	51.87
K ₀ Z ₁	27.01	48.20	66.17	66.60	3.17	5.02	7.10	8.10	2.00	4.26	23.10	54.82
K ₀ Z ₂	28.30	48.37	67.20	68.00	3.73	5.17	7.20	8.40	2.33	5.07	23.73	52.33
K ₁ Z ₀	28.87	49.33	64.33	65.30	3.47	5.67	7.80	7.83	2.08	5.77	22.20	51.11
K ₁ Z ₁	29.61	51.50	70.13	70.80	3.37	6.73	7.93	8.63	2.55	6.20	26.07	62.42
K ₁ Z ₂	30.13	50.67	69.27	69.27	3.67	6.74	7.97	8.80	2.11	7.03	27.93	62.44
K ₂ Z ₀	30.15	47.07	63.39	65.13	3.23	5.97	7.77	8.10	2.10	4.86	22.37	55.33
K ₂ Z ₁	30.33	50.40	73.33	70.27	3.60	6.73	8.30	8.87	2.80	7.35	25.67	68.89
K ₂ Z ₂	30.48	51.10	72.87	69.40	3.63	6.82	8.83	9.50	2.28	8.37	28.83	67.06
K ₃ Z ₀	30.00	46.73	64.67	65.17	3.47	6.00	8.00	7.83	2.07	5.77	22.70	54.77
K ₃ Z ₁	30.77	51.53	73.20	74.13	3.90	6.83	8.93	9.97	2.80	9.77	30.13	70.22
K ₃ Z ₂	31.75	52.77	75.53	83.73	4.23	7.00	9.30	10.67	3.29	10.13	32.87	76.00
SEm±	0.62	0.73	1.24	2.63	0.15	0.17	0.25	0.32	0.20	0.56	1.05	1.19
CD at 5%	1.83	2.14	3.65	7.72	NS	0.49	NS	0.93	NS	1.64	3.09	5.85

Table 4. Combined effect of potassium and zinc on yield and quality parameter of garlic.

Treatment	Dry weight of plant (g)					Fresh weight of bulb (g)	Dry weight of bulb (g)	Polar diameter of bulb (cm)	Equatorial diameter of bulb (cm)	Bulb yield (q/ha)	TSS content in bulb (°Brix)	Volatile oil content in bulb (%)
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest							
K ₀ Z ₀	0.40	1.29	4.26	17.44	21.07	1.76	3.91	21.97	51.87	0.40	32.61	0.21
K ₀ Z ₁	0.41	1.33	4.44	18.59	22.47	2.00	4.26	23.10	54.82	0.41	33.30	0.21
K ₀ Z ₂	0.44	1.42	4.77	19.36	22.87	2.33	5.07	23.73	52.33	0.44	33.92	0.23
K ₁ Z ₀	0.40	2.51	4.89	21.96	22.77	2.08	5.77	22.20	51.11	0.40	35.19	0.26
K ₁ Z ₁	0.49	2.76	6.04	25.26	25.47	2.55	6.20	26.07	62.42	0.49	36.64	0.33
K ₁ Z ₂	0.53	2.78	6.14	27.63	26.67	2.11	7.03	27.93	62.44	0.53	36.78	0.34
K ₂ Z ₀	0.42	1.68	6.52	26.55	23.33	2.10	4.86	22.37	55.33	0.42	37.81	0.23
K ₂ Z ₁	0.49	2.51	6.22	26.66	27.77	2.80	7.35	25.67	68.89	0.49	38.88	0.24
K ₂ Z ₂	0.54	3.08	6.51	29.67	28.67	2.28	8.37	28.83	67.06	0.54	39.81	0.32
K ₃ Z ₀	0.41	1.77	6.49	29.00	23.73	2.07	5.77	22.70	54.77	0.41	40.95	0.24
K ₃ Z ₁	0.57	2.77	7.12	30.45	29.73	2.80	9.77	30.13	70.22	0.57	41.45	0.36
K ₃ Z ₂	0.60	3.30	7.65	30.99	30.93	3.29	10.13	32.87	76.00	0.60	42.51	0.40
SEm±	0.03	0.13	0.18	0.54	0.64	0.20	0.56	1.05	1.19	0.03	0.32	0.10
CD at 5%	NS	0.38	0.52	1.6	1.89	NS	1.64	3.09	5.85	NS	NS	0.40

ha⁻¹) and lowest in Z₀ (0 kg Zn ha⁻¹). The increased in volatile oil content of garlic due to application of zinc has also been reported by Hatwal *et al.* (2015), Manna *et al.* (2014) Trivedi and Dhumal (2013) in onion.

Interaction effect of potassium and zinc

Combined effect of potassium and zinc exerted significantly influence on growth attributes viz., plant height, number of leaves per plant, fresh weight and dry weight of plant (g), at all the growth stages except number of leaves per plant, fresh weight dry weight at 30 DAS. Maximum plant height, number of leaves per plant, fresh weight and dry weight of plant (g), were recorded under treatment combination K₃Z₂. Minimum plant height, number of leaves per plant, fresh weight and dry weight of plant (g) were recorded under K₀Z₀. Similar results were also reported by Sakarvadia *et al.* (2009) in garlic.

Combined effect of potassium and zinc showed significantly influence on yield attributes viz., Maximum fresh weight of bulb (g), dry weight of bulb (g), polar diameter of bulb (cm), equatorial diameter of bulb (cm) and bulb yield (q ha⁻¹) were recorded under treatment combination K₃Z₂. Minimum fresh weight of bulb (g), dry weight of bulb (g), polar diameter of bulb (cm), equatorial diameter of bulb (cm), number of cloves per bulb and bulb yield (q ha⁻¹) were recorded under treatment combination K₀Z₀.

Combined effect of potassium and zinc showed significantly influence on quality attributes viz., TSS content in bulb (°Brix) and volatile oil content in bulb (%). Maximum amount of TSS content in bulb (°Brix) and oil content in bulb (%) were recorded under treatment combination K₃Z₂. Minimum amount of TSS content in bulb (°Brix) and oil content in bulb (%) were recorded under treatment combination K₀Z₀ in garlic.

On the basis of one year research it could be concluded that application of potassium and zinc influence the growth, yield and quality of garlic. The growth, yield and quality of garlic can be increased by application of K₃Z₂ (75 Kg K₂O/ha + 10 Kg Zn/ha) should be advocated for garlic.

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Nutrient status of acid lime orchard soils in Sikar district of Rajasthan

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(Received: 26.05.2018; Accepted: 21.08.2018)

Abstract

Studies were conducted on the mineral nutrition status of acid lime fruit orchards located in Sikar district of Rajasthan. Electrical conductivity was found to be in normal range and soil pH was in the high ranging from 7.73 to 9.31. The organic carbon content and available nitrogen of acid lime orchard soils were found low whereas available phosphorus, available iron, zinc, copper, and manganese were found low to medium. Available potassium was found medium whereas available sulphur was found low in range. The soils were found medium to high in exchangeable Ca and Mg. There was wide variation found in the calcium carbonate percentage at different soil depths in orchards.

Key words: Acid Lime, orchards, nutrient status.

Introduction

The Sikar district has moderate climate with seasonal temperature variation with scanty rainfall to the magnitude of 450-500 mm per annum during normal rainfall years. The high temperature (up to 48°C) along with high wind velocity, low soil fertility status, low water retention capacity of soil, high soil pH, salinity, calcium carbonate concretion in sub soil etc. are hard impediment in successful cultivation of many fruit crops in arid region. Increasing the production of fruits thus has sufficient scope in arid region of Rajasthan. In Sikar district, the area under fruit crops is 0.002 lac ha with production of 0.02 lac metric tonnes (Anonymous, 2005). There is a vast potential of increasing area under fruit cultivation in arid region of Rajasthan provided irrigation facilities are available. These areas are suitable for cultivation of fruit crops such as aonla, ber, beal citrus, pomegranate etc. Presently Sikar district has nearly 2,12,096 lac hectares irrigated area through tube wells/wells. Irrigation facilities has opened great avenues for cultivation of fruit crops likes ber, aonla, bael, lime, pomegranate, datepalm, guava, jamun, karonda, phalsa etc, besides traditionally grown fruits such as Ker (*Capparis decidua*), Gonda (*Cordia myxa*), Pilu (*Salvadora oleoides*), Khejri (*Prosopis cineraria*) etc. In spite of all vagaries, the farmers of Sikar district has shown tremendous response towards fruit cultivation particularly of ber, bael, lime and aonla fruits. Citrus is an important fruit crop of India. It is next to banana and mango in acreage and economic point of view. Citrus industry in India is the third largest industry of the country. Acid lime (*Citrus aurantifolia*) is the third important fruit after mandarin and sweet orange. India is perhaps the largest producer of acid lime. Citrus

cultivation particularly of acid lime has become quite popular in arid irrigated areas of Western Rajasthan. Acid lime fruits are highly appreciated for their medicinal and nutritional value.

People inhabitation in arid areas is known to suffer from a number of nutritional disorders owing to lower intake of protective foods like fruits and vegetables. In Indian fruit industry, poor nutrition is the major cause of low orchard efficiency resulting poor productivity and poor fruit quality. Sufficient information on nutrient management in fruit crops has been generated, but response and requirement of nutrients of perennial fruit crops vary markedly in a particular area depending on soil and climatic conditions and also depend on growth, bearing habit, age, root stock and management practices. Balanced nutrition of fruit crops is paramount importance particularly in arid areas having largely sandy soils of poor fertility status. For knowing the exact status of mineral nutrition in the fruit trees, survey of the orchards for their fertility status and plant nutrients is done. A number of nutritional surveys have been conducted on various fruit crops in northern and western states of the country viz., Punjab, Haryana, Himachal Pradesh and Maharashtra to study fertility status of soil. Studies on nutritional survey of arid fruits in Rajasthan are meagre in spite of their great importance and relevance. Therefore, present investigation was conducted to survey the fruit orchards in Sikar district of Rajasthan to gain information about their nutrient status.

Materials and Methods

A detailed soil survey was conducted in Sikar district of Rajasthan. Orchards were selected in such a way that these

can represent general conditions of area under study. Eight acid lime orchards were selected covering different tehsils viz.

Srimadhopur, Laxmangarh, Danta Ramgarh and Piparali. The details of locations and name of the fruit growers are given below.

S.No.	Name of fruit grower	Village	location
1.	Shri Prahalad	Raghunathgarh	Raghunathgarh
2.	Shri Panna Ram	Pachar	Pachar-IV
3.	Shri Ram Dev Singh	Purohit Ka Bas	Purohit Ka Bas-II
4.	Shri Roopchand Pipliwal	Pachar	Pachar-V
5.	Shri Hanumana Ram	Sanwalod	Sanwalod
6.	Shri Pokhar Mal	Purohit Ka Bas	Purohit Ka Bas-III
7.	Shri Guljari Kumawat	Jorawar Nagar	Jorawar Nagar
8.	Shri Harlal Singh	Palsana	Palsana-III

Soil samples were collected from fruit orchards, on the basis of variability and orchard performance at different locations of Sikar district. Thereafter, from each selected orchards, three soil profiles, based on soil fertility variation and plant performance were taken up. The sampling was done in each profile up to depth of 120 cm i.e. 0-15, 15-30, 30-45, 45-60, 60-75, 75-90, 90-105 and 105-120 cm. from orchards. The soil samples were analysed for organic carbon, available nitrogen, available phosphorus and available potash by Walkley and Black rapid titration method (Jackson, 1973), Alkaline permanganate method (Subbiah and Asija, 1956), Olsen's method (Olsen *et al.*, 1954) and Flame photometer method (Jackson 1973), respectively. The available Fe, Cu, Zn, and Mn were extracted with DTPA solution as per procedure of Lindsay and Norvell (1978) and were determined by atomic absorption spectrophotometry. Exchangeable Ca and Mg were determined by method given by Richards, 1954. Available sulphur was determined by the method given by Chesnin and Yien, 1957.

Results and Discussion

Organic carbon, electrical conductivity and pH of soil

The organic carbon status of acid lime orchard soils was generally poor. It varied from 0.058 to 0.230 per cent with a mean value of 0.156 for all the depths. The data presented on organic carbon content of orchard soils showed a decreasing trend with increase in depths. As per the ratings given by Muhr *et al.* (1963), the soils having organic carbon <0.5 per cent organic carbon have been categorized under low category. All the acid lime orchard soils were found low in organic carbon content. Low content of organic carbon in the soils of Sikar district appears to be mainly due to the type of climate of the region. It is difficult to build up organic matter in the soils of arid regions on account of high temperature which causes rapid oxidation of organic matter.

The electrical conductivity of acid lime orchard soils ranged from 0.053 to 0.270 dsm^{-1} with a mean value of 0.112 dsm^{-1} for all the depths. The electrical conductivity of different acid lime orchard soils revealed a decreasing trend with increase in depth. As per the limits given by Muhr *et al.* (1963), the soils have been categorized into three i.e. 1, 1-2 and >2 mmhos/cm for normal, critical for germination and severe

injury to crops. Data indicated that all the acid lime orchard soil samples were having electrical conductivity values less than 1 dsm^{-1} . A comparative low conductivity value of most of the soils may be attributed to leaching of soluble salts from the soil column, being high permeability of light textured soils.

The pH of soils was found to be high as it ranged from 7.73 to 9.31 with mean value of 8.67 for all the soil depths. The relatively high pH of these orchard soils might be due to their fairly high base saturation.

Nutrient status of acid lime orchard soils

The available nitrogen content ranged between 73.00 to 139.00 kg ha^{-1} with a mean value of 112.22 for all the depths. The data presented on available nitrogen content of orchard soils showed a decreasing trend with increase in depths. As per the ratings given by Tandon (1992a), the soils having <125 mg kg^{-1} have been categorized under low category. All the acid lime orchard soils were found low in available nitrogen content. The cause of low available nitrogen content in all these soils had been due to the absence of natural vegetation, low organic carbon, low precipitation and high temperature which aggravates decomposition of organic matter by enhancing oxidation and aeration. The results of present study are in confirmation with those reported by Bhatnagar *et al.* (2000).

The available phosphorus content varied from 6.46 to 29.48 kg ha^{-1} with a mean value of 15.83 for all the depths. The data presented on available phosphorus content of orchard soils showed a decreasing trend with increase in depths. As per the ratings given by Tandon (1992a), the soils having <10.26 mg kg^{-1} have been categorized under low soils whereas those having 10.26 to 25.85 mg kg^{-1} falls under medium category. A close examination of data revealed that available phosphorus was low in 75 per cent whereas, 25 per cent orchards were medium in respect to available phosphorus in orchards. The low to medium availability of phosphorus might be due to the presence of high pH, low organic carbon, calcareousness, low precipitation, high temperature and light textured coarse sandy soils. The results of present investigations are in accordance with those reported by Bhatnagar *et al.* (2000), Ghosh and Hassan (1979) and Sharma and Mahajan (1990).

The available potassium content ranged between 110.00 to 183.00 kg ha^{-1} with a mean value of 148.78 for all the

depths. In the present study, the available potassium content of orchard soils showed a decreasing trend with increase in depths. As per the ratings given by Tandon (1992a), the soils having <58.03 to 149.55 mg kg⁻¹ falls under medium category. All the soil samples of acid lime were medium in available potassium. A satisfactory potassium status of the studied area might be due to the presence of potash bearing minerals (muscovite, biotite and feldspar) which on weathering slowly

release potash. Bhatnagar *et al.* (2000) reported similar results.

The exchangeable calcium content varied from 2.66 to 3.83 cmol kg⁻¹ with a mean value of 3.32 for all the depths. The exchangeable magnesium content of these orchard soils ranged from 1.44 to 2.22 cmol kg⁻¹ with a mean value of 1.75 for all the depths. In the present study, the exchangeable calcium and magnesium content of orchard soils showed a increasing trend with increase in depths. All the soil samples

Table 1. Nutrient status of acid lime orchard soils of Sikar district of Rajasthan

Soil depths/ characters	0-15 cm.		15-30 cm.		30-45 cm.		45-60 cm.	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
pH	7.73-8.90	8.43	7.84-9.03	8.53	7.89-9.11	8.59	8.00-9.14	8.65
EC(dsm ⁻¹)	0.103-0.270	0.146	0.093-0.267	0.135	0.090-0.250	0.126	0.087-0.243	0.118
OC(%)	0.101-0.230	0.175	0.098-0.227	0.171	0.093-0.222	0.166	0.089-0.219	0.161
N(kgha ⁻¹)	99.00-139.00	123.38	93.00-136.00	120.00	91.00-134.00	117.00	88.00-129.00	113.13
P(kgha ⁻¹)	12.04-29.48	18.91	10.80-28.21	17.61	10.12-26.46	16.50	8.95-26.26	15.90
K(kgha ⁻¹)	127.00-183.00	161.00	125.00-179.00	158.00	123.00-178.00	154.50	120.00-176.00	151.13
Ca(cmolekg ⁻¹)	2.66-3.44	3.16	2.76-3.62	3.22	2.81-3.67	3.27	2.87-3.70	3.32
Mg(cmolekg ⁻¹)	1.44-1.85	1.66	1.45-1.92	1.66	1.47-1.94	1.68	1.50-1.97	1.71
S(mgkg ⁻¹)	6.84-9.06	7.87	6.76-9.00	7.81	6.64-8.88	7.59	6.41-8.72	7.28
Fe(mgkg ⁻¹)	3.81-6.38	4.71	3.79-6.36	4.69	3.76-6.33	4.65	3.71-6.31	4.61
Zn(mgkg ⁻¹)	0.393-1.017	0.796	0.367-0.997	0.775	0.347-0.970	0.753	0.317-0.947	0.728
Cu(mgkg ⁻¹)	0.157-0.420	0.285	0.140-0.397	0.269	0.137-0.370	0.250	0.130-0.340	0.229
Mn(mgkg ⁻¹)	1.88-5.15	3.25	1.74-5.07	3.15	1.68-5.00	3.09	1.62-4.95	3.03
Caco ₃ (%)	2.44-3.92	3.33	2.55-3.94	3.38	2.65-3.99	3.45	2.76-4.01	3.51
Soil depths/ characters	60-75 cm.		75-90 cm.		90-105 cm.		105-120 cm.	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
pH	8.08-9.19	8.72	8.15-9.24	8.77	8.22-9.27	8.83	8.25-9.31	8.89
EC(dsm ⁻¹)	0.080-0.233	0.110	0.073-0.223	0.102	0.063-0.200	0.090	0.053-0.173	0.076
OC(%)	0.083-0.211	0.156	0.077-0.205	0.149	0.069-0.198	0.143	0.058-0.188	0.134
N(kgha ⁻¹)	86.00-127.00	110.75	81.00-121.00	107.63	78.00-118.00	104.50	73.00-116.00	101.38
P(kgha ⁻¹)	8.65-26.05	15.47	7.58-25.38	14.69	6.95-25.00	14.08	6.46-24.75	13.54
K(kgha ⁻¹)	116.00-174.00	147.38	114.00-172.00	143.63	112.00-164.00	139.13	110.00-159.00	135.50
Ca(cmolekg ⁻¹)	2.91-3.73	3.35	2.96-3.77	3.39	3.02-3.81	3.43	3.04-3.83	3.46
Mg(cmolekg ⁻¹)	1.54-2.00	1.74	1.62-2.14	1.82	1.60-2.18	1.85	1.65-2.22	1.90
S(mgkg ⁻¹)	6.18-8.59	7.11	6.09-8.43	7.03	5.90-8.35	6.94	5.75-8.14	6.86
Fe(mgkg ⁻¹)	3.69-6.25	4.57	3.64-6.20	4.53	3.58-6.15	4.48	3.54-6.10	4.43
Zn(mgkg ⁻¹)	0.300-0.917	0.705	0.273-0.897	0.682	0.253-0.867	0.656	0.247-0.780	0.609
Cu(mgkg ⁻¹)	0.120-0.317	0.218	0.117-0.310	0.204	0.113-0.290	0.194	0.103-0.270	0.173
Mn(mgkg ⁻¹)	1.57-4.90	2.98	1.51-4.83	2.92	1.43-4.79	2.87	1.37-4.74	2.81
Caco ₃ (%)	2.83-4.10	3.61	2.88-4.15	3.65	2.95-4.21	3.75	3.02-4.26	3.77

drawn from acid lime orchards were found high in exchangeable calcium and magnesium content. The high exchangeable calcium content in all these soils could be because of calcareous nature of the soils which further due to in accumulation i.e. of exchangeable calcium in the profile zone. Being high in base saturation all the soil samples of acid lime orchards were found having fairly good amount of exchangeable magnesium content. Bhatnagar *et al.* (2000) reported similar results.

The available sulphur content ranged between 5.75 to 9.06 mgkg⁻¹ with a mean value of 7.31 for all the depths. The data presented on available sulphur content of orchard soils showed a decreasing trend with increase in depths. Based on the ratings given by Tandon (1992a), the soils having less than 10 mg kg⁻¹ falls under low category, those having more than 10 mg kg⁻¹ falls under medium category. All the soil samples of acid lime orchards were found low in available sulphur content. The low content of these soils may be due to high temperature, low precipitation, very low organic matter and light textured coarse sandy soils. The findings reported by Bhatnagar *et al.* (2000) and Kumar (2004) are almost similar to the results of present investigations.

The DTPA extractable iron content ranged between 3.54 to 6.38 mgkg⁻¹ with a mean value of 4.58 for all the depths. The data presented on DTPA extractable iron content of orchard soils showed a decreasing trend with increase in depths. As per the ratings given by Tandon (1992a), the soils having <4.5 mg kg⁻¹ falls under deficient category and those having >4.5 mg kg⁻¹ falls under sufficient category. A close examination of data revealed that DTPA extractable iron was deficient in 50 per cent, whereas 50 per cent orchards were sufficient in respect to DTPA extractable iron in orchards. The deficient to sufficient status of iron found in the soil might be due to calcareousness, low organic carbon content, light textured coarse sandy soils. Similar observations were reported by Bhatnagar *et al.* (2000) and Bhatnagar and Chandra (2003).

The DTPA extractable zinc content ranged between 0.247 to 1.017 mgkg⁻¹ with a mean value of 0.713 for all the depths. The data presented on DTPA extractable zinc content of orchard soils showed a decreasing trend with increase in depths. As per the ratings given by Tandon (1992a), the soils having less than 0.6 mg kg⁻¹ falls under deficient category, those having 0.6 to 1.2 mg kg⁻¹ falls under sufficient category. Twenty five per cent soil samples of acid lime orchards were deficient in DTPA extractable zinc. Remaining 75 per cent soil samples of acid lime orchards were sufficient in DTPA extractable zinc. This range of zinc in soils might be due to the presence of quartz, feldspar or the exchange complex being such as to have sites saturated with Ca/Mg under alkaline soil reaction. Calcareous nature and low organic matter are some of the other properties where low levels of zinc are anticipated. Similar findings were reported by Sharma and Bhandari (1995) and Kameariya (1995).

The DTPA extractable copper content ranged between 0.103 to 0.420 mgkg⁻¹ with a mean value of 0.227 for all the depths. The data presented on DTPA extractable copper

content of orchard soils showed a decreasing trend with increase in depths. As per the ratings given by Tandon (1992a), the soils having <0.2 mg kg⁻¹ falls under deficient category, those having >0.2 mg kg⁻¹ falls under sufficient category. Twenty five per cent soil samples of acid lime orchards were deficient in DTPA extractable copper. Remaining 75 per cent soil samples of acid lime orchards were sufficient in DTPA extractable copper. The deficient to sufficient available copper status of orchard soil might be due to high pH, calcareousness, lower organic carbon and light textured coarse sandy soils. The present results are in accordance with those reported by Baser and Lodha (1971) who reported that available copper status in sandy soils of Rajasthan varied from 0.05 to 2.38 ppm.

The DTPA extractable manganese content ranged between 1.37 to 5.15 mgkg⁻¹ with a mean value of 3.01 for all the depths. The data presented on DTPA extractable manganese content of orchard soils showed a regular decreasing trend with increase in depths. As per rating given by Tandon (1992a), the soils having <2 mg kg⁻¹ falls under deficient category, those having >2 mg kg⁻¹ falls under sufficient category. Twenty five per cent soil samples drawn from surface soil depth of acid lime orchards were deficient and 75 per cent were sufficient in DTPA extractable manganese in the present study. Results of DTPA extractable manganese in all the orchards clearly indicate that deficiency of manganese in the fruit orchards is now coming. Another in the present study only 1/4th orchards have shown deficient. The deficiency of DTPA extractable manganese might be due to the presence of high CaCO₃ content and low organic carbon content. These results are in accordance with those reported by Bhatnagar *et al.* (2000); Bhatnagar and Chandra (2003) and Kumar (2004).

The calcium carbonate percentage ranged between 2.44 to 4.26 with a mean value of 3.55 for all the depths. Calcium carbonate percentage increased with the increasing depths. It indicates that the calcium leached down from surface soil to sub-surface soils accumulated in the form of calcium carbonate as secondary carbonate. A comparative high calcium carbonate content of soil might be due to dominance of alkaline earth carbonates in the soils. Similar results were also observed for arid and semi arid regions by Bhatnagar *et al.* (2000) and Kumar (2004).

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Analysis of price variation and market integration of ragi in selected markets of Tamil Nadu and Karnataka

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(Received: 10.08.2018; Accepted: 12.09.2018)

Abstract

Agriculture supply is uncertain and this leads to fluctuations in prices. The study investigates the price details, market integration of ragi in selected markets of Tamil Nadu and Karnataka. The time series data of ragi in wholesale prices were collected for 15 years for the time period of 2003-2017. The results from the analysis of price variations, the seasonal indices of ragi are found to be higher in sowing months and the ragi price trend showing more fluctuation, as the consumption pattern of ragi has widened and demand for Ragi is increasing the years. The unit root test revealed that the four wholesale markets except Vellore market were non stationary at 1 per cent level and become stationary after first differencing. In Johansen co-integration procedure there is three co-integration equations at 5 per cent level of significance among the ragi prices. The VECM estimates in short-run Chintamani market price converged into equilibrium within 6 days. The shock observed by the Tumkur market price will be corrected within 10 days. In the long-run Chintamani and Tumkur markets were influenced by their own monthly lagged price and Hosur markets were influenced by Denkanikottai first month lagged prices of the market.

Key words: Market intelligence, price variation, Tamil Nadu

Introduction

Agricultural commodity prices are well known to fluctuate over time and markets. Price stabilization efforts for various essential agricultural commodities continue to maintain be the major concern for policy makers. Both the producers and consumers are affected by price instability. The increase in the prices of agricultural commodities spills over to other sectors of the economy leading to an increase in the overall rate of inflation. Knowledge of relative price relationships and variability over seasons and trends is important for understanding the patterns of change and resource allocation in the agricultural sector (Byerlee and Iqbal, 1987).

Material and Methods

Five ragi markets from Tamil Nadu and Karnataka were related based on regular availability of data during study period. The selected markets were Chintamani and Tumkur in Karnataka and Denkanikottai, Hosur and Vellore in Tamil Nadu. Data on monthly wholesale prices were collected for 15 years (2003 to 2017). The Wholesale price were collected from Agmarknet, Regulated markets and DEMIC.

Seasonal Variations

Seasonal variations indicated the regularity of upward and downward movements during the year. These price variations resembled the cycle but covered a period of 12 months or less. Moving averages were useful to eliminate periodic movements. An average represented the "middling" value of a set of numbers.

The percentage of actual moving average was calculated by the following formula

Seasonal Index = (Actual data for the month/Centered moving average for the month) x 100

The percentage of actual moving averages was arranged in the form of monthly patterns and the average of each index was calculated and adjusted their sum value to become 1200. This was done by working out a correction factor and multiplied the average index for each month by this factor.

Correction factor (K) = $1200/S$

Where, S = Sum of average index for a year

Seasonal indices were constructed for different months and plotted in a graph to understand the price variations.

Trend analysis

Analysis of long-term movements (trend) for estimating the long run trend of prices, the method of least squares estimate was employed. This method of ascertaining the trend in a series of annual prices involved estimating the coefficient of intercept (a) and slope (b) in the linear functional form. The equation adopted for this purpose was specified as follows.

$$Y = a + bx$$

Where,

Y = Trend values at time t

a = intercept parameter

b = slope parameter, which also indicates the trend rate

X = independent variable- monthly average price of ragi

(Rs/kg).

Market Integration

A relatively unrestricted modeling approach based on the error correction mechanism (ECM) advocated by Banerjee *et al.* (1986), Hendry and Richard (1982), Hendry and Mizon (1990) and Banerjee *et al.* (1993) were utilized to this study. The empirical exercise consists:

Testing for a Unit Root

Testing for stationarity in the time series data is pre requisite since the time series has the presence of trend components (Davidson and Mackinnon, 1993). Augmented Dickey fuller (ADF) test involved in testing stationarity of the variables and if the time series is found to be non-stationary, the first differences of the series are tested for stationarity.

The test mentioned above consider the null hypothesis of a time series has a unit root (non-stationary). The test is applied by running the regression of the following form:

$$\Delta y_t = (\rho - 1)y_{t-1} + u_t = \delta y_{t-1} + u_t$$

This model can be evaluated and testing for a unit root is proportional to testing $d = 0$ (where $d = ? - 1$) and Augmented-Dickey Fuller (ADF) unit root test are used. The null hypothesis of non-stationary is tested using a t-test. The null hypothesis is rejected if estimated variable is significantly negative.

Once the time series data checked for stationary and are of same order, integration between them tested using the models as ADF test @ Johansen co-integration test in a bivariate as well as multivariate framework of the estimated value of the error exceeds critical values at 1, 5 and 10 per cent of level of significance and the conclusion would be that the residual term is stationary and hence the time series, through the non-stationary are co-integrated in the long run.

Johansen's multiple co-integration frameworks

The individual time series of the prices may be non-stationary on levels, but a linear combination of them may be

stationary indicating a long-run equilibrium relationship between them (Engle and Granger, 1987). The linear combination of co-integration regression as follows

$$Y_t = \beta_1 + \beta_2 X_t + Z_t$$

Where Y_t and X_t are two price series in levels and Z_t is the residual term testing for co-integration

Estimation of price adjustment-Vector error correction mechanism

Regression is one random walk on the other has a stationary error term. Subsequently building up that a relationship exists between unit root factors, That relationship is called the co-integrating vector, which for our example is (Abbasa and Foreman-Peck, 2007) since the sum is stationary.

$$X_t = \alpha_1(\beta_1 Y_{t-1} + \beta_2 X_{t-1} + \varepsilon_t + \theta_t)$$

$$\Delta Y_t = \alpha_2(\beta_1 Y_{t-1} + \beta_2 X_{t-1} + \mu_t + \theta_t)$$

Whereas alpha contains speed of adjustment and beta contains co-integrating equation. These time series analyses of econometric models are carried out using Eviews 7.0.0.1.rar.

Results and Discussion

Ragi - Area, production and productivity

In India, Karnataka and Tamil Nadu are the principle ragi growing states, besides Andhra Pradesh, Maharashtra, Uttar Pradesh and Bihar (TNAU Agritech Portal). Karnataka is the largest Ragi growing state and it has seen a steady rise in production. Between 2011 and 2014, Ragi production in the state grew 12.7 per cent while the total area under ragi cultivation grew 4.1 per cent. Yield per hectare has also risen steadily. Ragi yield across the country rose 8.34 per cent from 1,534 kg per hectare in 2005-06 to 1,662 kg per hectare in 2014-15 (Directorate of Economics and Statistics, 2016).

The tables below indicate the selected state wise average normal area, production and productivity of ragi in India (Average of 2011-12 to 2015-16).

Table 1. State-wise Normal Area, Production and Yield of Ragi

State	(Average of 2011-12 to 2015-16)		
	Area (in 000 Hectare)	Production (in 000 Tonnes)	Productivity (In Tonnes/Hectare)
Karnataka	681.8	1182.7	1.73
Tamil Nadu	93.2	269.3	2.88

Source: Ministry of Agriculture and Farmers Welfare, Govt. of India (2017).

Ragi Prices

In the decade to December 2016, ragi prices increased 270 per cent compared with a 113 per cent rise in the wholesale price index for all cereal, (Centre for Monitoring Indian Economy). The domestic and international export market for ragi was estimated to be \$4.5 billion, "If the policies of the government are right, given this demand, the area under ragi cultivation can grow 30 per cent in the next few

years", (Indiastat). Minimum support prices for Ragi was Rs.1650/- and above per quintal as on November 2016. (Source: Directorate of economics and statistics, 2017).

The price variations of selected markets were shown in the fig. 1 to fig. 5. It is observed from the graphs that, in the case of all above markets (Chintamani, Tumkur, Denkanikottai, Hosur, and Vellore) the monthly average price of ragi in the year 2017 is showing a declining trend over the

months. During the year 2013 the price series of ragi in Vellore and Tumkur market were found to be decreasing and in other markets the trend was found to be increasing. For the year 2008 and 2003, all the markets were showing a slight increasing and stable price trend. During early years the ragi price trend was observed to be stable, this may be due to the demand for ragi was low but in case of recent years (2013-17) the ragi price trend is showing more fluctuation, as the consumption pattern of ragi has widened and demand for ragi is increasing the years.

Seasonal index for the selected markets

Seasonal index for the selected markets are given in the table 2. From the table highest seasonal indices were played in the months are represented in the table. In these months the price had a higher realization over the years (2003-2017). In Chintamani wholesale market highest seasonal indices were found October-April, Tumkur market found that February-April, June-August and October, Denkanikottai wholesale market found that November, December and May-July, Hosur wholesale market found to be January, March-June and September, and Vellore wholesale market found that December-April have been played the highest seasonal indices over the years (2003-2017).

Comparison of Seasonal Index in Selected Markets of Tamil Nadu and Karnataka

Comparison of seasonal index in selected markets of Tamil Nadu and Karnataka with their harvesting seasons was given in the table 3 and 4. From the tables the results could be inferred that Chintamani market seasonal price index was less than one during July to September since it was the harvesting period and the arrivals were very high. In the case of Tumkur and Hosur market the seasonal indices value than one were observed during October to January which was their harvesting period. The seasonal indices were high during other months. In the case of Vellore market the seasonal index value less than one was observed during September which comes immediately after the harvesting period of ragi. In the all above markets seasonal index value less than one coincides with the harvesting season of ragi because of huge amount of arrivals in the market.

From this comparison farmer in Tumkur market catchment area harvest their ragi in November, December and January months, were advised to link the Chintamani markets for their high price realization due care must be taken additional transaction cost involved. Similarly farmers in Denkanikottai market catchment area can exploit the Hosur market during the harvesting period for higher price realization. Farmers in Chintamani market catchment area were link to the Tumkur, Denkanikottai and Hosur for higher realization. Farmers in Vellore catchment area for better price realization they can store and sell later rather than link with other market because distance with high realization market distance were more than 160 kilometers.

Market Integration

In general, market integration usually conceived in terms of the co-movements or long run relationship between the spatial prices, Fackler and Goodwin (2001) and Goodwin and Schroeder (1991). Several distinct methodologies for econometric analysis have been developed in recent years.

Unit Root Test (Augmented Dickey-Fuller Test)

The estimated test statistics from ADF tests for wholesale in levels and first differences are reported in Table 5. From the table the results could be revealed that the unit root test suggest that all the four wholesale markets except Vellore market were non-stationary at one per cent level. Vellore market has stationary property but other four market price series has non-stationary property. Hence in this study Chintamani, Tumkur, Hosur and Denkanikottai were included in Johansen co-integration test.

Testing for the Number of Co-integrating Vectors in the System

Johansen multiple co-integration tests were carried out to study long run relationship between the selected markets. In this study, co-integration were examined for Chintamani, Hosur, Denkanikottai and Tumkur ragi price using the maximum Eigen value procedure as well as trace test suggested by Johansen and Juselius (1990) and Johansen (1991).

Both trace test and Maximum-Eigen value test of Johansen co integration test are presented in Table 6 and 7. Both trace test and Maximum-Eigen value test of Johansen co integration gave the same conclusion that there were three co integrating equations existing among the selected markets. There are three co-integration relationships among the Chintamani, Hosur, Denkanikottai and Tumkur markets.

Estimation of long-run wholesale price integration of ragi

Co-integration implies that the transitory components of the series can be given a dynamic error correction representation; one that allows for flexibility in short-run dynamics but constraints the model to return to long-run equilibrium, Engle *et al.* (1987). If there is evidence of a co-integrating relationship, casual inferences can be made by estimating the parameters of the following vector error correction model (VECM) equation.

The reduced forms of vector error correction estimates were given in the table 8 and 9. From the table the results could be inferred that any shock in the price of Chintamani market would be return back to original equilibrium price within 6 days. Whereas Tumkur market, any shock in price of ragi, bounce back to the original position within 10 days. From that it was concluded that any shock were adjusted quickly in Chintamani rather than Tumkur. This may be due to large volume of trade in Chintamani.

In the long run, positive and negative coefficients exhibited in the Vector Error Correction estimates of selected ragi markets. VECM concluded that in the long run,

Chintamani market price was influenced by two month (-0.238) lagged own market price and also by one month (0.172) lagged Tumkur market price. Tumkur market price was guided by its one month (-0.422) lagged own market price and also by two month (-0.220) lagged Chintamani market price. In case of Hosur market in the long run, price was influenced by one month (0.318) lagged Denkanikottai market price. Denkanikottai was not influenced by any other market. Hence it is considered as independent market.

Co-integration Analysis through Vector Error Correction Mechanism is consolidated in the table 10. From that table it is inferred that both the markets in Tamil Nadu

linked together, similarly both markets in Karnataka linked together. There is no linkage between Tamil Nadu and Karnataka markets.

The study revealed that Chintamani and Tumkur markets were influenced by their own monthly lagged price and Hosur markets were influenced by Denkanikottai first month lagged market prices. Denkanikottai market acts as an independent market. The VECM conclude that Chintamani market price converged into equilibrium within 6 days. The shock observed by the Tumkur market price will be corrected within 10 days.



Fig. 1: Price trend over the years of Vellore wholesale market

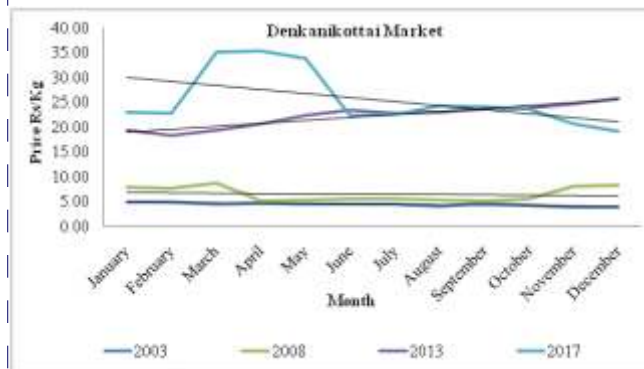


Fig. 2: Price trend over the years of Denkanikottai wholesale market

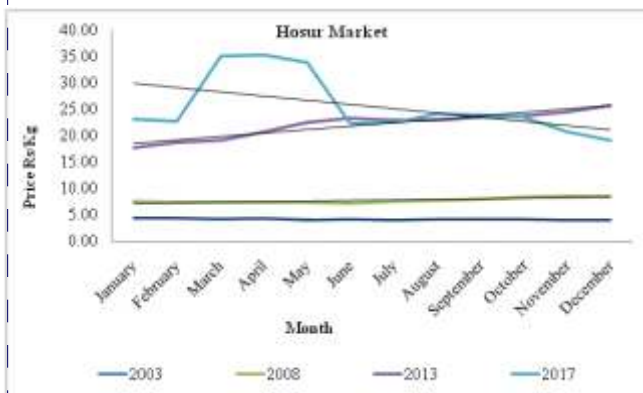


Fig. 3: Price trend over the years of Hosur wholesale market

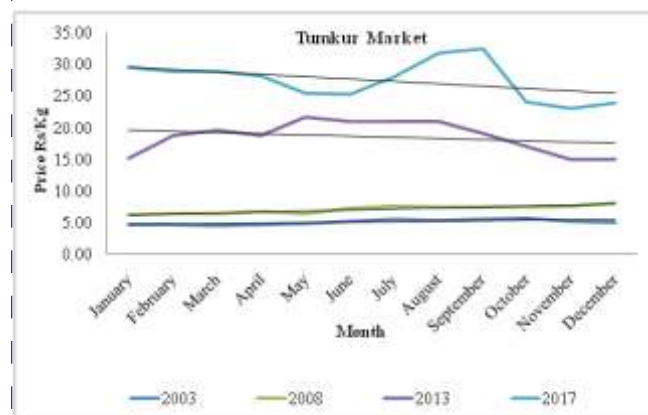


Fig. 4: Price trend over the years of Tumkur wholesale market

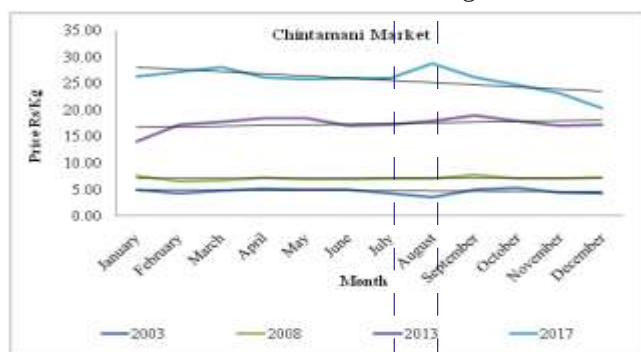


Fig. 5: Price trend over the years of Chintamani wholesale market

Table 2. Seasonal index for the selected markets

Period (in months)	Chintamani	Tumkur	Denkanikottai	Hosur	Vellore
January	1.00064	0.97430	0.99544	1.00299	1.05213
February	1.02718	1.00235	0.97054	0.98196	1.08418
March	1.01348	1.00764	0.99522	1.00405	1.07591
April	1.01334	1.00587	0.99837	1.01354	1.03922
May	0.98842	0.99989	1.01745	1.01693	0.99847
June	0.99043	1.01124	1.04513	1.01752	0.96416
July	0.98427	1.01626	1.01694	0.99956	0.95582
August	0.99040	1.01506	0.97016	0.99947	0.92509
September	0.98464	0.99193	0.99998	1.00172	0.92109
October	1.00476	1.00660	0.97464	0.98454	0.95055
November	1.00126	0.99117	1.00010	0.98265	0.99270
December	1.00117	0.97768	1.01605	0.99506	1.04068

Table 3. Seasonal indices for the selected markets

Markets	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chintamani	✓	✓	✓	✓						✓	✓	✓
Tumkur		✓	✓	✓		✓	✓	✓		✓		
Denkanikottai					✓	✓	✓				✓	✓
Hosur	✓		✓		✓	✓			✓			
Vellore	✓	✓	✓	✓								✓

Table 4. Harvesting Seasons of ragi

Markets	Harvesting seasons	Lowest Seasonal Index	Highest Seasonal Index
Chintamani	June-September	July	February
Tumkur	October -January	January	July
Denkanikottai	January-April	August	June
Hosur	October-January	February	June
Vellore	May-July	September	February

Table 5. Results of the ADF test for the order of integration

Wholesale price of tomato markets	Augmented Dickey-Fuller Test statistics		
	Level	First difference	Critical value
Chintamani	-2.665846 (0.2522)	-11.80854 (0.0000)	- 4.010143 (0.01 level) -3.435125 (0.05 level) -3.141565 (0.10 level)
Tumkur	2.928157 (0.1562)	-10.73642 (0.0000)	
Hosur	-3.237719 (0.0805)	-12.41547 (0.0000)	
Denkanikottai	-3.143840 (0.0995)	-9.914883 (0.0000)	
Vellore	-4.399886 (0.0028)	-15.49381 (0.0000)	

Note: *Significant at 1 per cent level.

*Mackinnon critical values for rejection of hypothesis of a unit root.

Table 6. Trace test (Unrestricted co-integration rank test)

Hypothesized no. CE(s)	Eigen Value	Trace statistic	Critical value	Probability
None *	0.201274	82.83435	47.85613	0.0000
At most 1 *	0.132047	43.05592	29.79707	0.0009
At most 2 *	0.095998	17.98961	15.49471	0.0206
At most 3	0.000712	0.126072	3.841466	0.7225

Table 7. Maximum Eigen value test (Unrestricted co-integration rank test)

Hypothesized no. CE(s)	Eigen Value	Max-Eigen statistic	Critical value	Probability**
None *	0.201274	39.77843	27.58434	0.0009
At most 1 *	0.132047	25.06631	21.13162	0.0132
At most 2 *	0.095998	17.86354	14.26460	0.0129
At most 3	0.000712	0.126072	3.841466	0.7225

Note: Max-eigenvalue test indicates 3 co-integrating eqn(s) at the 0.05 level

*denotes rejection of the hypothesis at 5% significance level

**mackinnon-Haug-Michelis (1999) p-values

Table 8. Estimation of long-run wholesale price integration of ragi

Co integrating Eq:	Co-int Eq1
CHINTAMANI(-1)	1.000000
TUMKUR(-1)	-0.916433 (0.04618) [-19.8452]
DENKANIKOTTAI(-1)	0.416617 (0.14381) [2.89691]
HOSUR(-1)	-0.431572 (0.14319) [-3.01400]
C	0.044658

Table 9. Reduced forms of Vector Error Correction Estimates

Error Correction:	D(CHINTAMANI)	D(TUMKUR)	D(DENKANIKOTTAI)	D(HOSUR)
Co-intEq1	-0.203377 (0.08355) [-2.43422]	0.339441 (0.10933) [3.10475]	-0.228512 (0.17418) [-1.31195]	-0.021039 (0.17779) [-0.11833]
D(CHINTAMANI(-1))	-0.076847 (0.09306) [-0.82582]	0.051613 (0.12177) [0.42386]	0.235229 (0.19399) [1.21256]	0.242042 (0.19802) [1.22230]
D(CHINTAMANI(-2))	-0.238872 (0.08553) [-2.79277]	-0.220682 (0.11192) [-1.97170]	0.308393 (0.17831) [1.72952]	0.240782 (0.18201) [1.32289]
D(TUMKUR(-1))	0.172841 (0.07259) [2.38116]	0.422501 (0.09499) [4.44807]	0.160445 (0.15132) [1.06027]	0.232893 (0.15447) [1.50774]
D(TUMKUR(-2))	0.116590 (0.07383) [1.57919]	-0.066959 (0.09661) [-0.69308]	-0.224902 (0.15391) [-1.46123]	-0.089423 (0.15711) [-0.56918]
D(DENKANIKOTTAI(-1))	0.110879 (0.07363) [1.50586]	-0.081050 (0.09635) [-0.84119]	0.008643 (0.15350) [0.05630]	0.318691 (0.15669) [2.03392]
D(DENKANIKOTTAI(-2))	0.001020 (0.07216) [0.01413]	-0.031847 (0.09442) [-0.33728]	-0.128484 (0.15043) [-0.85411]	0.047262 (0.15355) [0.30779]
D(HOSUR(-1))	-0.133072 (0.07315) [-1.81927]	0.017601 (0.09572) [0.18389]	0.069826 (0.15249) [0.45791]	-0.232822 (0.15565) [-1.49576]
D(HOSUR(-2))	-0.056239 (0.07104) [-0.79170]	-0.095701 (0.09296) [-1.02953]	0.054125 (0.14809) [0.36548]	-0.078518 (0.15117) [-0.51942]
C	0.099687 (0.06521) [1.52863]	0.110948 (0.08534) [1.30013]	0.031677 (0.13595) [0.23300]	0.013436 (0.13877) [0.09682]

Note: All the values in square brackets are t-values.

Table 10. Results from Co-integration Analysis through Vector Error Correction Mechanism are consolidated in the table below

1	2	3	4
CHINTAMANI	TUMKUR	DENKANIKOTTAI	HOSUR
CHINTAMANI (-2)	CHINTAMANI (-2)		
TUMKUR (-1)	TUMKUR (-1)		
			DENKANIKOTTAI (-1)

() indicates lagged time period in terms of monthly: each columns under specific headings indicate the markets co integrated with the boldly indicated markets.

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Value addition of tamarind: An option for livelihood of tribal people of Panchmahal

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(Received: 30.08.2018; Accepted: 21.09.2018)

Abstract

Tribal rural families of district Panchmahals, Gujarat are living in poverty due to small holding size which is low in productivity due to poor soil fertility and unavailability of irrigation facilities resulting in to subsistence farming. However, these tribal families traditionally grow many minor fruit crops having drought tolerance especially tamarind and manila tamarind on the fringes of their land; fruits of which they sold in the market at cheaper rates. KVK, Panchmahal has promoted value addition in tamarind through training with the help of scientist of C.H.E.S., Godhra and N.G.O. Anandi for higher income generation. Different types of value added products were made from tamarind fruits viz. tamarind puree, toffee and Oil polished tamarind pulp. Study was carried out to determine the levels and preference range of ingredients in the various products to formulate recipes of the products prior to processing and training the community members. The products made in this study were shown to be viable, of good quality and good sources of income for rural tribal communities. As promotion of minor fruit crops like tamarind without market linkage is risky, it is advisable to train the community for development of value added products so that they generate more income from available resources and to avoid seasonal glut in the market.

Key words: Tamarind, value addition, livelihood security

Introduction

Tamarind (*Tamarindus indica* L) a member of sub family Caesalpiniaceae of family Leguminosaceae, is highly drought hardy and can be grown in dry land areas and on degraded wasteland. It is considered to be one of the most exquisite and valuable fruits of the tropics and sub tropics. It is source of timber, fruits, seeds, fodder, medicinal extracts and has potential of industrial use (Karale, *et al*, 1999, Pareek and Awasthi, 2002 and Singh and Singh, 2005, Singh and Singh, 2007). In India, the pulp is used mainly for culinary purposes, while in other countries it is processed in to nectar, juice, sauce, jam, jelly, beverages including carbonated drinks. Tamarind kernel powder (TKP) is extensively used for starching of cotton yarns and jute fabrics. The TKP can also be used as a cattle feed.

Panchmahal is a tribal populated district of the Gujarat. Climatologically it comes under semi-arid zone. This region is endowed with plenty of scattered tamarind plants in nearby villages and on the fringes of the cultivable land. Tamarind pods produced in these areas are sold locally by the rural people at very cheap rate. Tribal people collect the tamarind pods and after dehusking and it is sold to local traders @ Rs 20 to 30 per kg. Farmers were not adopting any technology for value addition of tamarind pulp. KVK, Panchmahal observed these problems and organized training programme for value addition of tamarind pulp with the collaboration of NGO Anandi and C.H.E.S., Godhra.

Materials and methods

Groups of the Tribal women of different villages of Goghamba & Shehra Taluka, Panchmahal were formed to undertake the activities for value addition of tamarind pulp. There were 30 tribal women selected from different villages and they were advised to collect tamarind pods from their locality. Collected pods were dehusked and deseeded properly. They were also suggested to harvest the pods at ripening stage. For assessment of correct stage of ripening, separation of pulp from rind was followed. After harvest, pods were dried in open sunlight for two days which resulted in easy pulp extraction. Total soluble solids and titratable acidity were determined by standard methods. Vitamin C and sugars were analyzed by the method advocated by AOAC, (1990). Different products were prepared from the pulp:

Oil polished tamarind pulp:

Ingredients : Deseeded tamarind pulp 1 Kg., castor oil 50 ml,

Collect & Select the fully ripened tamarind pods

↓
Dehusked and deseeded

↓
Clean all the fiber

↓
Mix Salt 5 gm/kg. pulp

Polished with castor oil @ 50 ml/1 kg. pulp

↓
Fill in Plastic Jar and Seal

Tamarind puree:

Ingredients : Deseeded tamarind pulp 1 Kg., vinegar 10 ml,

Collect & Select the fully ripened tamarind pods

↓
Clean, dehusk & deseed

↓
Pour in water for 1 hr.

↓
Mash and remove all the fiber, husk, seed etc.

↓
Strain the pulp with Nylon net cloth or strainer

↓
Mix 100 ml vinegar/kg. pulp

↓
Fill in Plastic bottle and seal

↓
Labeled

Tamarind Chutney :

Ingredients : Deseeded tamarind 250 gm, Jaggery 250 gm, water 250 ml, black salt ½ tea spoon, salt ½ tea spoon red chilli powder roasted cumin

Soak deseeded tamarind in water for 30 minutes in a steel pan

↓
Keep the pan on the flame and boil (simmer) 10 minutes

↓
Switch off the flame and allow the pulp to cool till it is easier to handle

↓
Strain the pulp and discard left in the sieve

↓
Transfer the tamarind pulp in pan and keep on flame

↓
Add jaggery and mix stir and cook the pulp till the jaggery melt

↓
Add the Salt, Black Salt, Cumin Powder red chilly resins and cardamum powder and mix well

↓
Fill in Clean and dry bottle

↓
Seal and label (If required)

Ten participants were trained as panelists to evaluate the various products. Each tribal farm women was asked to taste the coded samples of each product and score each product for preference on a five -point scale, ranging from “most preferred” (preference score = 1) to the “least preferred” (preference score = 5). This process was repeated three times in three days and the results were recorded for statistical

analysis. The data statically calculated as per method given by Snedecor and Cochran, (1994).

Results and Discussion

After drying, rind becomes bristol and it separates easily from pulp. Earlier they sold dehusked fruit with seed only. Tamarind is leguminous crop, seed of which is rich in protein and this caused early spoilage due attack of insect-pests which resulted in heavy economic loss to the tribal farmers. It has been observed that a tribal farmer can earn only Rs. 600 to 700 from single tree of tamarind annually through selling of dehusked pod to the local trader. In this way, it fetches less price in the market as compared to its potential. Therefore, there was need of fusion of value addition technology. Primary processing and value addition activities have potential of improving livelihood. Its little primary processing can significantly improve family income of Tribal Farmers. KVK organized a training programme for tribal women with the collaboration of Anandi NGO. In this training, 30 tribal women farmers' have been skilled in value addition of tamarind. They were trained for development of 05 value added products. Tribal farm women were trained through learning by doing process. Most of the products were prepared with low cost technology i.e. without chemical treatment or with the use of vinegar only. Different physico-chemical characters were also studied. The pod weight ranged between 16.98 to 26.40g among the samples collected from different villages.

The data given in table 2 revealed that the overall highest grade was given by the panel to Goli (3.65) followed by puree (3.60) and oil polished pulp and chutney (3.50). For appearance, puree got maximum score (3.80) followed by oil polished pulp (3.50), Goli and Chutney (3.40). The highest score (3.75) for colour of product was given to puree followed by Goli (3.60) and oil polished pulp and chutney (3.50) of various products. The preference mean scores for flavor of the various products, maximum recorded to Goli followed by puree, chutney and minimum to oil polished pulp, 3.80, 3.70, 3.60 and 3.40 respectively. On the basis of taste of products, the oil polished pulp and Goli got equal rank (3.60) followed by puree (3.55) and the minimum to chutney (3.50). This is may be due puree was prepared from freshly removed pulp that is more shiny and attractive do not blended and season or fry. The similar findings are also reported by Lingappa, *et al*, (1993), Shankaracharya, (1998) and Ulrich, (1970) in tamarind. The similar findings also reported by Lata, *et al*, (2006) in turmeric. After compilation of training program, tribal women have been skilled in value addition of tamarind. They are preparing chemical free various products, sold and earned Rs 150-200 per kg in comparison to Rs 15-20/kg earlier. These products are sold in their locality and nearby markets. So tamarind products has got preference and acceptability, only the potential for its popularization through awareness campaign, skilled training and assured linkage of market is the need of the hour.

It can be concluded from the study that there is a promising future for the processed, stored products using

tamarind fruits. The study further emphasizes the need for popularization and development of diversified value added products from the tamarind so as to create ready market for the products. This will not only reduce spoilage of fruits but also enable for quick disposal of the produce which will in turn bring potential earnings to the farmers, unemployed youth or S.H.G members of the district.

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Table 1. Fruit quality attributes of tamarind collected from different villages.

Name of villages	Taluka	Pod weight (g)	Seed weight (g)	Shell weight (g)	Pulp weight (g)	TSS (Degree Brix)	Acidity (%)	TSS/ Acid Ratio	Total Sugar (%)
Sanayada	Ghoghamba	18.58	5.56	4.89	8.13	62.00	9.10	6.81	46.42
Khan Patla	Ghoghamba	17.89	6.50	5.41	5.98	63.50	10.53	6.03	47.20
Sajora	Ghoghamba	16.98	4.40	4.45	8.10	52.00	12.89	4.03	41.30
Gajapura	Ghoghamba	20.45	6.20	6.75	7.50	63.56	13.15	4.83	47.40
Kaatu	Ghoghamba	19.75	6.78	5.20	7.77	62.00	12.20	5.05	45.50
Bhesal	Shehra	22.20	5.49	5.40	11.31	64.50	11.85	5.44	49.72
Nava Mehla	Shehra	21.89	7.50	4.42	9.95	63.70	12.40	5.13	47.86
Vaghjipura	Shehra	26.40	7.70	10.10	8.60	65.40	13.49	4.84	51.40
Nandarva	Shehra	22.00	6.30	6.74	8.96	64.10	14.50	4.42	49.50
Dhandalpur	Shehra	23.12	8.70	5.20	9.22	62.00	14.40	4.30	48.10
Khojal Vasa	Shehra	22.50	6.20	6.63	9.67	61.20	13.50	4.53	47.20
CD (p= 0.05)		1.05	0.52	0.62	0.63	2.20	1.02	0.45	1.59

Table 2. Preference mean scores for value added products of tamarind pods

Product	Appearance	Color	Texture	Flavor	Taste	Over all	Grading
Oil polished pulp	3.50	3.50	3.60	3.40	3.60	3.50	III
Puree	3.80	3.75	3.75	3.70	3.55	3.60	II
Goli	3.40	3.60	3.50	3.80	3.60	3.65	I
Chutney	3.40	3.50	3.60	3.60	3.50	3.50	III

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Effect of NAA and thiourea on growth, yield and quality of garlic (*Allium sativum* L.)

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(Received: 25.08.2018; Accepted: 5.10.2018)

Abstract

A field experiment was conducted to study the "Effect of NAA and thiourea on growth, yield and quality of Garlic (*Allium sativum* L.)" during the *rabi* season, 2017-18 at the Horticulture Farm, S.K.N. College of Agriculture, Jobner (Rajasthan). The experiment consisted of twenty treatment combinations including five NAA and Thiourea levels (control, NAA @ 100 ppm, NAA @ 200 ppm, Thiourea @ 100 ppm and Thiourea @ 200 ppm). They were under taken in factorial randomized block design with three replications. The results of the study clearly indicated that foliar application of thiourea @ 200 ppm to the garlic crop significantly increased the plant height (cm), number of leaves per plant, chlorophyll content in leaves, fresh weight of leaves, neck thickness, polar diameter, fresh weight of bulb, number of cloves per bulb, bulb yield (134.58 q/ha) and quality attributes viz., TSS, sulphur, protein content, nitrogen content and ascorbic acid) and net returns (Rs. 1,08,062 /ha) and B: C ratio (1.34) as compared to control.

Key words: NAA, thiourea, growth, yield, garlic

Introduction

Botanically, garlic is known as *Allium sativum* L. which belongs to the family Amaryllidaceae. It is a multiple or compound bulb consists of smaller bulblets called 'cloves' and is surrounded by a thin white or pinkish papery sheath. The economic yield is obtained from these cloves. It is the second important bulb crop after onion. Garlic has higher nutritive value than other bulb crops. It is specially rich in protein, carbohydrate and ascorbic acid. About 142 calories of energy is obtained from 100 g of garlic. Garlic is used in flavoring of foods, preparing chutneys, pickles, curry powder, tomato ketchup, etc. It also contains phosphorus, potash, calcium, magnesium, carbohydrates and a colourless as well as odourless water soluble amino acid called 'allin'. On crushing the cloves, an enzyme allinase acts upon allin and breaks down to produce allicin. The principal ingredient of which is odoriferous diallyl-disulphide, which is the major flavouring component of garlic. Garlic also contains about 0.1 per cent volatile oil and the green garlic is rich in ascorbic acid. India ranks second in area and third in production of garlic in the world. The productivity of this crop is quite low i.e. 5.09 tonnes per hectare (Gupta, 2014) which is far less than that of China and Egypt. In India, garlic is cultivated throughout the country occupying an area of 261 thousand hectare with production of 1400 thousand MT (Anonymous, 2015). In India, the major garlic producing states are Madhya Pradesh, Odisha, Rajasthan, Karnataka and Gujarat (Anonymous, 2015). In Rajasthan, it is grown extensively in Chittorgarh, Baran, Jodhpur, Jhalawar, Kota, Bundi, Jaipur and Sikar

districts. Availability of garlic in India is only 6.34 kg/year/capita in comparison to 11.14 kg / year/capita of Korean republic. This situation of the crop in India may be due to its unscientific cultivation and lesser care of growers to its nutritional management (Anonymous, 2011).

Plant growth regulator presents a new possibility to break yield barrier, particularly imposed by the environment. Application of growth regulators at a specific or critical growth stage influences the key processes of plants favouring manipulation of protein content of the crop. The application of triacontanol (a long chain aliphatic alcohol) based plant growth regulators and naphthalene acetic acid (NAA) has been reported to induce physiological efficiencies including photosynthetic ability of plants which resulted in better growth and yield of several crop without substantial increase in cost of production (Sumeriya *et al.*, 2000). Naphthalene acetic acid (NAA) is a synthetic auxin, can bring changes in the phenotype of plants and affect growth either by enhancing or by stimulating the natural growth regulatory systems from seed germination to senescence (Das and Das, 1995). NAA (Naphthalene acetic acid) stimulates cell elongation, cell division in the cambium, differentiation of phloem and xylem and induce flowering. The effect of NAA on plant growth is greatly dependent on the time of application and its concentration. NAA play a vital role for modifying the growth behaviour of plant resulting in increase in growth rate of shoot and root and finally increase yield (Patil and Patel, 2010). It plays a key role in root and shoots development, promoting the germination of seeds and inducing the flower buds. Thiourea is

a sulphhydryl compound which contains one-SH group besides containing nitrogen in the form of NH_2 . It plays a vital role in the physiology of plants both as a sulphhydryl compound and to some extent as an amino compound like urea. The stimulating action of thiourea in various physiological activities of plant is well known. It has been proved effective in mitigating drought in clusterbean and mothbean. It promotes growth in cytokinin requiring callus tissues in absence of kinetin in various crops. Kolyada (1970) noticed significant increase in germination and seedling vigour after soaking of seeds of sugarbeet in 10 ppm thiourea solution. It has also been reported that thiourea regulates the plant growth by maintaining higher photosynthetic rate upto the reproductive stage and increased the yield improving carbon partitioning towards sink. Thiourea is mainly known for its dormancy breaking and germination stimulating effect. Keeping these points in view, the present investigation entitled "Effect of NAA and thiourea on growth, yield and quality of garlic (*Allium sativum* L.)" was therefore carried out to find out the effect of NAA and thiourea on growth, yield and quality of garlic.

Materials and Methods

The field experiment entitled "Effect of varying levels of nitrogen on growth, yield and quality of garlic (*Allium sativum* L.)" was conducted at the Horticulture farm and quality observations recorded at Laboratory of Department of Horticulture, S. K. N. College of Agriculture, Jobner during the *rabi* season, 2017-18. The experiment was laid out at the Horticulture farm, S. K. N. College of Agriculture, Jobner during *rabi* season 2017-18. Jobner is situated at 26°05' North latitude, 75°28' East longitude and an altitude of 427 meters above mean sea level in Jaipur district of Rajasthan. The experiment was laid out in randomized block design with three replications. Four levels of nitrogen treatments were taken. The treatments were randomly allotted to different plots using random number table of Fisher and Yates (1963). The experimental field was thoroughly ploughed and cross-ploughed with the help of mould board plough and cross-harrowing was done with tractor, followed by planking and levelling to bring the field to a good tilth. Beds of 1.5 m x 1.2 m size and paths and channels were also prepared according to the layout of the experiment.

The seeds of cv G-41 procured from NHRDF, Karnal (Haryana). The seeds of garlic were first treated with bavistin @ 2 g per kg seed to control seed borne diseases. The seeds were sown in row at 15 cm apart on 14th November 2017 by

hand dibbling method and 10 cm spacing within the row was maintained. Phosphorus, potash and sulphur dose were applied uniformly in all plots as per recommended dose of P, K and S as basal dose only. The experiment was comprised of five levels of NAA and Thiourea. Two foliar spray of NAA @ 100 and 200 ppm and thiourea @ 100 and 200 ppm through planofix (4.5%) and thiourea (99.9%), respectively were done at 20 and 40 DAS using 500 litres water per spray per hectare. NAA is a synthetic auxin and its empirical formula is $\text{C}_{12}\text{H}_{10}\text{O}_2$. Thiourea is a sulphhydryl compound and as an amino compound and its empirical formula is $\text{CH}_4\text{N}_2\text{S}$. In order to evaluate the effect of NAA and thiourea on growth, yield and quality of crop, periodical observations on various growth and yield parameters were recorded.

Results and Discussion

Effect of NAA and thiourea on growth parameters

The application of different growth regulators had favourable effect on growth. The data (Table 1) showed that foliar application of thiourea @ 200 ppm significantly increased the plant height, number of leaves per plant, chlorophyll content in leaves, fresh weight of leaves of garlic followed by thiourea @ 100 ppm, being *statistically* at par with each other. This may be due to the effect of chemicals on cell division and cell elongation during plant growth stage (Haldar *et al.*, 2012). Thiourea is a good source of nitrogen and sulfur which promotes vegetative growth of the plant. The favourable effect of thiourea on plant growth might be due to improved photosynthetic efficiency and bio-regulatory role in plants. Nitrogen increases chlorophyll content in leaves thus, resulting in higher photosynthetic rate and higher vegetative growth of the plant (Pooja Rani *et al.*, 2015; Nagar *et al.*, 2017). Thiourea treated crop showed more chlorophyll content for photosynthate preparation and translocation towards sink. This might have been due to improved phloem loading of assimilates under the influence of thiourea spray, most probably on account of SH-group present in thiourea molecules. The SH-group stimulated the photosynthetic carbon fixation mechanism and hence, foliar spray of thiourea might have increased the plant height, number of leaves and chlorophyll content, which ultimately resulted in higher vegetative growth of garlic plants. Similar results were also reported by Solanki and Sahu (2007) in clusterbean and Meena (2011) in coriander.

Effect of NAA and thiourea on yield parameters

Application of different growth regulators

Table 1. Effect of NAA, thiourea on growth parameters of garlic

Treatments	Plant height (cm)	Number of leaves per plant	Total chlorophyll content (mg/g)	Fresh leaves weight (g)
P ₀ Control	34.54	6.50	0.709	18.58
P ₁ - NAA 100 ppm	37.68	7.72	0.899	21.02
P ₂ - NAA 200 ppm	39.26	8.64	0.954	21.36
P ₃ - Thiourea 100 ppm	40.72	8.97	1.008	23.09
P ₄ - Thiourea 200 ppm	42.18	9.53	1.117	23.59
SEm±	1.00	0.27	0.026	0.65
CD (P = 0.05)	2.86	0.76	0.073	1.85

significantly increased the neck thickness, polar diameter, fresh weight of bulb, number of cloves per bulb and bulb yield. The data (Table 2) showed that application of thiourea @ 200 ppm followed by thiourea @ 100 ppm being at par to each other significantly enhanced all the above yield parameters, over control and NAA levels. The increase in yield attributes with the application of thiourea might be because of better utilization of the sources in the plants. An increase in yield attributing characters with foliar application of thiourea might have induced large number of reproductive sinks leading to greater activity of carboxylating enzymes resulting in higher photosynthetic rates with greater translocation and accumulation of metabolites in sink and ultimately higher yield (Nehra *et al.*, 2006; Balai *et al.*, 2017). Similar response with foliar spray of thiourea was also recorded by Balai and Keshwa (2011), Shanu *et al.* (2013) in coriander and Gupta and Yadav (2009) in fenugreek. This stimulatory effect may be occurred with foliar application which might have transferred to roots and finally resulting an increase in organic acid and protons efflux. This can increase the uptake of ions such as nitrogen and phosphorus by plants, which ultimately enhance yield and yield attributes (Maleki *et al.*, 2013; Meena and Bhati, 2016). The obtained results are in agreement with the result of Jaafari and Hadavi (2012a & b). The increase in yield attributes and yield with foliar application of thiourea was most probably due to increase in crop photosynthesis favoured by both improved photosynthetic efficiency and source to sink relationship. Similar response with foliar spray of thiourea was also recorded by Balai and Keshwa (2010) and Bochalnia *et al.* (2011) in fenugreek.

Effect of NAA and thiourea on quality parameters

Results revealed that TSS content, crude protein content, sulphur content, N content and ascorbic acid in garlic influenced by application of different growth regulators. Quality parameters were significantly increased with the application of thiourea @ 200 ppm (Table 3) being statistically at par with thiourea @ 100 ppm. The increased accumulation of nutrients especially N, P and Zn in vegetative parts concomitant the improved metabolism led to greater translocation of these nutrients to reproductive structure of crop. Application of thiourea resulted in better utilization of nitrogen and phosphorus in plants probably due to the fact that application of thiourea might have helped in improved metabolic process of plants and better growth & development leading to greater absorption of nutrients from rhizosphere. Solanki (2002) reported that thiourea being a sulphhydryl compound significantly improved the root growth in clusterbean crop. This might be due to metabolic role of SH group in root physiology and biochemistry. The findings of present experiment are also in close conformity with those of Halder *et al.* (2012) in garlic and Mani *et al.* (2013) in potato.

It is apparent from data that net returns of garlic crop influenced significantly with foliar spray of different growth regulators. The maximum net returns Rs.1,08,062 per hectare was recorded under treatment P₄ (Thiourea @ 200 ppm) followed by P₃ (Rs. 1,03,372 /ha), being statistically at par with each other and found significantly superior over control, P₁ and P₂. The increase in net returns under treatment P₄ was found to be 200.23, 38.58 and 16.50 per cent higher as

Table 2. Effect of NAA, thiourea on yield parameters of garlic

Treatments	Neck thickness (cm)	Polar diameter (cm)	Av. weight of bulb (g)	No. of cloves	Bulb yield (kg/plot)	Bulb yield (q/ha)
P ₀ - Control	0.65	2.56	26.28	16.41	1.48	82.43
P ₁ - NAA 100 ppm	0.78	3.50	38.77	18.27	2.04	113.27
P ₂ - NAA 200 ppm	0.80	3.59	39.78	18.42	2.23	123.92
P ₃ - Thiourea 100 ppm	0.82	3.76	49.68	20.20	2.36	131.21
P ₄ - Thiourea 200 ppm	0.87	3.94	50.69	20.42	2.42	134.58
SEM±	0.02	0.09	0.44	0.60	0.03	1.59
CD (P = 0.05)	0.06	0.27	1.24	1.73	0.08	4.55

Table 3. Effect of NAA, thiourea on quality parameters of garlic

Treatments	TSS (%)	S content (mg/kg)	N content (%)	Protein content (%)	Ascorbic acid (mg/100g)
P ₀ - Control	35.63	1.21	0.842	5.26	8.30
P ₁ - NAA 100 ppm	38.65	1.35	0.987	6.17	11.23
P ₂ - NAA 200 ppm	38.93	1.40	1.006	6.29	11.43
P ₃ - Thiourea 100 ppm	39.37	1.51	1.118	6.99	13.72
P ₄ - Thiourea 200 ppm	41.74	1.55	1.126	7.04	13.79
SEM±	1.03	0.04	0.024	0.18	0.37
CD (P = 0.05)	2.95	0.11	0.069	0.53	1.06

compared to control, P₁ (NAA @ 100 ppm) and P₂ (NAA @ 200 ppm), respectively.

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Genetic variability, heritability, correlation and path analysis in fenugreek (*Trigonella foenum graecum* L.)

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(Received : 19.09.2018, Accepted : 10.10.2018)

Abstract

Thirty fenugreek genotypes (*Trigonella foenum graecum* L.) were evaluated during rabi season of 2012-13 to explore its existing gene pool and identify the selection indices with an eye on a more comprehensive breeding programme. Characters like number of pods per plant, protein content in seed, days to 50% flowering and dry weight at flower initiation were found to have least variation among the coefficients both at phenotypic and genotypic level. Broad sense heritability estimates were high for protein content in seed (96.9), followed by number of pods per plant (96.7). The highest genetic advance as percentage of mean was recorded for dry matter content and dry weight at flower initiation indicating that these characters are governed by additive gene action. Correlation coefficients at phenotypic and genotypic level envisaged that biological yield was having significant and positive correlation with chlorophyll content of the leaves, number of pods per plant, straw yield per plant, 1000 seed weight, dry matter content of the plant as whole and seed yield per plant while negatively correlated with the harvest index. Path coefficient analysis revealed that biological yield per plant, harvest index, dry weight at flower initiation, chlorophyll content in leaves, number of branches per plant and 1000 seed weight were the most important characters contributing towards seed yield and hence purposeful and balanced selection based on these traits would be more rewarding for improvement of fenugreek.

Key words: Genetic variability, heritability, correlation, path coefficient analysis.

Introduction

Fenugreek (*Trigonella foenum graecum* L.), popularly known as "Methi" is an important seed spice crop largely grown in India during Rabi season. Rajasthan and Gujarat are the major fenugreek producing states followed by Madhya Pradesh in which Malwa plateau contributes a major share. In Madhya Pradesh, fenugreek growing districts are Jabalpur, Chhatarpur, Indore, Mandsaur, Neemuch, Ratlam and Shajapur. The genus *Trigonella* has two species, viz. *T. foenum-graecum* and *T. corniculata*. *Trigonella foenum-graecum* plants are semi-erect, tall, moderately branched with bold, typically yellow grains. Fenugreek seeds are used as condiments and flavouring food preparations. They are aromatic, carminative, tonic and galactagogue. Externally they are used in poultices for boils, abscesses, ulcers and internally as emollient for inflammation of intestinal tract. The seeds contain important steroid 'diosgenin' which is used in preparation of contraceptives. Very little effort has been made in collection maintenance and utilization of different genotypes for the improvement of this crop. There is need to assess and improve the existing genotypes and introduce cultivars for seed purpose. Study of variability is a prerequisite for improvement of yield in any crop. The performance of locally available cultivars of fenugreek is poor in the Malwa region of Madhya Pradesh. Hence, an urgent need was felt for genetic improvement to develop high yielding cultivars

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Materials and Methods

The experimental material comprising of thirty divergent genotypes were sown during Rabi season of 2012-13 under randomized block design with three replications at Horticulture Research Farm, College of Horticulture, Mandsaur (M.P.), India, situated in Malwa plateau in Western part of Madhya Pradesh at North latitude of 23.450 to 24.130 and 74.440 to 75.180 East longitudes at an altitude of 435.02 meters above mean sea level. This region falls under agro climatic zone No.10 of the state. Row to row and plant to plant spacing were maintained at 40 cm and 20cm respectively. Requisite agronomic package of practices were adapted to raise a healthy crop. In each replication, five plants were randomly selected and tagged for observation. Observations were recorded for ten characters, viz. days taken to 50% flowering, plant height (cm) at 90 DAS (Days after sowing), number of branches per plant at 90 DAS, dry weight per plant at initiation of flowering, number of branches per plant, days to 50 % flowering, umbel/plant, umbellets /umbel, seeds/umbel, number of pods per plant, number of seeds per

pod, 1000 seed weight (g), biological yield (g), seed yield per plant (g), dry matter content (g), length of pods (cm), harvest index, straw yield per plant (g), protein content in seed (%), oil content in seeds (%), chlorophyll content in leaves (%) and seed yield per plant. The recorded data were subjected to statistical analysis as suggested by Panse and Sukhatme (1985). The genotypic and phenotypic coefficient of variance was calculated as per the formula suggested by Burton (1952), Heritability and genetic advance as per Hanson *et al.* (1956) and Johnson *et al.* (1955) correlation coefficient.

Results and Discussion

The analysis of variance (Table 1) revealed that significant variability was present in the germplasm for all the characters studied. Estimates of genotypic (GCV) and phenotypic (PCV) variances indicated that in general, the phenotypic variances were higher than the corresponding genotypic coefficient of variations, indicating the masking influence of environmental factors in expression of these traits. Wide variability occurred in dry weight at flower initiation (PCV22.56, GCV21.36) followed by straw yield per plant (PCV21.63, GCV18.23), dry matter content (PCV19.06, GCV17.09), biological yield per plant (PCV17.97, GCV15.89). This indicates the presence of sufficient amount of genetic variability for these traits and can be exploited through breeding procedure for the improvement of these characters. This is in accordance with the findings of Sharma and Shastry (2008). The difference between the value of PCV and GCV was narrow for dry matter content, number of seeds per pod, 1000 seed weight and plant height, which indicates that phenotype was truly corresponding to its genotype for these characters. Characters like number of pods per plant, protein content in seed, days to 50% flowering and dry weight at flower initiation were found to be consistent in its behavior, both at phenotypic and genotypic level and having lowest coefficient of variation. It suggests that these traits were least influenced by the non genetic factors and were hence quite stable. This is in accordance with the findings of Banerjee and Kole (2004) and Naik (2012). Heritability estimates in broad sense were classified into three groups, high > 70, medium 50 - 70, and low < 50. In the present investigation broad sense heritability estimates were high for, protein content in seed (96.9), followed by number of pods per plant (96.7), dry weight at flower initiation (89.7) and chlorophyll content in leaves (87.10). Similar findings were reported by Meena *et al.* (2011) and Naik (2012). The genetic advance is more useful than heritability alone in predicting the resultant effect on selecting the best individuals. In the present investigation, expected genetic advance was recorded high with dry matter content (17.83), followed by number of pods per plant (17.39), biological yield (10.75) and plant height (10.50). This is in accordance with the findings of Prajapati *et al.* (2010) and Naik (2012). Heritability estimates along with the genetic advance are more useful than heritability alone in predicting the resultant effect on selecting best individuals. In the present investigation, expected genetic advance expressed as

percentage of mean was high for straw yield per plant (31.66%), followed by dry matter content (31.56%), protein content in seed (30.88%), biological yield (28.95%) and number of pods per plant (26.05%). High heritability coupled with high genetic advance was observed for the above characters indicating that these characters are governed by additive gene action, hence there lies a good chance of improvement in these traits through direct selection in the present material. Similar findings were reported by Datta and Chatterjee (2004) Naik (2012). Narolia *et al.* (2017)

Correlation and Path Studies

The estimates of genotypic correlation coefficient were higher than their corresponding phenotypic correlation coefficient values for most of the characters under study (Table 2 and 3). Phenotypic and Genotypic level envisaged that biological yield was having significant and positive correlation with chlorophyll content of the leaves, number of pods per plant, straw yield per plant, 1000 seed weight, dry matter content of the plant as whole and seed yield per plant while negatively correlated with the harvest index. However, biological yield per plant too showed positive and significant correlation with plant height and number of branches per plant only at genotypic level. Similar associations were observed for straw yield per plant, number of pods per plant which too exhibited positive and significant correlation with number of branches per plant, chlorophyll content, straw yield per plant, 1000 seed weight, dry matter content and seed yield per plant, however it was negatively and significantly correlated to harvest index. Number of seeds per pod was positively and significantly associated to dry weight during flower initiation, pod length, protein content and seed yield per plant. Pod length enjoyed a significant and positive correlation with protein content, plant height, dry weight at flowering phase, 1000 seed weight, dry matter content, harvest index and seed yield per plant at genotypic level. Protein content in the seed, too exhibited positive and significant association with number of branches per plant, number of seeds per pod at both phenotypic and genotypic level. Plant height was having positive association with 1000 seed weight, dry matter content, seed yield per plant in a significant manner both at phenotypic and genotypic level. Genotypic path analysis (Table 4) of the different characters revealed that biological yield had highest positive direct effect on seed yield per plant followed by harvest index, dry matter content, chlorophyll content in leaves, number of seeds per pod, dry weight at flower initiation, number of pods per plant, 1000 seed weight and number of branches per plant. The straw yield per plant and pod length had the highest negative direct effect on seed yield followed by days to 50% flowering, plant height and protein content in seed. Phenotypic path analysis (Table 5) of the different characters revealed that biological yield per plant had highest positive direct effect on seed yield per plant followed by harvest index, dry weight at flower initiation, chlorophyll content in leaves, number of branches per plant and 1000 seed weight. Straw yield per plant and plant height

Table 1. Genetic parameter of yield and yield attributing characters in fenugreek genotypes

Character	Mean	Range		PCV%	GCV%	Heritability (BS) %	Genetic Advance	Genetic advance as percentage of mean
		Min.	Max.					
Plant height (cm)	65.91	46.20	74.83	9.89	8.74	78.2	10.50	15.93
No. of branches/plant	14.60	11.23	16.20	10.99	6.42	34.2	1.13	7.73
Dry weight at flower initiation(g)	3.86	2.23	5.27	22.56	21.36	89.7	1.61	14.70
Chlorophyll content in leaves (SPAD Unit)	54.11	45.47	59.47	7.19	6.71	87.1	6.98	12.89
No. of pods/plant	66.74	51.10	80.14	13.08	12.86	96.7	17.39	26.05
No. of seeds / pod	15.50	13.86	17.47	7.32	5.92	65.4	1.53	9.87
Pod length (cm)	11.12	9.82	12.19	7.10	3.51	24.4	0.40	3.59
Biological yield/plant (g)	37.13	26.20	46.83	17.97	15.89	78.2	10.75	28.95
Straw yield per plant (gm)	24.92	13.50	33.62	21.63	18.23	71.0	7.89	31.66
Protein content in seed (%)	18.91	14.03	25.53	15.46	15.23	96.9	5.84	30.88
Days to 50% flowering	48.41	43.67	53.33	5.19	4.32	69.4	3.56	7.35
1000 seed wt (g)	14.41	11.10	19.10	14.08	12.97	84.8	3.55	24.63
Dry matter content (g)	56.48	39.53	75.23	19.06	17.09	80.4	17.83	31.56
Harvest index	34.19	27.89	50.24	16.16	12.32	58.1	6.62	19.36
Seed yield /plant(g)	12.49	9.77	17.03	16.02	13.30	68.9	2.84	22.73

Table 2. Genotypic correlation coefficient of yield and its component characters of fenugreek

Characters	Plant height (cm)	No. of branches/plant	Dry wt at flower initiation (g)	Chlorophyll content (SPAD Unit)	No. of pods/plant	No. of seeds/ Pod	Pod length (cm)	Biological yield/plant(g)	Straw yield/plant (g)	Protein content in seed (%)	Days to 50% flowering	1000 seed wt (g)	Dry matter content (g)	Harvest index	Seed yield /plant (g)
Plant height (cm)		-0.049	0.283	0.413*	0.286	0.196	0.607**	0.430*	0.337*	0.101	-0.150	0.683**	0.588**	-0.177	0.413*
No. of branches/ plant			-0.153	0.594**	0.592**	0.272	-0.052	0.456**	0.449**	0.653**	-0.247	0.509**	0.160	-0.060	0.515**
Dry wt at flo. initiation (g)				0.069	0.240	0.482**	0.580**	0.200	0.161	0.241	0.017	0.300	0.253	-0.008	0.288
Chlorophyll (SPAD Unit)					0.380*	-0.147	0.031	0.518**	0.527**	0.181	-0.106	0.581**	0.207	-0.293	0.420*
No. of pods/plant						0.321	0.161	0.850**	0.826**	0.318	-0.169	0.375*	0.538**	-0.428*	0.680**
No. of seeds/pod							0.773**	0.215	0.089	0.567**	-0.086	0.386*	0.400*	0.226	0.483**
Pod length (cm)								0.248	0.056	0.445**	-0.300	0.462**	0.674**	0.356*	0.646**
Biological yield/p (g)									0.969**	0.213	-0.167	0.609**	0.749**	-0.607**	0.741**
Straw yield per plant (gm)										0.096	-0.041	0.532**	0.632**	-0.755**	0.575**
Protein content in seed (%)											-0.073	0.275	0.448**	0.329	0.550**
Days to 50% flowering												-0.433**	-0.314	-0.411*	-0.572**
1000 seed wt (g)													0.522**	-0.105	0.690**
Dry matter content (g)														-0.193	0.759**
Harvest index															0.073
Seed yield /plant(g)															

** 1% level of significance * 5% level of significance

Table 3. Phenotypic correlation coefficient of yield and its component characters of fenugreek

Characters	Plant height (cm)	No. of branches/plant	Dry wt. at flower initiation (g)	Chlorophyll (SPAD Unit)	No. of pods/plant	No. of seeds/ Pod	Pod length (cm)	Biological yield/plant(g)	Straw yield per plant (gm)	Protein content in seed (%)	Days to 50% flowering	1000 seed wt (g)	Dry matter content (g)	Harvest index	Seed yield /plant (g)
Plant height (cm)		0.011	0.219	0.341*	0.235	0.123	0.270	0.326	0.217	0.097	-0.093	0.558**	0.486**	-0.108	0.297
No. of branches/ plant			-0.077	0.265	0.355*	0.030	-0.046	0.285	0.207	0.379*	-0.023	0.268	0.184	0.032	0.401*
Dry wt at flo. initiation (g)				0.063	0.220	0.407*	0.310	0.162	0.118	0.224	0.027	0.252	0.207	0.031	0.258
Chlorophyll (SPAD Unit)					0.351*	-0.106	-0.049	0.419*	0.411*	0.167	-0.047	0.512**	0.192	-0.039	0.289
No. of pods/plant						0.196	0.071	0.770**	0.713**	0.310	-0.152	0.351*	0.487**	-0.356*	0.560**
No. of seeds/pod							0.390*	0.128	0.006	0.455**	-0.169	0.223	0.279	0.196	0.371*
Pod length (cm)								0.063	-0.035	0.211	-0.171	0.167	0.272	0.231	0.304
Biological yield/p (g)									0.953**	0.189	-0.106	0.479**	0.634**	-0.573**	0.623**
Straw yield per plant (gm)										0.086	-0.022	0.398*	0.494**	-0.750**	0.385*
Protein content in seed (%)											-0.051	0.254	0.399*	0.232	0.437**
Days to 50% flowering												-0.353*	-0.218	-0.265	-0.375*
1000 seed wt (g)													0.419*	-0.096	0.498**
Dry matter content (g)														-0.013	0.639**
Harvest index															0.263
Seed yield /plant(g)															

** 1% level of significance * 5% level of significance

Table 4. Genotypic path coefficient of yield and its component characters of fenugreek (Dependable variable-seed yield per plant)

Characters	Plant height (cm)	No. of branches/plant	Dry wt. at flower initiation (g)	Chlorophyll (SPAD Unit)	No. of pods/plant	No. of seeds/Pod	Pod length (cm)	Biological yield/plant (g)	Straw yield per plant (g)	Protein content in seed (%)	Days to 50% flowering	1000 seed wt (g)	Dry matter content (g)	Harvest index
Plant height (cm)	-0.059	0.000	0.032	0.173	0.012	0.033	-0.145	0.792**	-0.366*	-0.006	0.013	0.007	0.166	-0.088
No. of branches/plant	0.003	0.000	-0.017	0.103	0.026	0.046	0.012	0.839**	-0.489**	-0.036	0.021	0.006	0.032	-0.030
Dry wt. at flo. initiation (g)	-0.017	0.000	0.112	0.012	0.010	0.082	-0.139	0.367*	-0.175	-0.013	0.001	0.003	0.050	-0.004
Chlorophyll (SPAD Unit)	-0.024	0.000	0.008	0.173	0.016	-0.025	-0.007	0.954**	-0.574**	-0.010	-0.009	0.006	0.041	-0.146
No. of pods/plant	-0.017	0.000	0.027	0.066	0.043	0.039	-0.039	1.566**	-0.900**	-0.017	0.014	0.004	0.106	-0.213
No. of seeds/pod	-0.011	0.000	0.054	-0.025	0.010	0.171	-0.185	0.395*	-0.096	-0.031	0.007	0.004	0.079	0.112
Pod length (cm)	-0.036	0.000	0.065	0.005	0.007	0.132	-0.239	0.456**	-0.061	-0.024	0.025	0.005	0.133	0.177
Biological yield/p (g)	-0.025	0.000	0.022	0.090	0.337*	0.037	-0.059	1.841**	-1.055**	-0.012	0.014	0.007	0.148	-0.302
Straw yield per plant (gm)	-0.020	0.000	0.018	0.091	0.036	0.015	-0.013	1.785**	-1.089**	-0.005	0.003	0.006	0.125	-0.376*
Protein content in seed (%)	-0.006	0.000	0.027	0.031	0.014	0.097	-0.106	0.392*	-0.104	-0.055	0.006	0.003	0.088	0.164
Days to 50% flowering	0.009	0.000	0.002	-0.018	-0.007	-0.015	0.072	-0.308	0.044	0.004	-0.084	-0.005	-0.062	-0.205
1000 seed wt (g)	-0.040	0.000	0.034	0.101	0.016	0.066	-0.111	1.121**	-0.579**	-0.015	0.036	0.011	0.103	-0.052
Dry matter content (g)	-0.034	0.000	0.028	0.036	0.026	0.068	-0.161	1.379**	-0.688**	-0.024	0.026	0.006	0.197	-0.096
Harvest index	0.010	0.000	-0.001	-0.051	-0.018	0.039	-0.085	-1.117**	0.822**	-0.018	0.034	-0.001	-0.038	0.498**

** 1% level of significance * 5% level of significance

Table 5. Phenotypic path coefficient of yield and its component characters of fenugreek (Dependable variable-seed yield per plant)

Characters	Plant height (cm)	No. of branches/plant	Dry wt. at flower initiation (g)	Chlorophyll (SPAD Unit)	No. of pods/plant	No. of seeds/Pod	Pod length (cm)	Biological yield/plant (g)	Straw yield per plant (gm)	Protein content in seed (%)	Days to 50% flowering	1000 seed wt (g)	Dry matter content (g)	Harvest index
Plant height (cm)	-0.079	0.000	0.014	0.017	-0.004	0.000	0.004	0.583**	-0.189	-0.001	0.003	0.018	-0.004	-0.067
No. of branches/plant	-0.001	0.046	-0.005	0.013	-0.006	0.000	-0.001	0.511**	-0.181	-0.003	0.001	0.009	-0.002	0.020
Dry wt. flower initiation (g)	-0.017	-0.004	0.064	0.003	-0.004	0.001	0.005	0.290	-0.103	-0.002	-0.001	0.008	-0.002	0.019
Chlorophyll (SPAD Unit)	-0.027	0.012	0.004	0.049	-0.006	0.000	-0.001	0.749**	-0.359*	-0.001	0.002	0.017	-0.002	-0.148
No. of pods/plant	-0.019	0.016	0.014	0.017	-0.017	0.000	0.001	1.379*	-0.623**	-0.002	0.005	0.012	-0.004	-0.220
No. of seeds/pod	-0.010	0.001	0.026	-0.005	-0.003	0.002	0.006	0.230	-0.005	-0.003	0.006	0.007	-0.002	0.121
Pod length (cm)	-0.021	-0.002	0.020	-0.002	-0.001	0.001	0.017	0.113	0.031	-0.002	0.006	0.006	-0.002	0.143
Biological yield/plant(g)	-0.026	0.013	0.010	0.021	-0.013	0.000	0.001	1.790**	-0.832**	-0.001	0.004	0.016	-0.006	-0.353
Straw yield per plant (gm)	-0.017	0.009	0.008	0.020	-0.012	0.000	-0.001	1.705**	-0.874**	-0.001	0.001	0.013	-0.004	-0.463
Protein content in seed (%)	-0.008	0.017	0.014	0.028	-0.005	0.001	0.004	0.338*	-0.075	-0.007	0.002	0.008	-0.004	0.143
Days to 50% flowering	0.007	-0.001	0.020	-0.020	0.003	0.000	-0.003	-0.190	0.109	0.000	-0.035	-0.012	0.002	-0.164
1000 seed wt (g)	-0.044	0.012	0.016	0.025	-0.006	0.001	0.003	0.858**	-0.348*	-0.002	0.013	0.033	-0.004	-0.059
Dry matter content (g)	-0.039	0.008	0.013	0.029	-0.008	0.001	0.005	1.136**	-0.432**	-0.003	0.008	0.014	-0.009	-0.064
Harvest index	0.009	0.001	0.020	-0.012	0.006	0.000	0.004	-1.025**	0.655**	-0.002	0.009	-0.003	0.001	0.617**

** 1% level of significance * 5% level of significance

had the highest negative direct effect on seed yield. Traits like straw yield per plant and plant height imparted negative direct effect on seed yield per plant. Thus, for increasing seed yield per plant emphasis on traits having positive and direct effect should be given due importance and balanced selection based on these traits would be more rewarding for improvement of fenugreek. Similar observations have been cited by scientists like Dashora *et al.* (2011), Naik *et al.* (2011) Fikreselassie *et al.* (2012) and Kumar *et al.* (2018)

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In-vivo evaluation of fungicides against *Lasiodiplodia theobromae* infecting die back disease of mango (var. Alphanso)

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(Received: 20.01.2017; Accepted: 23.11.2017)

Abstract

In vivo evaluation of fungicides showed Bordeaux mixture (1.0%) was found to be the most effective in controlling the die back disease of mango after each spraying and it has given cent per cent infection control along with thiophanate methyl, hexaconazole, propiconazole and hexaconazole + zineb. All these fungicides inhibit the growth of fungus in first and second spraying on both the mango orchard during 2011-12 to 2012-13 respectively. The study is to promote commercial cultivation of the mango var. alphanso by small and middle scale farmers.

Key words : Die back, fungicides, in-vivo, *Lasiodiplodia*, mango.

Introduction

Mango (*Mangifera indica* L.) belonging to family Anacardiaceae is the most important commercially grown fruit crop of the country, commonly cultivated in many tropical and subtropical regions. The mango is a juicy stone fruit called as the king of fruits. India has the richest collection of mango cultivars. Cultivation of mango is believed to have originated in south east asia from where it has been distributed worldwide to become one of the most cultivated fruits in the tropics. Mango is considered to be an allopolyploid, most probably amphiploid and out breeding species having chromosome number $2n=40$ (Mukherjee, 1950).

Lasiodiplodia theobromae Pat. causes die back disease of mango affects the plants twigs die from the tips back into old wood, giving a scorched appearance to the limb. The young green twigs start withering first at the base and then extending outwards along the veins of leaf edges. The affected leaf turns brown and its margins roll upwards. Leaves scorch and fall, leaving a dead branch. In severe conditions, branches start drying one after another in a sequence resulting in death of the whole tree. Therefore, the present investigation has been carried out with the management of die back disease and find out the appropriate fungicides against the pathogen *L. theobromae*.

Materials and Methods

The field experiments was conducted at two separate fields. First at mango orchard of Horticulture field, Dr. Balasaheb Savant Konkan Krishi Vidyapeeth, Dapoli (M.H.) and another in farmer's field at Kapde-Wakan, Tah. Poladpur, district Raigad (M.H.) during the years from 2011 to 2013.

Five fungicides thiophanate methyl (topsin, 0.2%), Bordeaux mixture (1%), hexaconazole (topper, 0.1%), propiconazole (tilt, 0.1%) and hexaconazole + zineb (avatar, 0.2%) that gave the best inhibition of *L. theobromae* *in vitro* were used in the field trials. Five fungicidal treatments were tried in randomly block design (RBD). There were four plants per fungicide treatment. The plants were thoroughly sprayed two times at two months interval. The first spray was conducted in the month of June and second in September. Observations on disease severity were recorded one month after the spraying.

Before the first spray the plants were tagged. Isolation from the branches of treated and control plants were made to determine the infection on each plant. Both disease incidence and severity were evaluated before spraying and after one months of second spray. The number of infected branches were counted and percent disease reduction of disease over control was calculated to determine the efficacy of test fungicides under field conditions.

Results and Discussion

In field experiment, Bordeaux mixture (1.0%) proved to be the highly effective fungicide for the control of die back disease of mango followed by thiophanate methyl (0.2%), hexaconazole (0.1%), propiconazole (0.1%) and hexaconazole + zineb (0.2%). It was accompanied with a gradual reduction in the disease severity and disease incidence in treated trees as compared to untreated control trees. It was also noted in the trees treated with fungicides that new vegetative growth comprising of new shoots and leaves appeared and increased with each fungicidal treatment. After the 2nd spray the trees sprayed with Bordeaux mixture 1.0 %

(horticulture field 2012 and 2013, farmer's field 2013) showed promising result followed by thiophanate methyl (0.2%), propiconazole (0.1%) and hexaconazole (0.1%) respectively. They produced large number of new shoots and complete disappearance of typical symptoms of the disease. However, the plants sprayed with thiophanate methyl (0.2%) and propiconazole (0.1%) still exhibit little gum exudation. Trees treated with hexaconazole + zineb (0.2%) and propiconazole (0.1%) produced less vegetative growth than trees treated with Bordeaux mixture (1.0%) or thiophanate methyl (0.2%). In untreated control plants, disease severity was increased with increase in time.

All the fungicides under field condition significantly reduced the incidence of *B. theobromae* as compared to the control. Consistent with the result under *in vitro* condition, maximum disease control was achieved in plants sprayed with Bordeaux mixture (1.0%) and thiophanate methyl (0.2%) under field condition respectively.

Disease Intensity

Mean of infected branches of disease trees as recorded before first spraying and the infected area of disease trees were recorded after first and second spraying. The observations were taken before spraying, ten days after spraying and one month after spraying (including first and second spray) and same was analysed statistically and presented in Table 1 to 3 and pooled analysis of fungicidal spray presented in Table 4.

Disease Intensity of Die back Disease of Mango at Horticulture field during year 2011-2012

The maximum disease reduction over control was recorded in Bordeaux mixture (99.12 %). All the fungicidal treatments were found significantly superior to control. Bordeaux mixture (1%) was found superior to the rest of fungicides in checking the intensity of die back disease of mango. It was followed by hexaconazole (0.1%), thiophanate methyl (0.2%) and hexaconazole+zineb (0.2%) were found significantly superior over control. Among all the fungicides Bordeaux mixture showed less mean percentage of infected branches *i.e.* 0.035%. It was followed by hexaconazole, thiophanate methyl and hexaconazole+zineb *i.e.* 0.065%, 0.110% and 0.193% respectively. Maximum disease reduction over control was recorded in the treatment Bordeaux mixture *i.e.* 99.12% followed by hexaconazole (98.37%), thiophanate methyl (97.24%) and hexaconazole+zineb (95.15%) respectively. Whereas, minimum disease reduction over control (91.71%) was observed in the propiconazole (Table1).

Disease intensity of Die back Disease of Mango at Horticulture field during year 2012-2013

Maximum disease reduction over control was recorded in the treatment of Bordeaux mixture *i.e.* 99.19% followed by hexaconazole+zineb (98.29%), propiconazole (96.34%) and thiophanate methyl (95.49%) respectively. Whereas, minimum per cent growth inhibition (86.45%) was observed in the hexaconazole (Table 2).

All the fungicidal treatments were found significantly superior to control. Bordeaux mixture (1%) was found superior to the rest of fungicides in checking the intensity of die back disease of mango. It was followed by hexaconazole + zineb (0.2%), propiconazole (0.1%) and thiophanate methyl (0.2%). Among all the fungicides Bordeaux mixture (1%) showed less mean percentage of infected branches *i.e.* 0.043%. It was followed by hexaconazole + zineb, propiconazole and thiophanate methyl *i.e.* 0.090%, 0.193% and 0.238% respectively.

Disease intensity of Die back Disease of Mango at Farmer's field during year 2012-13

The cent percent disease reduction over control was recorded by Bordeaux mixture. All the fungicidal treatments were found significantly superior to control treatment. Bordeaux mixture (1.0%) was found superior to the rest of fungicides. It was followed by propiconazole (0.1%), hexaconazole+zineb (0.2%) and hexaconazole (0.1%) which were found significantly superior over control. Maximum disease reduction over control was recorded in the treatment Bordeaux mixture *i.e.* 100% followed by propiconazole (95.38%), hexaconazole+zineb (95.22%), and hexaconazole (90.76%) respectively. Whereas, minimum per cent growth inhibition (89.20%) was observed in the thiophanate methyl (Table 3).

Pooled analysis of fungicidal spray

At one month after spraying, maximum mean number of infected branches were observed in control (4.184) followed by hexaconazole + zineb (1.1%) and the minimum mean infected branches were showed by Bordeaux mixture 1% (0.0 %) at first spraying (June month) and statistically on par with thiophanate methyl (0.2%), hexaconazole (0.1%) and propiconazole (0.1%) with 0.248 %, 0.119 % and 0.280 % respectively. At second spraying (September month), the minimum pooled mean of infected branches was showed by Bordeaux Mixture (0.039%) and statistically on par with thiophanate methyl (0.2%), hexaconazole (0.1%), propiconazole (0.1%) and hexaconazole + zineb (0.2%) with 0.174 %, 0.390 %, 0.141 % and 0.261 % respectively (Table 4).

These results are more or less in close agreement with the following workers. Ahmed *et al.* (1995) reported thiophanate methyl (1.5 g/lit.) and benomyl (0.5 g.lit.) were effective in controlling die back of mango caused by *B. theobromae*. Li *et al.* (1995) observed that the gummosis is disease in Japanese apricot and peach orchards caused by *L. theobromae* were controlled by thiophanate methyl. Prakash and Raoof (1989) reported that in India *Lasiodiplodia theobromae* disease was effectively controlled by pruning the affected portions and spraying the wounded areas with 5:5:50 Bordeaux mixture. Mahmood *et al.* (2002) who recorded that 1st foliar spray of thiophanate methyl (Topsin-M) @ 1 gL⁻¹ reduced the infestation of *L. theobromae* to 10% and 2nd spray of the same fungicide completely inhibited the fungus as no tissue yielded this fungus. Shelar (1994) who recorded that

Table 1. *In vivo* evaluation of fungicides against *B. theobromae* at Horticulture field, Dapoli (Sept., 2012)

Fungicides	Conc. (%)	Disease incidence before spray	10 days after Spraying		One Month After Spraying	
		Mean of infected branches (%)	Mean of infected branches (%)	Disease reduction over control (%)	Mean of infected branches (%)	Disease reduction over control (%)
Thiophanate Methyl	0.2	3.063 (10.063)	1.705 (7.407)	31.73	0.110 (1.342)	97.24
Bordeaux Mixture	1.0	2.918 (9.797)	1.605 (7.164)	35.61	0.035 (0.536)	99.12
Hexaconazole	0.1	3.410 (10.621)	1.793 (7.460)	28.08	0.065 (0.991)	98.37
Hexaconazole + Zineb	0.2	3.463 (10.708)	2.043 (8.179)	18.05	0.193 (1.758)	95.15
Propiconazole	0.1	3.270 (10.294)	2.043 (8.179)	18.05	0.330 (3.243)	91.71
Control		4.065 (11.607)	2.493 (9.003)		3.983 (11.445)	
SEm $\pm$		0.455	0.766		0.717	
CD (P = 0.05)		NS	NS		2.180	

(Figures in the parentheses are arc sine values)

Table 2. *In vivo* evaluation of fungicides against *B. theobromae* at Horticulture field, Dapoli (Sept., 2013)

Fungicides	Conc. (%)	Disease incidence before spray	10 days after Spraying		One Month After Spraying	
		Mean of infected branches (%)	Mean of infected branches (%)	Disease reduction over control (%)	Mean of infected branches (%)	Disease reduction over control (%)
Thiophanate Methyl	0.2	2.865 (9.724)	2.065 (8.222)	27.87	0.238 (2.610)	95.49
Bordeaux Mixture	1.0	3.438 (10.657)	2.343 (8.773)	18.16	0.043 (0.591)	99.19
Hexaconazole	0.1	2.898 (9.763)	2.330 (8.769)	18.62	0.715 (4.702)	86.45
Hexaconazole + Zineb	0.2	2.998 (9.926)	2.258 (8.416)	21.13	0.090 (1.471)	98.29
Propiconazole	0.1	2.305 (8.642)	2.245 (8.593)	21.59	0.193 (2.087)	96.34
Control		3.638 (10.981)	2.863 (9.727)		5.278 (13.258)	
SEm $\pm$		0.525	0.535		0.623	
CD (P = 0.05)		NS	NS		1.894	

(Figures in the parentheses are arc sine values)

Table 3. *In vivo* evaluation of fungicides against *B. theobromae* at Farmers field (September, 2013)

Fungicides	Conc. (%)	Disease incidence before spray	10 days after Spraying		One Month After Spraying	
		Mean of infected branches (%)	Mean of infected branches (%)	Disease reduction over control (%)	Mean of infected branches (%)	Disease reduction over control (%)
Thiophanate Methyl	0.2	1.435 (6.833)	1.960 (8.017)	44.52	0.538 (2.806)	89.20
Bordeaux Mixture	1.0	1.133 (6.099)	1.560 (6.999)	55.84	0.000 (0.000)	100
Hexaconazole	0.1	1.495 (6.998)	1.903 (7.908)	46.14	0.460 (3.372)	90.76
Hexaconazole + Zineb	0.2	1.485 (6.990)	2.375 (8.809)	32.78	0.238 (2.351)	95.22
Propiconazole	0.1	1.410 (6.754)	2.390 (8.882)	32.35	0.230 (2.169)	95.38
Control		1.745 (7.370)	3.533 (10.793)		4.980 (12.863)	
SEm $\pm$		0.385	0.571		1.040	
CD (P = 0.05)		NS	1.737		3.163	

(Figures in the parentheses are arc sine values)

Table 4. Pooled results of fungicide sprays on the severity of die back of mango (2011-12 and 2012-13)

Fungicides	One Month After Spraying (%) (mean no. of infected branches)					
	June 2012	June 2013	Pooled mean	September 2012	September 2013	Pooled mean
Thiophanate Methyl	0.35	0.145	0.2475	0.11	0.238	0.174
Bordeaux Mixture	0	0	0	0.035	0.043	0.039
Hexaconazole	0.113	0.125	0.119	0.065	0.715	0.39
Hexaconazole + Zineb	0.158	0.43	0.294	0.193	0.09	0.1415
Propiconazole	1.265	0.943	1.104	0.33	0.193	0.2615
Control	3.615	4.753	4.184	3.983	5.278	4.6305
SEm $\pm$			0.612			0.549
CD (P = 0.05)			1.765			1.584

carbendazim (0.1%) was found to be most effective in controlling the disease intensity of die back of mango after fourth spraying followed by thiophanate-M (0.1%), captan (0.2%), benomyl (0.1%) and mancozeb (0.25%). Bokhari *et al.* (2008) found that Topsin-M reduces cent percent guava decline after second spray followed by alert plus and Reconil-M.

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Changes in total phenolics and total antioxidant activity of kair (*Capparis decidua*) fruits during maturity

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(Received: 24.09.2018; Accepted 3.10.2018)

Capparis decidua (Forsk.) Edgew (Capparidaceae), commonly known as Kair, is a hardy plant, resistant to almost all type of abiotic stresses like heat, cold, drought salinity etc. naturally grow in arid region of India specifically Rajasthan, Haryana, MP, Gujarat states. This plant is also a vital component in nutritional and income security of the rural peoples, especially in the arid region. Besides many socioeconomic and ecological benefits, all parts of this plant have a number of medicinal properties. The plant is traditionally used to cure toothache, arthritis, cough, asthma, inflammation, intermittent fevers, malaria, rheumatism, and swelling. It is also believed to possess laxative, astringent and vermi-fuge properties (Jeseph and Jini, 2011; Singh *et al.* 2011). The alcoholic extract of fruit pulp and root bark is reported to have anthelmintic activity (Singh and Singh, 2011) and the seeds oil is edible when processed and which contain nitrogen and sulphur, so used to cure skin problems (Singh *et al.* 2011; Baloda and Bangarwa, 2010). The blanched fruit is used as a vegetable, green berries are used in food preparations such as pickles and fully ripe fruits are consumed as fresh since ripe fruits has a unique type sweet test (Baloda and Bangarwa, 2010). Zia-Ul-Haq *et al.* (2011) studied the proximate composition, amino acids, fatty acids, tocopherols, sterols, glucosinolate and phenolic content in extracts obtained from different aerial parts of *C. decidua*, reported its antidiabetic and antioxidant activity. But there is no study on kair fruits regarding which maturity stage possess highest phenolic content and antioxidant activity. In this study we reported the changes happening during fruits ripening with regard to its phenolic content and total antioxidant activity.

Fresh fruits of *Capparis decidua* (Forsk.) Edgew (kair) of different maturity stages (Tender to fully ripe) were harvested from the ICAR-CIAH, Bikaner research farm during April-May, 2017 and divided in five groups as per their maturity stages as stage 1 (Tender fruits), stage 2 (Little mature fruits), stage 3 (Medium Mature fruits), stage 4 (Mature fruits) and stage 5 (fully ripe Fruits) as shown in Figure 1. from each group 10 fruits were counted and weighed to note the average fresh fruit weight, these weighed fruits were subjected to drying in oven at $60 \pm 3^\circ\text{C}$ till the constant weight and calculated the percent dry matter content. The dried samples were ground using kitchen milling machine and passed through 100 micron sieve for getting uniform samples and extracted with 70 % ethanol for total phenolic and total antioxidant activity estimations. Total phenolic content was

determined with the Folin- Ciocalteu reagent (Medini *et al.* 2014) and expressed as mg GAE/g DW. Total antioxidant activity (TAA) of the ethanolic extract was determined by DPPH radical scavenging activity by following the method of Re *et al.* (1999) and expressed as mg Vit C equi./g DW. All analyses were performed in triplicate and values expressed as the mean $\pm$ standard deviation. Data analysis was carried out using the analysis of variance and OPSTATE statistical computer package ([www. http://hau.ac.in/about/opstat.php](http://hau.ac.in/about/opstat.php))

In the present study, Ker fruits of different maturity stages (shown in figure 1) were analyzed for changes in their average fruit weight, dry matter content, total phenolic content and total antioxidant activity along with maturity. A significant difference was observed in all the analyzed parameters along with fruit maturity (Table 1). A significant increase in average fruit weight was observed with maturity, it increase from 0.38 g to 4.11 g per fruits. The increase in average fruits weight is a natural phenomenon of fruit development as deposition of nutrients in sink part of the plant with fruit growth is happen. While, It was observed that dry matter content is continuously decreased from 30.31% (stage 1) to 23.22% (stage 5), it was decreased slowly till maturity stage 4 but a drastic reduction was observed between maturity stage 4 to stage 5. Total phenolic content and total antioxidant activity were also increased from maturity stage 1 to stage 5. Total phenolic content increased from 3.98 mg GAE/g to 4.96 mg GAE/g while total antioxidant activity increased from 0.64 mg Vit.C equi./g to 1.57 mg Vit.C equi./g respectively from maturity stage 1 to stage 5. For total phenolic content and total antioxidant activity, a non-significant increment was observed till the maturity stage 3 but afterward a significant increase



Table 1. Fresh Fruit weight, Dry matter %, phenolic content and Total antioxidant activity of kair (*Capparis decidua*) fruits at different maturity stages.

S.No.	Maturity Stages	Fresh Fruit weight (g)	Dry Matter content(%)	Total Phenol (mg GAE/g DW)	Total antioxidant activity (mg Vit C Equi./g DW)
1	Stage 1	0.38	30.31	3.98	0.64
2	Stage 2	0.94	29.03	4.03	0.75
3	Stage 3	1.34	28.61	4.22	0.81
4	Stage 4	2.84	27.49	4.64	0.87
5	Stage 5	4.11	23.22	4.96	1.57
	C.D.	0.09	0.81	0.28	0.17
	SE(m)	0.03	0.25	0.09	0.05

*GAE- Gallic acid equivalent, DW-Dry weight basis

was observed in both the parameters (Table 1). Studies on the presence of phenolic compounds and antioxidant compounds in kair fruits were also reported by Tlili *et al.* (2010) and Zia-Ul-Haq *et al.* (2011). The absolute values reported by these scientists for phenolic compounds are somehow differed from our values. This difference might be due to difference in extraction method or standard compound used, since they expressed against catechin while we expressed against gallic acid.

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Tolerance of brinjal to saline irrigation under drip and flood irrigation systems

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(Received: 14.03.2017, Accepted: 20.06.2018)

Arid region of Rajasthan, while, already faces problem of saline underground waters, rapidly declining water resources further add to its misery. Under such a situation, judicious use of irrigation water has, now a days, become matter of concern for researchers. Development of technology for efficient and safer utilization of poor quality water for crop production is one of the thrust areas of research, as share of water allocation to agriculture is anticipated to reduce. It is well known that judicious use of poor quality saline ground waters is possible through micro-irrigation system. In case of drip, relatively small amount of irrigation water is applied at frequent interval and movement of salts in root zone take place at low leaching fraction pushing salts to periphery of wetting zone. As a result plants may experience low salinity stress compared surface irrigation. However, the degree of permissible water salinity for use in drip system depends on water quality, soil properties and salinity tolerance of particular crops. Drip irrigation is the most effective way to supply water and nutrients to the plant, which not only saves water but also increases yield of fruits and vegetable crops (Tiware *et al.*, 1998; Hatami *et al.*, 2012; Nadiya *et al.*, 2013; Iqbal *et al.*, 2014). This water saving is because maximum amount of water is stored in the root zone and deep percolation losses are minimized (Singandhupe *et al.*, 2007; Bhogi *et al.*, 2011). There is meagre information on use of saline water in sandy soils of western Rajasthan under drip method of irrigation in vegetables. Considering these in view an investigation was undertaken of sandy soils with poor quality irrigation water, to study the efficiency of drip irrigation on brinjal.

A field experiments was conducted on sandy soils of Agricultural Research Station, Bikaner in 2011 and 2012 to assess the tolerance of brinjal to different levels of irrigation water salinity through drip and flood methods. Treatment comprised three salinity levels of irrigation water (EC 0.25, 3.0 and 6.0 dS m⁻¹) under two methods of irrigation i.e. drip and flood. The soils of experimental field was sandy in texture, alkaline in reaction (pH 8.4), low in organic carbon (0.10%) and medium in available phosphorus (24 kg P₂O₅/ha) and potash (200 kg K₂O/ha). The experiment was laid out in randomized block design with three replications in plot size of 3 m x 3 m. Brinjal seedlings, hybrid Kanhaya were transplanted on 12 August, 2011 and 08 August, 2012 and final harvesting was done upto first week of March during both the seasons of experimentation keeping crop geometry of 60 cm x

30 cm. The standard recommended agronomic practices were followed. Recommended dose of 40, 60 and 40 kg N, P₂O₅ and K₂O ha⁻¹ was applied through urea, SSP and MOP at the time of transplanting in all the plots and remaining 40 kg N ha⁻¹ was top dressed in two splits. Water was applied in drip irrigation through emitters having discharge of 4 lph and operated at pressure of 1.25 kg cm⁻². Sintex tank of 1000 litres capacity each were used to supply water 0.25, 3.0 and 6.0 dS m⁻¹. The required salinity was achieved by adding the pre calculated amount of salts. The treatments were evaluated in terms of yield attributing parameters, yield and water use efficiency. For analysis of salinity build up in soil profile due to saline water irrigation under drip method, soil samples were also taken at three points which were located horizontally at 0, 15 and 30 cm apart from the either side of emitters. At each of these three locations soil samples were collected from three depths i.e. 0-15, 15-30 and 30-45 cm. Similarly, in case of flood irrigation soil samples were taken from the same three depths but at only one location. Soil samples were collected at transplanting and harvesting of crop and analysed as per method outlined by Richards (1954). Rainfall received during the crop season was 166.3 and 188.2 mm during 2011 and 2012, respectively.

Yield and yield attributes

The weight, fruits per plant and yield of brinjal fruits differ significantly with EC_{iw} levels. Results showed that drip method of irrigation was superior to flood method at all the levels of EC_{iw} and resulted in 26.5 per cent higher fruit yield. The highest fruit yield of brinjal was obtained under drip method of irrigation with water having EC_{iw} 3.0 dS m⁻¹ (BAW) over rest of the treatments and a significant decrease yield was observed with water having EC_{iw} 6.0 dS m⁻¹ on pooled basis. Increase in the levels of EC_{iw} to 3.0 dS m⁻¹ brought about significant improvement in fruit weight per plant under drip irrigation, but further increment EC_{iw} i.e. 6.0 dS m⁻¹ caused significant reduction in fruit weight per plant and resultant the marketable yield. Maximum number of fruits per plant (7.7) and highest fruit weight (59.5 g) were recorded in treatment EC_{iw} 3.0 dS m⁻¹ under drip system (Table 1). Increasing levels of EC_{iw} decreased the weight, fruits per plant and yield of brinjal fruits significantly in flood method of irrigation. It might be owing to decreased nutrient availability at higher salinity levels. The detrimental effects of increasing

salinity on plant water status and metabolism were generally more pronounced at flowering than the vegetative stage. Kaswala *et al.* (2015) reported that fruit yield of brinjal was increased (22.2 %) with 4 dS m⁻¹ over 8 dS m⁻¹ of irrigation water salinity but, it was 5 per cent higher when compared to BAW (40.1 t/ha).

Water Use and WUE

Maximum water use was observed in flood method of irrigation which was 46.64 per cent higher than drip method of irrigation. Whereas, highest mean water use efficiency of 300 kg/ha-cm was observed in treatment having EC_{iw} 3.0 dS m⁻¹ under drip method of irrigation (Table 2). Aujla *et al.* (2007) reported that 50 per cent water saving could be achieved through drip irrigation in brinjal while obtaining 4 per cent yield increase as compared to furrow irrigation. Goswami *et al.* (2006) also reported that drip irrigation in Brinjal gave superior fruit yield and saved 37-49 per cent water when compared to surface irrigation. Kadam and Kartikeyan (2004) also advocated superiority of drip method over surface method.

Salinity Buildup

Besides water economy noticed under drip irrigation system, study on salt accumulation in root zone further encourages the use of drip irrigation system for optimum production of brinjal under saline irrigation situation. The EC_e of soil recorded after harvest of brinjal crop as affected by salinity levels of irrigation water in 0-45 cm soil profile at 0, 15 and 30 cm lateral distances from the emitter has shown that the maximum salinity was registered at 30 cm distance from

emitters with 6.0 dS/m saline water (Table 3). In general, the soil salinity increased with increase in salinity of irrigation water at all depth and locations. Zone of minimum salt concentration existed below the emitter in studied soil profile. The trend clearly indicate that the salt concentration in soil profile increase with increase in lateral as well as vertical distance from the emitters. This is due to differences in moisture content of ponded, wetted zone of area irrigated by a particular emitter. The ponded zone have always higher moisture both laterally and vertically which starts decreasing as we move toward wetted zone with minimum at the end of wetting zone. This moisture variation causes movement of salts from the near vicinity of emitter, creating comparatively much less saline zone in which root perform there activity. In order words, it can be inferred that the salts are leached away from the active zone of plant providing better growing conditions. Salt concentration was highest at 30 cm distance from emitter. This may be due to fact that salts have moved with water away from active root zone. The trend clearly indicates that the soluble salt distribution in the root zone decreased gradually with the depth for all the treatments. These results are in agreement with the findings of Bhargava *et al.* (1995) who reported that application of saline water increased the soil salinity upto a depth of 120 cm; however, the increase was more within the top 60 cm of soil.

From the results, it is concluded that in tube well irrigated area of arid tract water having EC 3.0 dS m⁻¹ may be used for reasonably good yields of brinjal under drip irrigation. Drip method was found superior over flood method in producing 26.5 per cent higher fruit yield of brinjal.

Table 1. Effect of methods of irrigation and salinity of irrigation water on yield of brinjal

Treatments	Fruit weight (g)			Fruits/plant			Yield (q/ha)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Drip									
0.25 EC _{iw} dS/m	56.7	56.4	56.5	6.9	7.4	7.2	187.8	215.3	201.5
3.0 EC _{iw} dS/m	49.3	69.8	59.5	5.6	9.8	7.7	183.9	235.6	209.7
6.0 EC _{iw} dS/m	33.2	48.1	40.6	4.2	5.3	4.8	154.7	186.2	170.3
Flood									
0.25 EC _{iw} dS/m	41.4	49.6	45.5	6.1	6.8	6.5	170.5	193.5	182.0
3.0 EC _{iw} dS/m	39.6	44.9	42.1	4.8	5.1	5.0	141.0	156.8	148.9
6.0 EC _{iw} dS/m	26.5	39.3	32.9	2.6	3.4	3.0	120.2	137.1	128.6
SEm±	2.5	1.6	1.6	0.4	0.5	0.3	2.8	8.29	4.4
C.D. at 5%	7.9	5.0	4.7	1.2	1.6	0.9	8.9	26.05	12.9

Table 2. Effect of methods of irrigation and salinity of irrigation water on water use (mm) and WUE (kg/ha/cm)

Treatments	Water use (mm)			WUE (kg/ha/cm)		
	2011	2012	Mean	2011	2012	Mean
Drip						
0.25 EC _{iw} dS/m	688	710	699	273	303	288
3.0 EC _{iw} dS/m	688	710	699	267	332	300
6.0 EC _{iw} dS/m	688	710	699	225	262	244
Flood						
0.25 EC _{iw} dS/m	1013	1036	1025	168	187	178
3.0 EC _{iw} dS/m	1013	1036	1025	139	151	145
6.0 EC _{iw} dS/m	1013	1036	1025	119	132	126

Table 3. Salinity (EC_e) build-up in the soil profile after harvest of brinjal

Distance from emitter (cm)	Soil depth (cm)	EC_{iw} (dS/m)					
		Mean of both the years					
		Drip		Flood			
		0.25	3.0	6.0	0.25	3.0	6.0
0	0-15	0.47	1.14	1.41	0.51	1.51	2.13
	15-30	0.44	1.01	1.28	0.37	1.28	1.76
	30-45	0.36	0.88	1.16	0.32	1.01	1.36
15	0-15	0.57	1.25	1.68	-	-	-
	15-30	0.54	1.17	1.49	-	-	-
	30-45	0.48	0.94	1.35	-	-	-
30	0-15	0.65	1.38	1.93	-	-	-
	15-30	0.63	1.33	1.88	-	-	-
	30-45	0.53	1.04	1.68	-	-	-

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Effect of different methods of defoliation on growth, flowering and yield in lasora (*Cordia myxa* L.)

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(Received: 8.08.2018; Accepted: 3.10.2018)

Lasura (*Cordia myxa* L.) popularly known as Gonda or Lehsua is an underutilized fruit crop grown in arid and semi arid region of India and worldwide. In Rajasthan, flowering occurs in 10th March to 23rd April under Jodhpur condition with new leaves (Vashishtha *et al.*, 1985). In Rajasthan especially in western Rajasthan demand of lasura fruit is increases near the festival of 'Holi' or in month of March. But, the availability of fruit in market is in month of May. Defoliation of leaves in lasura in the month of December-January produces early flowering and fruiting in arid region. (Sharma *et al.*, 2013). So, the growers use traditional or manual method of defoliation to advance the crop without use of any chemicals. An overriding need exists to develop new and modern system to advance the crop to increase yield. Therefore, to achieve desired production at desired period of time defoliation is one of the most important factor.

Eight year old plants of lasura, planted 6×6 m apart at orchard at Agriculture Research Station, Mandor, Agriculture University, Jodhpur during the year 2016-17 were selected for the study, single plant considered as an experiment unit was replicated three times in Randomized Block Design with eight treatments. The treatments consisted of Manual defoliation, Thiourea 5g + Ethephon 2ml + DAP 5g ltr⁻¹, Thiourea 7.5g + Ethephon 3ml + DAP 7.5g ltr⁻¹, Thiourea 10g + Ethephon 4ml + DAP 10g ltr⁻¹, Ethephon 4ml ltr⁻¹, 2,4-D 3ml ltr⁻¹, 2,4-D 4ml ltr⁻¹ and water is sprayed as control. Observations were recorded on physical parameters, flowering and yield of crop during experimental period. Physical parameters (i.e. defoliation % at 10, 20 and 30DAT, burning of tips, days taken in 80% defoliation, sprouting after defoliation, length of sprout at 30, 45 and 60 days after sprouting and leaf area) were recorded after recording initial observations in each treatment. Five newly emerged shoots were selected and tagged randomly in each treatment for measuring burning, length of sprout same as five fully developed leaves from each treatment were selected for leaf area. Days taken to 80 per cent defoliation, sprouting after defoliation and flower initiation were recorded by visual observation through regular visiting the orchard. The Number of flowers was counted on five selected branches and average numbers of flowers per branch were calculated. Total number of flowers which set into fruit were counted and per cent fruit set was calculated on the basis

of number of flower emerged. Number of days taken to maturity stage of fruit from date of defoliation was counted as maturity of fruits days after defoliation. The yield/plant was calculated by sum of weight obtained from all the pickings and yield/ha. was calculated by multiplying the yield per plant with number of plants (278) per ha. Fruit weight was calculated by average of five fruits from each treatment. Statistical analysis was carried out as per methods prescribed by Panse and Sukhatme (1985).

The analysis of data on physical parameters, flowering and yield as influenced by different defoliation methods are presented in table-1 & 2.

Physical parameters and flowering

It is revealed from the data presented in table there is significant effect of all the methods on physical parameters and flowering. Manual method of defoliation recorded significantly higher defoliation per cent (100%). Defoliation per cent is also significantly increased with T.U. 10g + Ethephon 4 ml + DAP 10 g ltr⁻¹ (88%) followed by lower concentration of T.U. + Ethephon + DAP and Ethephon. Similar effect of defoliation was reported in pomegranate by Sheikh (2014). It might be because of abscission regulating hormone ethylene. Abscission zones of most abscising organs like leaves are highly sensitive to ethylene with only a few reports of ethylene insensitive abscission, reported by Van Doorm (2001). Manual method of defoliation recorded minimum days to defoliation (1 day). Among chemical methods T.U. 10g + Ethephon 4 ml + DAP 10 g ltr⁻¹ recorded 6.33 days for defoliation. The results are in accordance with the findings of Sheikh, 2014. They found 84.33 per cent defoliation after 21 days in pomegranate. The maximum burning of tips was recorded with all the concentration of 2,4-D (11% and 19.57%). Because if the above-ground parts of the plant are sprayed or dusted with 2,4-D, the response is different, for leaf growth ceases, the rate of respiration of the plant is increased, and its reserve food materials are broken down and subsequently burned up. This study is supported by Mitchell (1947). Results showed that minimum days in sprouting (9.67) and flower initiation (16) was recorded with control because growth was initiated just after defoliation in lasura tree, this was supported by Vashishtha *et al.* (1985). But flowering with natural defoliation occurs late in month of

April. Among all the chemical treatments T.U. 10g + Ethephon 4 ml + DAP 10 g ltr⁻¹ recorded earliest sprouting (14.67 days) and earliest flower initiation (25 days) is caused due to use of dormancy breaking and flower initiative chemicals viz. Thiourea and Ethephon. Thiourea increases starch content of cells (Rahman *et al.*, 2002) and alters the protein structures (Pandey *et al.* 2013) thereby increases C:N ratio of cell which broke dormancy. Application of ethephon found effective for induction of early flowering. Ethephon release ethylene when come in contact with the plant tissue. This in turn, triggers the mechanism of flowering and brings the shoots to flowering. These results were also recorded in pomegranate (Sheikh, 2014, Chandra *et al.*, 2011), in many fruit crops (Tandel *et al.* 2010), in mango (Dalal *et al.* 2005), in custard apple (Vinay *et al.* 2015), in Asian pear (Jana and Das, 2014) and in guava (Hiremath *et al.*, 2017). Application of thiourea can induce flowering in certain varieties of mango (Nartvaranant *et al.*, 2000). maximum length of sprout (41.53, 48.77 and 54.73 cm) at 30, 45 and 60 days after sprouting was recorded with treatment T.U. 10g + Ethephon 4 ml + DAP 10g ltr⁻¹ while minimum length was recorded with both the concentration of 2,4-D. This result gets full support from Chandra *et al.* (2011) and Sheikh (2014). High concentration of 2,4-D can inhibit cell division and growth (Tu *et al.* 2001). The number of flower maximum in treatment ethephon 4ml ltr⁻¹ (222, 310.67 and 378) was found and the minimum no. of flower was recorded in 2,4-D 4 ml ltr⁻¹ (53.67, 91 and 166.33) at 30, 45 and 60 DAD, respectively. Similar findings are found in custard apple by Vinay *et al.* (2015) that defoliated plants with ethephon 2000 ppm recorded significant number of flowers on 30, 60 and 60 DAT and similar results were observed in guava by Jain and Dasora (2007) that 250 and 500 ppm ethephol recorded maximum number of flowers per shoot. Treatment T.U. 10g + ethephon 4ml + DAP 10 g ltr⁻¹ recorded maximum leaf area (72 cm²) followed by T.U. 7.5g + ethephon 3ml + DAP 7.5 g ltr⁻¹ (67.67 cm²) which were on par with each other. Minimum leaf area 20 cm² was recorded with 2,4-D 4 ml ltr⁻¹. Mitchell (1947) reported that presence of 2,4-D on young leaves prevent it from expanding, and new leaves curled up and become distorted. Chemical caused a quick check in growth of leaves. Treatment T.U. 5g + Ethephon 2ml + DAP 5g ltr⁻¹ recorded maximum fruit set (20.78%) which is at par with T.U. 7.5g + Ethephon 3ml + DAP 7.5g ltr⁻¹ (20.77) and treatment T.U. 10g + Ethephon 4ml + DAP 10g ltr⁻¹ (19%). Minimum fruit set percentage was recorded with control (9.03%). This result get full support from Jana and Das (2014) on Asian pear, it was also proved in custard apple by Vinay *et al.* (2015) and in mango cv. Langra by Koruna *et al.* (2007). Contrary to this Singh and Reddy (1997) reported maximum reduction in fruit

set with 1800 ppm ethephon in guava crop. Data revealed that treatment with high concentration of ethephon cause early maturity in lasura fruits. Treatment T.U. 10g + ethephon 4ml + DAP 10g ltr⁻¹ recorded minimum days (55.40) in maturity closely followed by ethephon 4ml ltr⁻¹ (55.47) and treatment T.U. 7.5g + ethephon 3ml + DAP 7.5g ltr⁻¹ (57.57) which were at par with each other. Maximum days for maturity were recorded with control (64.80). These results are in confirmation with results obtained by Aroosa *et al.* (2005) on plum, on mango by Singh and Dwivedi (2009) and on pomegranate by Rathod *et al.* (2017) by the use of ethephon and by Patel *et al.* (2016) on mango by use of thiourea. Early maturity provides opportunities to have the commercial advantages of early marketing in season which fetches a higher price of fruit. The maximum number of fruits (8426.68) was recorded with manual method. Among chemical treatment ethephon 4 ml ltr⁻¹ recorded maximum number of fruits followed by Treatment T.U. 10g + ethephon 4ml + DAP 10g ltr⁻¹ (7455.97) which were at par with each other. Minimum number of fruits was recorded with control (4889.77). Results related to maximum number of fruits confirmed by Mishra *et al.* (2014), by Murthy (2014) in pomegranate and by Supe *et al.* (2015). maximum fruit weight was recorded with treatment T.U. 7.5g + ethephon 3ml + DAP 7.5g ltr⁻¹ (8.19g) closely followed by T.U. 5g + ethephon 2ml + DAP 5g ltr⁻¹ (8.12g) and T.U. 10g + ethephon 4ml + DAP 10g ltr⁻¹ (7.85g) which in term at par with each other whereas, minimum fruit weight was recorded with control (6.39g). These findings are in accordance with findings of Jana and Das (2014); Jana (2016) with thiourea, George (2007); Murthy (2014); Rathod *et al.* (2017) with ethephol.

Yield

Data regarding yield per plant and per ha shows significant effects of different treatment. Data shows that maximum yield per plant was recorded with T.U. 10g + ethephon 4ml + DAP 10g ltr⁻¹ (58.40 kg) whereas, minimum yield were recorded with control (31.23 kg). Among all the treatments T.U. 10g + ethephon 4ml + DAP 10g ltr⁻¹ (16235.20 kg) recorded maximum yield per ha however, minimum yield per ha was recorded with control (8682.87 kg). A great number of studies provide evidence regarding efficacious role of foliar applied of thiourea and ethephon in modeling physiological mechanism and improving final yield. These findings are confounding with Jana and Das (2014) and Jana (2016) reported that application of thiourea resulted in modification of C:N ratio of shoots gave maximum fruit yield in asian pear. Significant results were found by Murthy (2014); Elkhishen (2015); Supe *et al.* (2015); Rathod *et al.* (2017) in reference to yield in with ethephon.

Table1. Effect of different defoliation methods on physical parameters

Treatment	Defoliation percentage			Burning of tips (%)	Days taken in 80 per cent defoliation	Sprouting after defoliation (days)	leaf area (cm) ²	Length of sprout		
	10 D.A.T.	20 D.A.T.	30 D.A.T.					30 days after sprouting	45 days after sprouting	60 days after sprouting
T ₁ Control	0	0	0	0	69	9.67	60	29.67	38.53	45.13
T ₂ Manual	100	100	100	0	1	15	58	38.37	44.77	51.18
T ₃ T.U. 5g+Ethephon 2ml+DAP 5g ltr ⁻¹	50	73	75.33	0	40	20.67	49	36.33	43.43	52.23
T ₄ T.U. 7.5g +Ethephon 3ml+DAP 7.5g ltr ⁻¹	79	82	82.66	2.53	12	16.67	67.67	35.6	41.83	49.24
T ₅ T.U. 10g +Ethephon 4ml+DAP 10g ltr ⁻¹	87	88	88	3	6.33	14.67	72	41.53	48.77	54.73
T ₆ Ethephon 4 ml ltr ⁻¹	49	64	66	0	48.67	18.67	53.33	27	31.13	39.27
T ₇ 2,4-D 3ml ltr ⁻¹	18	24.33	38.33	11	60	23	32	14.67	21.3	27.33
T ₈ 2,4-D 4ml ltr ⁻¹	18.33	26.67	47	19.57	55.33	27	20	21	24.1	31.36
SEM±	1.75	1.78	1.99	0.26	1.29	1.09	3.77	1.38	1.56	1.51
C.D. at 5%	5.32	5.39	6.06	0.81	3.94	3.30	11.45	4.18	4.73	4.61

Table 2. Effect of different methods of defoliation on flowering and yield parameters

Treatment	Number of flowers per branch			Fruit set (%)	Maturity of fruit days after defoliation	Numbers of fruits per plant	Fruit weight (g)	Yield per plant (kg.)	Yield kg ha ⁻¹	Flower initiation (DAD)
	(30DAD)	(45DAD)	(60DAD)							
T ₁ Control	103	128.33	213.33	9.03	64.80	4889.77	6.39	31.23	8682.87	16
T ₂ Manual	107.67	148.33	263	17.4	62.60	8426.68	6.72	56.80	15734.80	21.67
T ₃ T.U. 5g+Ethephon 2ml+DAP 5g ltr ⁻¹	120	157.33	241.67	20.78	58.70	6516.97	8.12	52.93	14715.47	27.67
T ₄ T.U. 7.5g +Ethephon 3ml+DAP 7.5g ltr ⁻¹	114.67	161.67	257.33	20.77	57.57	6780.07	8.19	55.50	15429	23
T ₅ T.U. 10g +Ethephon 4ml+DAP 10g ltr ⁻¹	142.67	205	311.67	19	55.40	7455.97	7.85	58.40	16235.20	20
T ₆ Ethephon 4 ml ltr ⁻¹	222	310.67	378	15.4	55.47	7704.25	6.32	48.67	13529.33	25
T ₇ 2,4-D 3ml ltr ⁻¹	87.67	119.67	200.67	13.77	64.53	5473.27	6.97	38.20	10619.60	28.67
T ₈ 2,4-D 4ml ltr ⁻¹	53.67	91	166.33	15.67	63.70	5418.47	6.48	34.83	9683.67	29.67
SEM±	6.63	5.20	7.58	0.73	1.85	294.06	0.21	1.67	465.90	1.44
C.D. at 5%	20.11	15.78	22.99	2.23	5.62	891.96	0.65	5.08	1413.16	4.38

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Effect of stem cuttings and IBA concentrations on rooting and percentage success in karonda (*Carissa carandas* Linn.) under semi-arid ecosystem of western India

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(Received: 29.08.2018; Accepted: 21.09.2018)

Karonda (*Carissa carandas* Linn.), a xerophytic plant can be grown commercially in semi-arid ecosystem of Western India as protective hedge and block plantation. It is native to India and popularly known as Bengal currant or Christ's thorn. It is now considered as important arid and semi-arid zone fruit crop because of its hardy nature and its nutritious fruits (Bhavya *et al.*, 2018). Therefore, it can be used for horticultural plantations in marginal and wastelands, owing its hardy nature with wide adaptability to saline sodic soils with high pH level (Rai and Misra, 2005). Fruits of karonda are used for preparation of value added products like pickles, chutneys, jelly, candy and Nakal cherry. Nakal cherry closely resembles the canned cherry fruits (Rai and Misra, 2005). According to Dey *et al.* (2017), the karonda fruits are one of the richest sources of iron (39.1 mg/100 g). It is mainly propagated by seeds, which leads a different degree of variation among the population. Various elite clones of karonda have been identified at different places from its variable indigenous genetic resources (Athani *et al.*, 2005; Mishra, 2007, Singh *et al.*, 2015) which have to be multiplied vegetatively for their popularization and adoption in farmer's field. Different asexual propagation methods have been recommended by several workers from different parts of country with variable degree of success viz., air layering (Ghosh *et al.*, 2011), chip budding (Ghosh *et al.*, 2011), softwood grafting (Bhavya *et al.*, 2018), wedge grafting (Ghosh *et al.*, 2011), hardwood cutting (Dey *et al.*, 2017) and micro-propagation (Rai and Misra, 2005). However, comparative study of hard and semi-hardwood cutting is lacking. Therefore, the present experiment was undertaken to study the comparative advantage of using semi-hardwood and hard wood cuttings when treated with different concentrations of IBA under semi-arid ecosystem of western India.

The present work was carried out at Central Horticultural Experiment Station (ICAR-CIAH), Godhra. The experiment was laid out under factorial Randomized Block Design with 6 treatments and 3 replication (Cochran and Cox, 1992). The experimental material consisted of 20 cm long stem cuttings with three nodes obtained from the middle portion of six months old and one year old shoots for semi-hardwood and hardwood cuttings respectively. The cuttings were collected during the month of July from three year old healthy mother plant of karonda cv. Thar Kamal. Six

concentrations of IBA viz. 1000 ppm, 2500 ppm, 5000 ppm and 7500 ppm were applied on the basal part of each cutting while in case of control, cuttings were untreated. Then these treated cuttings were planted in 2 kg capacity poly-bags containing growing media of Soil, FYM and sand in equal proportion. Overhead water sprinkling over the cuttings was done daily in the morning hours. Subsequently the stem cuttings were carefully maintained and examined during the experimental period. There were 20 cuttings per treatment per replication. The different root and shoot growth parameters were measured after 8th week of planting. Further, success percentage and root length were also recorded. The collected data were analyzed statistically and per cent data were angularly transformed and the critical differences (C.D.) at 0.05 level of probability were worked out for comparing the means.

A perusal of Table 1 indicated that various root and shoot growth characters were significantly influenced by type of cuttings and IBA concentrations. Among different types of cuttings, significantly semi-hardwood cuttings recorded higher number of primary (3.51) and secondary roots (24.28) in comparison to hardwood cuttings. Similarly higher number of shoots per plant (4.20) and success (35.00 %) percentage were observed with semi-hardwood cuttings while hardwood cuttings recorded only 3.18 shoots/plant and 19.50 % success. Similar kind of observations was made by Tripathi *et al.* (2014) at CHES, Chethali. Generally carbohydrates provide energy and carbon skeleton for the synthesis of organic compounds which are used for root formation (Deepika *et al.*, 2015). The increase in number of roots was probably due to accumulation of other internal substances and their downward movement as reported in citrus species (Pandey *et al.*, 2003). These results are also in accordance with Singh *et al.* (2015) who found that various factors influenced rooting in lemon cuttings. Results regarding effect of growth regulators on various characters of karonda cuttings showed that IBA 5000 ppm was found most effective for improving success percentage (49.75 %), number of primary roots (5.00), secondary roots (35.75) and shoots per plant (6.25) over other concentrations of IBA including control. In general, IBA 5000 ppm was found to improve number of roots, shoots and success percentage in both the types of cuttings. Semi-hardwood cutting with IBA 5000 ppm recorded higher success

percentage (61.10 %), number of primary roots (7.75), secondary roots (35.75) and shoots per plant (6.50) over hardwood cuttings which recorded 38.40 % success, 4.25 number of primary roots, 35.00 secondary roots and 6.0 shoots per plant. Application of auxin which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances at the base of cuttings and resulted in accelerated

cell division and cell elongation in suitable environment (Singh *et al.*, 2015). These results were in agreement with those obtained by Dey *et al.* (2017) and Bhavya *et al.* (2018) in cuttings of karonda while Ghosh *et al.* (2011) in karonda air layers. In conclusion, Karonda can be successfully propagated through semi-hardwood cuttings in the month of July by treating them with IBA @ 5000 ppm.

Table 1. Effect of stem cuttings and IBA concentrations on rooting, number of shoot and success percentage in Karonda.

IBA Conc. (ppm)	Av. number of Primary roots			Av. number of Secondary roots			Av. number of shoots/plant			Success (%)		
	HWC	SHWC	Mean	HWC	SHWC	Mean	HWC	SHWC	Mean	HWC	SHWC	Mean
Control	1.8	2.00	1.90	10.25	11.20	10.72	1.10	2.50	1.80	2.30 (8.13)	5.15 (12.92)	3.72 (10.52)
IBA 1000	2.20	2.75	2.47	18.80	18.50	18.65	1.50	2.60	2.05	8.70 (17.60)	18.20 (25.25)	13.45 (21.42)
IBA 2500	2.75	3.10	2.92	22.03	21.10	21.56	2.10	3.90	3.00	15.30 (21.39)	30.00 (33.21)	22.65 (27.30)
IBA 5000	4.25	5.75	5.00	35.00	35.75	35.37	6.00	6.50	6.25	38.40 (38.29)	61.10 (51.41)	49.75 (44.85)
IBA 7500	3.50	4.00	3.75	30.40	31.05	30.72	4.60	5.00	4.80	30.25 (33.52)	50.10 (45.06)	40.17 (39.29)
IBA 10,000	3.00	3.50	3.25	27.01	28.09	27.59	3.80	4.70	4.25	22.06 (28.38)	45.50 (42.42)	33.78 (35.40)
Mean	2.91	3.51		23.92	24.28		3.18	4.20		19.50 (24.55)	35.00 (35.04)	
CD (p=0.05)	T= 0.04 C=0.02 T X C=0.05			T= 0.41 C=0.17 T X C=0.29			T= 0.08 C=0.03 T X C=0.05			T= 0.89 C=0.36 T X C=0.63		

HWC- Hard wood cutting, SHWC-Semi Hard wood cutting

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Emerging issues in pest management for food safety and quality of arid horticultural produce

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(Received : 27.07.2018, Accepted : 20.09.2018)

Pomegranate

Pomegranate high valued fruit crop which was barely few hundred acres in 1960-69 has shot up roughly to 1,93,000 ha with annual production 13.46 lakh ton and productivity of 10.27 ton/ha in 2014-15 in India, which is contributing 70% of the total area from Maharashtra (Anon., 2015). Such important fruit crop is attacked by several insect and non-insect pests as well as diseases. Therefore, it is necessary to adopt integrated pest management in pomegranate. In this context the knowledge of key pest, natural enemies, pollinators, their life cycle and scouting of pest has become important in Integrated pest management.

a. Pests of National Significance:

Insect pests

1. Anar butterfly: *Deudorix Isocrates* Fabricius 2. Stem borer: *Coelosternaspinator* Fabricius 3. Shot hole borer: *Xyleborus perforans* Wollaston 4. Whitefly: *Siphoninus phillyreae* Haliday 5. Thrips: *Scirtothrips dorsalis* Hood 6. Fruit borers: *Conogethes punctiferalis*, 7. Root knot nematode: *M. incognita*

b. Pests of Regional Significance:

1. Pomegranate aphid : *Aphis punicae* Passerini 2. Mealy bugs: *Ferrisia virgata* Cockerell 3. Mites : *Tenuipalpus punicae* 4. Fruit fly : *Batocera* spp. 5. Fruit sucking moth: *Othreis fullonica* *Eudocima* spp. 6. Scale insect : *Parasaissetia nigra* 7. Termites: *Odonotermes* spp. 8. Animal and rodent pests : snails, animals like monkeys, squirrels, Jackals etc

c. Predator, parasite & Parasitoids

(Natural enemies)

1. Coccinellids (LBB,) 2. Crysoperla, 3. Egg parasitoid: *Trichogramma* spp. 4. Nymphal Parasitoid: 1. *Ceranisus menes* 2. *Encarsia inaron* 5. Larval Parasitoids: *Tetrastichus* spp., 2. *Telenomus* spp., 3. *Chelonus blackburni*, 4. *Carcelia* spp., 5. *Campoletis chloridae*, 6. *Bracon* spp., 7. Braconid wasp, 8. Tachinid flies 6. Larval/pupal parasitoids: 1. Parasitic wasp, 2. Predatory mites, 3. Predatory birds

D) Population Dynamics of Key pest

i. Aphids (*Aphis punicae* passerine) More incidence occurs during December and February.
 ii. Thrips: Maximum population build up is found in Mrigbahar and severity in July to August whereas, incidence in Ambiabahar was noticed in Feb to March.
 iii. Whitefly: More incidence of whitefly occurs during Ambiabahar followed by Hasta bahar and Mrigbahar. The whitefly, mealy bugs and scale insect are found abundant during Ambiabahar.
 iv. Shot Hole borer: Maximum pest intensity found in rainy season because of the congenial condition available for the growth of ambrosia fungus (*Monocrosporium ambrosium*) which is food source for the grub of this pest inside tunnels.
 vi. Fruit borer: Maximum build up of this pest has been reported during Mrigbahar (June to October).
 vii. Stem borer: Since there is one generation of pest in a year the maximum damage is found in between June to April
 viii. Fruit sucking moth: The incidence of the FSM is generally maximum August to October and peak period of damage is between 8 to 11 PM in the night. (Figure 1-3)
 ix. Root knot nematode, (*M. incognita*): Maximum activity August to January (and peak activity at 44 MW which was found negatively correlated with maximum and minimum temperature air and soil. (Walunj et al, 2015 and 2017)

Pre management strategies:

- Avoid planting in heavy soil to avoid wilt
- Collection and destruction of infested fruit of previous season.
- To follow recommended plant spacing. Avoid close planting or crowding.
- Avoid Mrigbahar as per availability of irrigation facilities
- Follow the crop rotation & avoid cucurbits cultivation
- Growing/ planting of *Agetus* spp. in between the plants.
- Use of biopesticide, neem based pesticide or 5% Neem seed extract on incidence of pests.
- Follow the resting period of three months.

A. At the time of planting:

Termites & White grub : Apply by dusting over pit & mix the 0.3% Fenvalerate dust. Apply FYM by thorough mixing *Trichoderma* plus @ 20 g/ plant

Aphids/whitefly & Mites: Spray the *B. bassiana*, *Metarhiziumanisopola* @ 5g/lit or neem base Dimethoate @ 1.5 ml/lit water

B. Before bahar initiation: At the resting period

Resting of orchard for 60-70 days after harvest with application of FYM at 25 ton/ha with split application ready mix of { *Trichoderma viridae* and *Pacelomyces lilacinus* } @ 17 g/plant at the time of bahar and 17 g per plant at 90 days after bahar in ring method . Planting of *tagetuss* species between plants.(Anon.,2016)

Cleaning: Collection and burning of dried/ infested fruits to kill overwintering stages of pests. Spraying of Bactinashak @ 250& 500 ppm with captan 50wp @ 2.0 g/lit as preventative measure for Oily spot on pomegranate.

pplication of recommended dose of N.P.K. (650:250:250) & trace element (Ca,Mg,B,Znso4)

aste application to the stem for controlling short hole borer, stem borer and mealy bugs.(Geru 4 kg + 30 ml chloropyrifos + 50 g copper ox chloride /10lit water)

On monitoring the stem borer incidence by excreta through hole, Use iron hole so as to kill the larvae and make it clean and inject 5 ml fenvalerate plus 2 ml dichlorovos 76WSC @ 5 ml in 1 litre of water from stock solution and plug the hole with sticky soap or mud.

C. After bahar initiation: At the vegetative & fruiting

Need base one or two insecticidal application of Imidacloprid 17.8 SL (0.3 ml/lit) Azadiraction 10000 PPM @ 1.5 /lit & cyantrilprole 18.5SC(0.3 ml/lit) upto flowering stage for the control of aphids,thrips, mites and mealy bugs (Walunj *et al.*, 2015)

Need base one or two insecticidal application of spinosad 2.5 EC (1.0 ml/lit followed by neem based (azadirachtin10000 ppm@ 2.0ml/lit), Two sprays Neem oil, plus karanj oil each @3 ml/lit up to 30-90 days at 50 per cent flowering stage for the control of thrips (Anon.,2018b.)

Three spraying of bioagent *Beaveriabassiana*, *verticilliumlecani*, & *Metaryzaanisopolae* during fruit formatting stage for the control of *Deudorixisocrates* @ 5 g/lit of water at an interval week.

Need base application of Emamectin benzoate @ 0.5g/lit, neem seed kernel extract (NSKE) 5% for the control of fruit borer and other pests.

One spraying of *Beaveriabassiana* @ 6 g/lit & *verticilliumlecani* 2 g/lit at an interval of 7 days for the control of mealy bugs/ white files

Use of yellow sticky cards (flyfix) for the control of white files.

Moth catches during night time (8.00 to 11.00 pm) for the control of fruit sucking moth

Use of cover bags (polypropylene cloth) as barriers to fruit.(Walunj, A.R. 2017)

2. Aonla (*Embllica officinalis* Gaertn.):

Among the insect pests, the aonla shoot gall maker, *Betousastylaphora* Swinhoe, leaf folder, *Garcillaria acidula* bark eating caterpillar, *Indarbelatetraonis* Moorethrips, anar fruit borer, *Deudorix Isocrates* Fabricius, Curculio spp. and mealy bug have been reported to be of major importance

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Anagyrusdacylopii and predators like *cryptolaemusmontrouzieri* Muls

- Use of *Lecaniicilliumlecani*@30-60 g/10 lit for spraying. (Ann.,2009)
- Use neem based pesticide or 5% Neem seed extract for spraying.
- Spraying of Buprofenin@ 1.5 ml followed by *B.bassiana*6.0 g followed by Azadirachtin 10,000 ppm 3.0 followed by *V. lecanii* @ 6.0 g showed better control of mealy bug on custard apple. (Anon.,2018 a)

4. FIG

1. Fig stem borer, thrips, Fruitfly and fig mite

Management

- Remove and destruct of affected shoots and fruits
- Spraying of dimehtoate or chlorpyrifos @15 ml/10 lit of water at the time of rainy season @ an interval of 15 days. Or Use neem based pesticide or 5%
- Neem seed extract for spraying. To avoid fruit fly infestation, fruits should be harvested when these are still firm/unripe.
- Fallen infested fruits should be collected and destroyed
- Insert the Iron spike in larval tunnel to kill the caterpillar.
- Application of DDVP or fenvalerate or quinalphos or Kerosene or petrol @ 5 ml in each larval tunnel through syringe or wash bottle or cotton wool and sealing the holes with mud.
- Thrips can be controlled by spraying with cypermethrin 10 EC @ 1.0 ml/lit
- Use of fruit fly : methyl eugenol traps for monitoring and trapping of fruit flies.
- Two Sprays of thiodicarb 75 WP @1.5g/lit water is recommended fortnightly interval on onset of monsoon for the control of stem borer (Ann.,2012)

5. BER

A. Major Pests of National Significance

1. Fruit fly: *Carpomyiavesuviana*Costa 2. Fruit borer: *Meridarchisscyroides* Meyr. 3. Stone Weevil: *Aubeushimalayanus*Voss

B. Pest of Regional Significance

1. Insect pests

1.Bark eating caterpillar: *Indarbelaquadrinotata*walker 2. Mite, *Eriophyescernus*Mssee3. Leaf eating caterpillar: *Euproctisspp*4. Grey hairy caterpillar: *Thiacidaspostica*Walker

Pest management

- ? Wild varieties should not be allowed to grow near about the ber orchard.
- ? Deep raking of soil underneath trees during summer will help in pupal mortality
- ? Resistant varieties viz. Tidaki and Illaichi as moderately resistant to this pest.(Shewale, B.S.,2002) However, the chandegaon sel-1, Mehurun and chalisgaon were found less susceptible to borer(Papade.,R.E., 2016).

- Collection and destruction of infested fruits should be a regular feature. Similarly, the shed fruits after the harvest should be destroyed.
- Off-season fruits of the various species of ber proved to be an important link in carrying over its population to the main crop-season and hence off-season fruits should not be allowed in or near the ber orchard.
- Deep raking of soil underneath trees during summer.
- Collection and destruction of infested/shed fruits from time to time.
- Monitoring the pest population through different types of traps light or with methyl eugenol (2 ml)+ malathion or DDVP 2 ml + water 1 lit by keeping in jar or (locally made plastic bottle with circular hole) to facilitate the entry of fruit fly.
- Spraying (rotationally) with fenvalerate 0.01%,Deltamethrin0.002%,Quinalphos 0.05 % and Carbaryl 50 WDP at 0.2 % after fruit set at an interval of 30 days(Shevale and Padule, 1992;).
- First sprays of spinosad 2.5 Sc followed by indoxacarb @ 1.0 ml/lit should be given at 50% flowering and 50% fruit setting for the control of fruit borer and stone weevil. (Ann., 2014)

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Standardization of propagation through patch budding in lasoda (*Cordia myxa* L.) under semi arid conditions of Rajasthan

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(Received: 25.07.2018; Accepted: 19.09.2018)

Lasoda or lehsua (*Cordia myxa* L.) belongs to family Boraginaceae, found growing all over the country especially in arid and semi arid situations so far. Lasoda is not explored to full potential economically and hence immediate attention to explore the potential of its cultivation. It is a medium sized broad leaved deciduous tree. It has great capacity to tolerate drought and hence quite widespread in arid and semi arid regions of North India. Being a multipurpose tree species, it has long been associated with health, nutrition and other diversified uses. The Immature fruits are used as vegetable, pickled with raw mango and can be dehydrated for use in off season. The fruits and other plant parts are used in curing various ailments viz. skin diseases, dropsy, dysentery, cholera, headache etc. The fruits are astringent, diuretic, demulcent and expectorant. The fruit contains about 80% pulp, 8.32 g crude protein, 25.7 g crude fibre and 57.08 g of carbohydrates (Aberoumand, 2011). Pareek and Sharma (1993) also reported lasoda fruits are rich source of carbohydrates, phosphorus and ascorbic acid (40 mg/100 g). The nutritive value of forage per 100 g dry matter: crude protein 15 g, crude fibre 20 g, ash 14 g, crude fat 6 g, N free extract 47 g, Calcium 2.5 g, Phosphorus 0.3 g (Oudhia, 2007).

The fruits are also rich source of phenolic compounds which have antioxidant properties. Aberoumand (2011) also reported ample amount of total phenolics (402 mg/100g) in the fruits of lasoda

Lasoda is commercially propagated by budding. However, several factors have restricted the expansion of area and production of Lasoda. Among these limiting factors, low quantity and non availability of quality planting material are some of the negative factors that hinder the increase of area and production of Lasoda. The percentage of successful budding in Lasoda is highly variable and often is low, probably due to failure of scion bud to sprout and budding at inappropriate physiological stage. Hence, the present investigation was carried out to explore the better success and suitable time of budding in Lasoda particularly under arid and semi arid conditions.

This study was carried out in the instructional Nursery, Department of Horticulture, SKN College of Agriculture, Jobner during the year 2013, 2014 and 2015. For raising root stocks, ripe fruits of lasoda were collected and the

sowing of seeds was completed in 2nd week of June, 2012 in plastic bags filled with a mixture of soil, FYM and sand (1:1:1) and 200 g of single super phosphate per cubic meter of potting mixture. One year old generative root stocks of Lasoda were used for budding. Consisting six treatments, 20 plants per treatment and four replications, thus having 480 plants as experimental material were taken for the study. Seedlings were maintained in sand conditions by providing ample quantity of fertilizers, water and other requirements when required. There were six treatments of budding dates comprising budding on 30th June, 15th July, 30th July, 16th August, 31st August and 15th September. Defoliation (removal of leaf blades with petioles intact on the shoot) was performed 2-3 days before the scion bud collected. Scion bud excised from twigs and defoliated just prior to budding. Budding was carried out as per the treatments during experimentation.

The data pertaining to patch budding performance of scion and stock were recorded. The bud take percentage was calculated by counting number of sprouted scions in every treatment. Budding success (%) was counted on the basis of continued survival of sprouted scion after four months of budding. Days required for first sprouting were recorded by watching the scion regularly in the nursery. Scion buds used were taken from vigorous flushes of terminal shoots with prominent auxiliary buds. A patch of 1.5 -2.0 cm long and 5-10 mm in width with one slightly swollen bud was selected.

The union point was wrapped with a plastic strip. The budded plants were maintained under natural shade net house conditions. Observations were recorded for days taken to bud sprout and sprout percentage of Lasoda buds. However, success per cent of Lasoda budding was recorded four month after budding. The experiment was setup under randomized block design with four replications which had 120 budding each. The different parameters under study were statistically analyzed for analysis of variance. Means were separated using Fisher's least significant difference at 5 per cent level of significance.

Days taken to bud sprout

The data mentioned in Table 1 indicated that budding done on different dates during the experimentation period had significant influence on days taken to bud sprout in Lasoda. The minimum number of days (11.44 and 11.98) required for bud

sprout recorded when budding was performed on 30th June during 2013 and 2015 respectively. This treatment was found significantly superior over rest of the treatments except when budding performed on 15th July which remained at par to it. However, budding performed on 15th July during 2014 took minimum of 12 10 days to bud sprout which was significantly better than other dates of budding but this treatment was found statistically at par with treatment of 30th June.

Further, the analysis of pooled data in same table clearly indicated that minimum days of 12.13 were taken when budding was done on 30th June which was found significantly superior over all the treatments except budding done on 15th July which was at par to it. This might be due to congenial atmospheric conditions as well as the physiological activities of rootstock and scion for better union and sprouting of scion buds during last week of June to first fortnight of July during experimentation. Similar results were also reported by Ganpathy *et al.*, 1985 in Coorg Mandarin.

Sprout percentage of bud

Data presented in Table 2 indicated that budding performed on 30th June recorded maximum sprout percentage (95.0 %) during 2013 and 94.46 per cent in 2015. However, in the year 2014, maximum sprout percentage (95.5 %) was recorded when budding was performed on 15th July which was noted at par

with budding performed on 30th July during 2014 and budding performed on 30th June during 2013 and 2015. Further, the pooled data in the same table clearly indicated that maximum sprout percentage of 93.33 was observed when budding was performed on 15th July. This treatment was found significantly better than other treatments except budding performed on 30th June and 30th July which were remained at par to it.

Success per cent of Lasoda bud

The examination of data mentioned in Table 2 further revealed that budding performed on 30th June gave maximum success per cent followed by budding performed on 15th July and 30th July in the year 2013 and 2015. However, maximum success per cent of 92.50 % was recorded when budding was performed on 15th July (92.50%) followed by 30th July (91.50%) during 2014. Further, in pooled analysis of three years data (Table 2) clearly indicated that significantly maximum success percentage of lasoda buds were observed when budding was performed on 15th July among all the treatments except budding performed on 30th June and 30th July which were statistically at par to each other. It may be accounted to rapid complete union of xylem and cambium tissue and congenial physical state (Hartmann *et al.*, 1997) of the scion and root stock favouring survival of the sprouts.

Table1. Effect of different budding dates on days taken to bud sprout in lasoda.

Treatments	Days taken to bud sprout			
	2013	2014	2015	Pooled
30 th June	11.44	12.97	11.98	12.13
15 th July	12.32	12.10	12.75	12.39
30 th July	20.05	16.75	20.59	19.13
16 th August	19.13	18.65	19.83	19.20
31 st August	16.13	19.58	17.00	17.57
15 th September	23.25	22.90	23.75	23.30
SEm±	1.12	0.72	0.32	0.75
CD at 5%	3.33	2.12	0.94	2.26

Table 2. Effect of different budding dates on sprouting and success per cent of lasoda bud.

Treatments	Sprout percentage of bud				Success per cent of bud			
	2013	2014	2015	Pooled	2013	2014	2015	Pooled
30 th June	95.00	84.00	94.46	91.15	92.50	81.50	92.40	88.80
15 th July	92.50	95.50	92.00	93.33	91.25	92.50	91.36	91.70
30 th July	91.25	94.00	90.48	91.91	88.75	91.50	89.20	89.82
16 th August	66.25	86.50	65.33	72.69	62.50	82.50	64.13	69.71
31 st August	55.00	77.00	53.93	61.98	47.50	72.00	57.46	58.99
15 th September	23.75	54.50	24.76	34.35	17.50	49.00	34.73	33.74
SEm ±	3.07	1.55	0.37	2.18	2.60	1.33	2.06	1.67
CD at 5%	9.13	4.60	1.11	2.57	7.73	1.96	6.12	5.04

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Correlation studies in watermelon [*Citrullus lanatus* (Thumb.) Mansf.]

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(Received: 15.12.2017; Accepted: 16.04.2018)

Watermelon [*Citrullus lanatus* (Thumb.) Mansf.] is one of the most important cucurbitaceous fruit crop grown in different parts of Rajasthan as well as in India. It is consumed as dessert fruit and very often known as thirst quencher. It is extensively cultivated both under irrigated and riverbeds. Watermelon is very low in cholesterol and sodium. It is rich source of lycopene, a powerful antioxidant. Its 100g edible portion contains 95.8g moisture, 0.2g protein, 0.2g fat, 0.2g fibre, 3.3g carbohydrate, 16 K cal energy, 11mg calcium, 12mg phosphorus, 7.9mg iron, 13mg magnesium, 0.02mg thiamine, 0.04mg riboflavin, 0.1mg niacin and 1mg vitamin C (Gopalan *et al.*, 1999). Correlation is the important selection parameters in plant breeding. Correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. It has been widely used to identify traits that have significant effect on yield for potential use in selection. The present investigation was undertaken to explore the possibility of developing hybrids possessing resistance/ tolerance to prevailing abiotic stress with higher yield, better shelf-life, high lycopene, high carotenoids content and better fruit quality. In view of its wide variability and economic importance, the present investigation has been undertaken with the aim to estimate correlation analysis among different horticultural traits including yield and quality characters in watermelon.

The present field experiment was undertaken during the *kharif* 2012 and *zaid* 2013 at NICHE Area of Excellence, S.K. Rajasthan Agricultural University, Bikaner which is situated at 28°01'N and 73°22' E at an altitude of 234.70 meters above MSL. The experimental material comprised of eight genotypes of watermelon viz., Sugar Baby, Thar Manak, Asahi Yamato, RW-187-2 (Durgapura Kesar), AHW-19, Durgapura Lal (RW-177-3), IC-582909 and Arka Manik which were crossed in all possible combinations (excluding reciprocals) during *zaid* 2012. The resultant 28 F₁'s along with parents were evaluated during *kharif* 2012 and *zaid* 2013 in Randomized Block Design (RBD) replicated thrice. All the recommended

package of practices was followed for raising the crop. The observations on 18 attributes including growth, yield attributes and quality parameters were recorded on five randomly selected plants from each replication during both the years. The collected data were averaged and correlation (phenotypic and genotypic) was computed as described by Singh and Choudhary (1977) and as per formula (Johnson *et al.* 1955).

All possible phenotypic (above diagonal) and genotypic (lower diagonal) correlation coefficients between fruit yield and its components were worked out and presented in Table 1. The perusal of data indicated that the magnitude of genotypic correlation coefficients for most of the characters were higher than their respective value of the phenotypic correlation coefficients.

Highest positive and significant correlation at phenotypic level was exhibited by number of marketable fruits per plant (0.718) with marketable fruit yield per plant followed by fruit weight (0.557), number of primary branches per vine (0.392), fruit diameter (0.391), main vine length at harvest (0.356), TSS content in fruits (0.352), carotenoids content (0.315), lycopene content (0.271), fruit length (0.237) and flesh firmness (0.186). On the other hand marketable fruit yield per plant was significantly and negatively correlated with 100-seed weight (-0.377) followed by number of seeds per fruit (-0.289), days to opening of first female flower (-0.232), days to first fruit harvest (-0.156), internodal length (-0.145) and number of node at which first female flower appeared (-0.137).

The existence of association between different characters is usefully determined by studying correlation existing between these. For this purpose, it is important to know that genetic correlation among different characters, which may provide information regarding the correlated response to selection. In the present study, generally, the genotypic correlation coefficients were higher than the corresponding phenotypic ones indicating the inherent association among the various traits (Table 1), which may be ascribed to the low effect of environment on the character

expression. The association of characters such as marketable fruit yield, fruit weight and various quality parameters is very important, before sets out to develop hybrids or parental lines. The knowledge of correlation between these characters is also helpful in the choice of parents for developing better F_1 hybrids. Interestingly in the present study, marketable fruit yield per plant was found to be significantly and positively correlated with number of marketable fruits per plant, fruit weight, number of primary branches per vine, fruit diameter, main vine length at harvest, TSS content in fruits, carotenoids content, lycopene content, fruit length and flesh firmness in pooled analysis at phenotypic level, thus it would be easier to develop variety having all these characters. Marketable fruit yield per plant exhibited significant negative correlation with

100-seed weight, number of seeds per fruit, days to opening of first female flower, days to first fruit harvest, internodal length and number of node at which first female flower appeared. Similar results were earlier obtained for significant positive correlation of fruit yield with number of fruits per vine and TSS (Singh and Singh, 1988); with vine length, number of fruits per vine, fruit weight and fruit diameter (Sundaram *et al.*, 2011); with number of primary branches per plant, fruit weight, and number of fruits per plant (Choudhary *et al.*, 2012); with fruit weight and number of fruits per plant (Yadav *et al.*, 2013) in bitter melon and with fruit weight, number of fruits per cluster and fruit length (Choudhary *et al.*, 2014) in ridge gourd.

Table 1. Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among different characters in watermelon in pooled data

Characters	MVL (m)	PBs	INL (cm)	DOFFF	NFFFA	NMF/P	DFFH	FD (cm)	FL (cm)	FW (kg)
MVL (m)	1.000	0.247**	0.077	-0.151*	0.166*	0.095	0.181**	0.331**	0.207**	0.388**
PBs	0.246	1.000	-0.149*	-0.137*	-0.153*	0.303**	-0.194**	0.264**	0.186**	0.195**
INL (cm)	0.510	-0.012	1.000	0.076	0.307**	-0.321**	0.269**	0.186**	0.137*	0.200**
DOFFF	0.079	-0.509	0.662	1.000	0.407**	-0.270**	0.399**	-0.067	-0.054	-0.015
NFFFA	0.707	-0.193	0.769	0.758	1.000	-0.357**	0.600	0.073	0.162	0.224**
NMF/P	-0.206	0.625	-0.726	-0.728	-0.566	1.000	-0.352**	0.038	-0.076	-0.169*
DFFH	0.689	-0.335	0.607	0.740	0.977	-0.435	1.000	0.048	0.084	0.194**
FD (cm)	0.941	0.419	0.590	0.572	0.634	-0.275	0.563	1.000	0.502**	0.522**
FL (cm)	0.965	0.482	0.709	0.711	0.739	-0.588	0.488	0.983	1.000	0.435**
FW (kg)	0.986	0.303	0.654	0.339	0.781	-0.512	0.691	0.991	0.989	1.000
RT (cm)	0.973	0.335	0.333	0.068	0.718	-0.243	0.594	0.737	0.920	0.860
100 SW (g)	0.426	-0.175	0.351	0.208	0.430	-0.672	0.460	0.147	0.437	0.479
TSS (%)	0.343	0.627	-0.511	-0.009	0.044	0.169	-0.207	0.531	0.327	0.458
FF (g/cm ²)	0.216	0.207	0.078	-0.281	0.013	0.357	-0.147	0.148	0.280	0.067
LC (mg/100 g)	-0.567	-0.397	-0.540	-0.227	-0.343	0.541	-0.145	-0.881	-0.949	-0.867
CC (mg/100 g)	-0.460	0.115	-0.525	-0.299	-0.430	0.590	-0.379	-0.642	-0.738	-0.621
NS/F	0.280	0.249	0.435	0.407	0.512	-0.422	0.390	0.231	0.775	0.411
MFY/P (kg)	0.683	0.940	-0.245	-0.493	0.028	0.671	0.115	0.604	0.333	0.291

* Significant at $p=0.05$ and ** significant at $p=0.01$

Table 1 contd..

Characters	RT (cm)	100 SW (g)	TSS (%)	FF (g/cm ²)	LC (mg/100g)	CC (mg/100g)	NS/F	MFY/P (kg)
MVL (m)	0.194**	0.020	0.255**	0.242**	-0.075	-0.036	0.031	0.356**
PBs	0.079	-0.255**	0.145*	0.164*	0.054	0.273**	-0.171*	0.392**
INL (cm)	0.137*	0.264**	-0.001	-0.035	-0.301**	-0.271**	0.331**	-0.145*
DOFFF	-0.088	0.136*	-0.263**	-0.153*	-0.206**	-0.141*	0.199*	-0.232**
NFFFA	0.146*	0.332**	-0.246**	-0.061	-0.239**	-0.242**	0.295**	-0.137*
NMF/P	-0.203**	-0.544**	0.238**	0.134*	0.441**	0.436**	-0.370**	0.718**
DFFH	0.107	0.285**	-0.121	-0.084	-0.200**	-0.236**	0.285**	-0.156*
FD (cm)	0.259**	-0.099	0.246**	0.156*	-0.039	0.025	-0.100	0.391**
FL (cm)	0.297**	0.041	0.136*	0.155*	-0.119	-0.088	0.044	0.237**
FW (kg)	0.395**	0.109	0.227**	0.112	-0.172*	-0.087	0.030	0.557**
RT (cm)	1.000	0.253**	0.182**	0.084	-0.181**	-0.293**	0.072	0.107
100 SW (g)	0.621	1.000	-0.181**	-0.264**	-0.414**	-0.370**	0.605**	-0.377**
TSS (%)	0.352	-0.271	1.000	0.223**	0.007	0.107	-0.140*	0.352**
FF (g/cm ²)	0.063	-0.665	0.748	1.000	0.145*	0.141*	-0.150*	0.186**
LC (mg/100g)	-0.537	-0.384	-0.534	0.171	1.000	0.665**	-0.427**	0.271**
CC (mg/100g)	-0.319	-0.381	0.022	0.127	0.515	1.000	-0.305**	0.315**
NS/F	0.432	0.633	-0.208	-0.259	-0.411	-0.398	1.000	-0.289**
MFY/P (kg)	0.448	-0.331	0.609	0.440	-0.131	0.111	-0.126	1.000

* Significant at $p=0.05$ and ** significant at $p=0.01$

MVL= main vine length at harvest (m), **PBs**= number of primary branches per vine, **INL**= internodal length (cm), **DOFFF**= days to opening of first female flower, **NFFFA**= number of node at which first female flower appeared, **NMF/P**= number of marketable fruits per plant, **DFFH**= days to first fruit harvest, **FD**= fruit diameter at harvest (cm), **FL**= fruit length at harvest (cm), **FW**= fruit weight at harvest (kg), **RT**= rind thickness at harvest (cm), **100 SW**= 100-seed weight (g), **TSS**= TSS content in fruits at harvest (%), **FF**= flesh firmness (g/cm²), **LC**= lycopene content (mg/100g), **CC**= carotene content (mg/100g), **NS/F**= number of seeds per fruit, **MFY/P**= total marketable fruit yield per plant (kg)

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