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

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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 mm y^{-1}) rainfall, high evapotranspiration (1600-2000 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 aeritinum, 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; Channabasarana *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 Sriguppa, Karnataka showed that IFS (rice-rice, maize sunflower, vegetable, fodder crop, goat, fish and poultry) had 26% higher yields than conventional rice-rice cropping (Channabasarana *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 converts 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 indiated 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 + piggery 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 (Setboosarng, 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 P_2O_5 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 CO_2, 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-boidiversity 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 CO_2 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 polices. Adequate coordination among different agricultural programme, polices, institutes and agencies for agricultural and rural development is must for quick and wider implementation of IFS.

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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 kahrif/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, Jhunhjunu, 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 annun^{-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 -4^0 C and very hot summer during May-June with temperature as high as 48-50 ^{0}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 ccucurbitaceous 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- *Cucum*is, 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 Rajastha 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 kahrif/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 ha rvesting 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

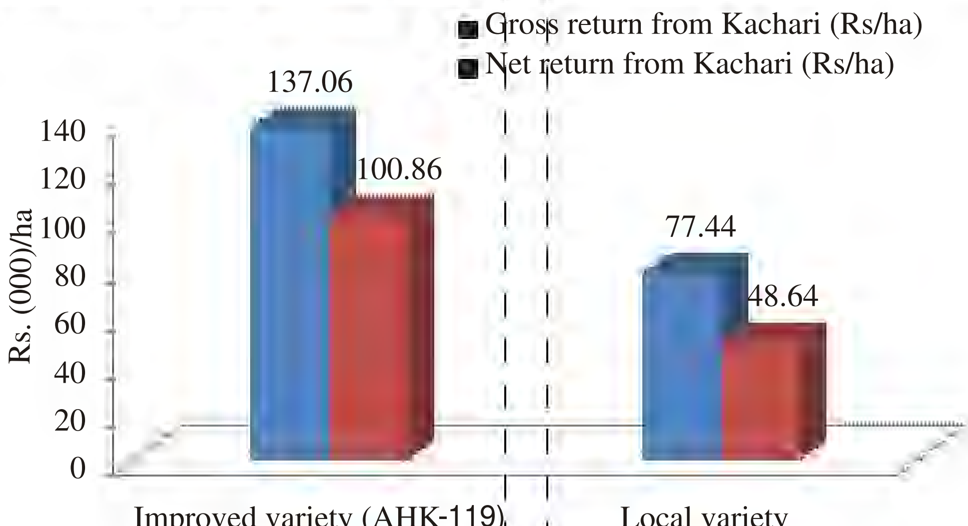

Fig 1: Difference in gross and net returns ('000'Rs./ha) from production of improved variety (AHK-119) and local variety of kachri.

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 Jhununjhunu. 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 verities 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 legging 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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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 m^3) 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 ^{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 trifoliate* [L.] Raf.) and Cleopatra mandarin (*Citrus reshni* 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 (m^3) 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 m^3) 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 m^3) 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 m^3) 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 ^{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 ^{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 (^{0}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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Value addition of tamarind: An option for livelihood of tribal people of Panchmahal

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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 Leguminoceae, 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. Famers 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 juggery and mix stir and cook the pulp till the juggery melt

↓

Add the Salt, Black Salt, Cumin Powder red chilly resins and cardmum 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 diffe rent 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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Short Communication

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

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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 (Tiwari *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 P_2O_5/ha) and potash (200 kg K_2O/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. Re commended dose of 40, 60 and 40 kg N, P_2O_5 and K_2O 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 use 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 ECiw levels. Results showed that drip method of irrigation was superior to flood method at all the levels of ECiw 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 ECiw 3.0 dS m^{-1} (BAW) over rest of the treatments and a significant decrease yield was observed with water having ECiw 6.0 dS m^{-1} on pooled basis. Increase in the levels of ECiw to 3.0 dSm^{-1} brought about significant improvement in fruit weight per plant under drip irrigation, but further increment ECiw i.e. 6.0 dS m^{-1} caused significant reduction in fruit weight per plant and resultantly the marketable yield. Maximum number of fruits per plant (7.7) and highest fruit weight (59.5 g) were recorded in treatment ECiw 3.0 dS m^{-1} under drip system (Table 1). Increasing levels of ECiw 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 ECiw 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 ECiw dS/m	56.7	56.4	56.5	6.9	7.4	7.2	187.8	215.3	201.5
3.0 ECiw dS/m	49.3	69.8	59.5	5.6	9.8	7.7	183.9	235.6	209.7
6.0 ECiw dS/m	33.2	48.1	40.6	4.2	5.3	4.8	154.7	186.2	170.3
Flood									
0.25 ECiw dS/m	41.4	49.6	45.5	6.1	6.8	6.5	170.5	193.5	182.0
3.0ECiw dS/m	39.6	44.9	42.1	4.8	5.1	5.0	141.0	156.8	148.9
6.0ECiw 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 ECiw dS/m	688	710	699	273	303	288
3.0 ECiw dS/m	688	710	699	267	332	300
6.0 ECiw dS/m	688	710	699	225	262	244
Flood						
0.25 ECiw dS/m	1013	1036	1025	168	187	178
3.0ECiw dS/m	1013	1036	1025	139	151	145
6.0ECiw 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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Short Communication

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

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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) there by increases C:N ratio of cell which broke dormancy. Application ofethephon 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 ethrel recorded maximum number of flowers per shoot. Treatment T.U. 10g + ethephon 4ml + DAP 10 g ltr^{-1} recorded maximum leaf area (72 cm^2) followed by T.U. 7.5g + ethephon 3ml + DAP 7.5 g ltr^{-1} (67.67 cm^2) which were on par with each other. Minimum leaf area 20 cm^2 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 + DAP105g 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 ethrel.

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$\pm$	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$\pm$	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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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 (Cochron 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 Second ary 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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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* Fabricus 2. Stem borer :*Coelosternaspinator*Febricius 3. Shot hole borer: *Xyleborusperforans* Wollastan 4. Whitefly:*Siphorinusphillyreae*Haliday5. Thrips: *Scirtothripsdorsalis*Hood 6. Fruit borers: *Conogethespunctiferalis,* 7. Root knot nematode: *M. incognita*

b. Pests of Regional Significance:

1. Pomegranate aphid : *Aphis punicae*Passerini2. Mealy bugs: *Ferrisiavirgata*Cockerell 3. Mites :*Tenuipaluspunicae* 4. Fruit fly :*Batocera*spp5. Fruit sucking moth: *OtherisfullonicaEudocima*spp6. Scale insect :*Parasaissetianigra*

7. Termites :*Odonotermes* spp.

8. Animal and rodent pests : snails, animals like monkeys, squirrels, Jackals etc

c. Predator, parasite & Parasitoids
(Natural enemies)

1. Coccinelids (LBB,)

2.Crysoperla,

3. Egg parasitoid :*Trichogramma*spp.

4.NymphalParasitoid: 1.*Ceranisusmenes* 2. *Encarsiainaron*

5.Larval Parasitoids: *Tetrastichus* spp., 2.*Telenomus* spp., 3.*Chelonusblackburni,* 4.*Carcelia* spp., 5.*Campoletis chlorideae,* 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 (*Aphispunicae* passerine) More incidence occurs during December and February.

ii. Thrips: Maximum population build up is found in mrigbaharand 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 baharandmrigbahar. 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(*Monocrosporusambrosium*) which is food source for the grub of this pest inside tunnels.

vi. Fruit borer: Maximum bulid up of this pest has been reported duringMrigbahar(June October).

vii. Stem borer: Since there is one generation of pest in a yearthe 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 a*l, 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 through mixing *Trichoderma* plus @ 20 g / plant

Aphids/whitefly & Mites: Spray the *B. bassiana, Metaryziumanisopolae*@ 5g/lit or need 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 {*Trichodermaviridae* and *Pacelimyceuslilacinus*} @ 17 g/plant at the time of bahar and 17 g per plant at 90 days after bahar in ring method . Planting of *tagetus* 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 & cyantrinilprole 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.,2018 b.)

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 (*Emblicaofficinalis* Gaertn.):

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

[illegible]

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 Buprofexin@ 1.5 ml followed by B.*bassiana6.0 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: *Meridarchisscyrodes* 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: *Euproctis*spp4. Grey hairy caterpillar: *Thiacidasposticа*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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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 explor 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 buding 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
30th June	11.44	12.97	11.98	12.13
15th July	12.32	12.10	12.75	12.39
30th July	20.05	16.75	20.59	19.13
16th August	19.13	18.65	19.83	19.20
31st August	16.13	19.58	17.00	17.57
15th 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
30th June	95.00	84.00	94.46	91.15	92.50	81.50	92.40	88.80
15th July	92.50	95.50	92.00	93.33	91.25	92.50	91.36	91.70
30th July	91.25	94.00	90.48	91.91	88.75	91.50	89.20	89.82
16th August	66.25	86.50	65.33	72.69	62.50	82.50	64.13	69.71
31st August	55.00	77.00	53.93	61.98	47.50	72.00	57.46	58.99
15th 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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Watermelon [*Citrullus lanatus* (Thunb.) 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 $28^0$01' N and $73^0$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 F_1'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 gourd 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/cm^2), 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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