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Dragon Fruit Cultivation in India: Scope, Constraints & Policy Issues

ICAR-National Institute of Abiotic Stress Management
Baramati, Pune, Maharashtra, India

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Dragon Fruit Cultivation in India: Scope, Constraints and Policy Issues

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Foreword

Climate change induced abiotic stresses are becoming major challenges for ensuring food and nutrition security to India's burgeoning population. There is a pressing need for reducing the adverse impacts of these environmental stresses on agriculture. As there scope for expanding the agricultural land in the country is limited, our focus should be on intensification of sustainable agriculture in about 120 million hectare degraded land of the country with abiotic stress adaptation and mitigation strategies, which should include the diversification to more stress-tolerant crops.

Dragon fruit (Kamalam) is a unique nutraceutical fruit crop that can be grown even with the poor resources of the degraded lands in the rainfed regions. However, for promoting dragon fruit as a promising crop in the stressed environments, information related to its adaptability, consumer acceptability and marketability should be studied and documented in details. The present bulletin on dragon fruit cultivation provides the desired information on the scope, potential areas of cultivation as well as production and trade at national and global levels. The bulletin outlines the cultural and post–harvest management practices, farmers' constraints, as well as major researchable and policy issues with detailed SWOT analysis for cultivating the crop in India. The bulletin will help in guiding the state agricultural departments, Krishi Vigyan Kendras, State Agricultural Universities, policy makers and private entrepreneurs to promote the crop for enhancing farmers' income in the abiotic stressed environments.

I sincerely acknowledge the valuable contributions made by the scientists of ICAR-National Institute of Abiotic Stress Management (NIASM), Baramati, Maharashtra in developing the technologies for cultivation of dragon fruit and preparing this useful publication.

I wish that the farmers, researchers, entrepreneurs, consultants, growers and students working on dragon fruit will make the best use of the information presented in this bulletin.

Trilochan Mohapatra

Secretary, DARE & DG, ICAR

Govt. of India

Krishi Bhawan, New Delhi

Preface

Food security of substantial population across the world depends on agro–ecologies constrained by abiotic stresses. The adverse effect of these stresses can be further exacerbated by the climate change, which can potentially reduce agricultural productivity. This can affect livelihood, income and socio economic status of poor and marginal farmers who are not equipped for adaptation to predicted climate change scenario. Hence, climate resilent technologies including crop diversification and intensification are highly essential particularly for vulnerable areas that include underutilised barren lands which constitutes about 36% of geographical area in India. ICAR–National Institute of Abiotic Stress Management has taken lead to carry out research for delivering stress mitigation and adaptation strategies for the benefits of farming community of barren, flood and drought prone regions through basic and strategic approches that includes diverisfication options involving underutilised, non conventional and exotic crops.

Dragon fruit is emerging as a super crop, even for degraded land owing to its ease of cultivation and several health and medicinal benefits. It has got potential to grow in diversified agro–climatic conditions and hence it is also gaining popularity in India. But the major challenge is to standardize region specific protocols of cultivation, harvesting and post–harvest management practices for enhancing yield and quality. For making dragon fruit cultivation profitable, particularly in degraded and barren regions of India, proper understanding of global and national scenario of production, marketing and consumption pattern in addition to production technology is highly essential. Thus main aim of this bulletin is to present an overview of global and national status, to identify farmer's constraints and to shortlist researchable and policy issues for popularization of dragon fruit in India.

We sincerely acknowledge the valuable guidance and contributions of Dr. P.S. Minhas and Dr. N.P. Singh, former Directors, ICAR-NIASM for initiating and facilitating experiments on dragon fruit. We also thank the DDG (NRM) and ADGs in the NRM Division of ICAR, the scientists, consultants, entrepreneurs and progressive farmers for their guidance, support and providing valuable information on dragon fruit. We sincerely thank devoted technical staff and administration who extended their support in establishing experimental dragon fruit orchard at ICAR–NIASM, Baramati.

We hope that the bulletin will serve as a ready–reckoner for the farmers, extension functionaries, researchers, policy makers, entrepreneurs, consultants, and students engaged in research, cultivation and marketing aspects of dragon fruit.

Authors

1. Introduction

Dragon fruit, pitaya or strawberry pear (*Hylocereus spp. and Selenicereus spp.*) or Kamalam is emerging as a super crop worldwide, even in the marginal lands, owing to its health and medicinal benefits. It is basically a climbing cactus vine, originated from Central and South America, tolerant to the abiotic stresses and resistant to pests and diseases. It has many advantages including low water and nutrient requirements, relatively less requirement of resources for establishing the orchard and maintenance; multiple harvest of fruit in a year; potential to sustain high yield up to 20 years; high benefit to cost ratio; and high nutraceuticals and functional properties (e.g. rich in antioxidants and fibres). All these qualities are attracting the growers worldwide to establish and expand dragon fruit farming, provide opportunity for global export and encourage for high quality produce to meet the market demand. Being a crassulacean acid metabolism (CAM) plant with xerophytes' characters, it has got ability to grow in a wide range of agro–climates including areas of high temperature and water scarcity regions. The dragon fruit can be cultivated commercially up to altitude of 1700 m with rainfall ranging from 500–1500 mm. With shallow roots (<40 cm), it is not much choosy in requirement of soils and can be cultivated in wide range of soils but without excess moisture. However, the slightly acidic (pH 5.5–6.0) loamy soil, rich in organic matter and atmospheric temperature ranging from 20–30°C are preferred as ideal conditions for commercial cultivation of dragon fruit orchards. Therefore in recent two decades, dragon fruit has gained wide popularity in tropical Asian countries, which initiated its commercial cultivation around the world (Sanoamuang, 2019).

In India, climate change induced abiotic and biotic stresses *viz.*, episodic and frequents droughts, floods, widespread land degradation, salinity/alkalinity, extreme temperatures, pest and diseases represents significant challenges for agriculture particularly in less fertile, barren land and semi–arid drought prone regions. In comparison to fertile areas, agriculture sector in these resource poor regions are severely affected by abiotic stresses and lag far behind in crop production, diversification and yield as well as agricultural market economization. Focusing on crop and fruit diversification, intensified farming system could cope with problems of water shortages/floods, low fertility and poor soil for sustainable development of these regions. Hence, there is an urgent need of identifying diverse native and exotic crops/fruits, species and genotypes that can be grow in a harsh ecosystem as an alternative and remunerative crop. However, for selecting such crop and fruits for introduction, facts related to its adaptation, shelf–life, consumer acceptability and market opportunity must be critically assessed for socio–economic development of debt ridden farming community of barren, flood and drought prone regions. Dragon fruit is one such potential crops that can be easily cultivated in large parts of degraded land and drought prone areas of the country. It has received worldwide recognition, first as an ornamental plant and then as a fruit crop, and has become a choicest fruit for salads owing to its colourful bracts, dark red flesh and edible tiny black seeds embedded in white flesh. Value added products like juice, jam, jelly, candy, syrup, and wine can be prepared from dragon fruit pulp. It is one of the fastest returning perennial fruit crops having potential to quick returns from investments with production in

second year and full production in five year of plantation. With all these qualities, this fruit is gaining popularity among the Indian farmers, entrepreneurs and consumers of both rural and urban areas. In the last 3–5 years, some of Indian growers have put forward steps to adopt cultivation technologies of dragon fruit for its commercial production. Since the crop is comparatively new for diverse agro-climatic conditions of India, the major challenge is to optimise region-specific protocols of cultivation, harvesting and post–harvest management practices for maximum yield and quality performance. Further, to ensure success in production of dragon fruit particularly in drought affected degraded and barren land areas of India, proper understanding of global and national scenarios of cultivation as well as marketing and consumption pattern is highly essential. The objectives of the present publication are to (i) know the present global and national cultivation status of dragon fruit; (ii) identify farmer's constraints and their views on dragon fruit cultivation and (iii) suggest researchable and policy issues for enhancing adoption and farmers profit in India.

2. Global Status

2.1. World dragon fruit production

Being a native of Southern Mexico, Guatemala and Costa Rica, dragon fruit was introduced during 1990 for its commercial cultivation in south Asian tropical countries. At present, significant production and expansion of fruit is occurring in many countries *viz.*, Vietnam, China, Mexico, Colombia, Nicaragua, Ecuador, Thailand, Malaysia, Indonesia, Australia and United States. However, its production and marketing data is rarely available apart from its spontaneous expansion around world. Dragon fruit is classified as group of minor tropical fruit depending on market availability, production, planted areas and economics consideration (FAO, 2012; Liaotrakoon, 2013). Further, it is believed to be listed in FAO database under item name *tropical fresh nes*. along other tropical fruits (FAOSTAT, 2020). Available evidences from individual countries and recent reports published by some of the private organisations suggesting the dragon fruit production increased significantly in past and current decade (Chen and Paull, 2018; Mordorintelligence, 2020).

At present world market contributes four types of dragon fruits: (i) red skin, white flesh (*Hylocereus undatus*), mainly from Vietnam and Thailand; (ii) red skin, red flesh (*Hylocereus polyrhizus*) come mainly from Israel and Malaysia; (iii) red skin, purple flesh (*Hylocereus costaricencis*) from Guatemala, Nicaragua, Ecuador, and Israel; and (iv) yellow skin, white flesh (*Hylocereus (Selenicerus)* megalanthus) from Colombia and Ecuador (Fig. 1). The red–skin with white flesh, red–skin with red flesh, and red–skin with purple flesh and yellow–skin with white flesh accounts approximately 94, 4.0, 1.5 and 0.5% shares in world market. Guesstimates can put on current world dragon fruit production to be more than 2.1 million tons (Mt) in an area of 1.12 lakh ha (2017–18). Vietnam, China, Indonesia, Thailand, Taiwan, Malaysia, Philippines, Cambodia, India and USA are the leading producers (Table 1).

Red skin, white flesh

Red skin, red flesh

Red skin, purple flesh

Yellow skin, white flesh

Fig. 1. Different types of dragon fruits.

Three major countries *viz.*, Vietnam, China and Indonesia contribute more than 93% of dragon fruit production of the world (Fig. 2). The share of Vietnam alone is more than half (51.1%) of the world production over an area of 55, 419 ha with average productivity of 22–35 t/ha/year. The volume of dragon fruit produced in Vietnam is more than 1 Mt (Table. 1) of worth US$ 895.70 million (Chen and Paull, 2018). Dragon fruit cultivated in almost all provinces of Vietnam, but largely concentrated in Binh Thaun, Tein Giang and Long An regions (Hein, 2018). China is second largest producer contributing 33.3% of world production of dragon fruit i.e., producing about 7, 00,000 tons dragon fruit of worth US$ 397 million over growing areas of 40,000 ha with average productivity of 17.5 t/ha/year (Table 1; Fig. 2; MZMC, 2020).

Table 1. Major dragon fruit producing countries (2017-18).

Country	Area (ha)	Production (ton)	Productivity (t ha^{-1})
Vietnam	55,419	10,74,242	22–35
China	40,000	7,00,000	17.5
Indonesia	8,491	2,21,832	23.6
Thailand	3,482	26,000	7.5
Taiwan	2,490.6	49,108	19.7
Malaysia	680	7,820	11.5
Philippines	485	6,062.5	10–15

Country	Area (ha)	Production (ton)	Productivity (t ha^{-1})
Cambodia	440	4,840	11.0
India	400	4,200	8.0–10.5
USA	324	5,832	18.0
Australia	40	740	18.5
South Africa	12	100	8.3
Total	**1,12,264**	**21,00,777**	-

Source: Compiled from Ahmad et al. (2019); Chen (2018); Chesda (2018); Hein et al. (2018); Muas et al. (2019); and other digital information available in public domain.

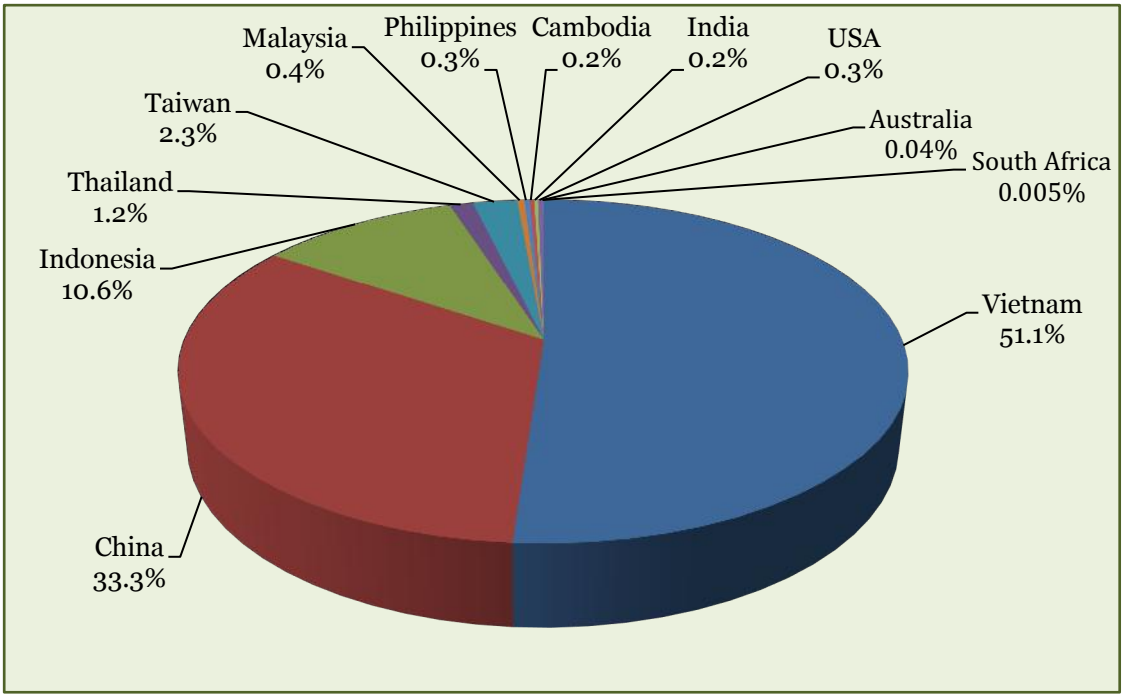

Fig. 2. Global dragon fruit production (% share country-wise).

Among major provinces and regions of China, Guangxi has the largest growing area of 13,000 ha, followed by Guangdong with 10,000 ha and Hainan and Guizhou, each with about 6,600 ha (MZMC, 2020). Indonesia is third largest producer of dragon fruit contributing 10.6% of world production and produces annually about 2.22 lakh tons dragon fruit over an area of 8,491 ha. Dragon fruit is mainly cultivated in Java, Kalimantan, Sumatra and Bali Island of Indonesia and its average productivity varies from 15–30 t/ha/year. After 2014, more than 700 ha of dragon fruit orchards in East Kalimantan and West Sumatra provinces became unproductive due to severe damage of stem canker disease (Muas et al., 2019). Taiwan and Thailand contributes approximately 2.3 and 1.2% in world production (Fig. 2). The production area in Taiwan rising steadily from 380 ha in 1999 to 2,490 ha in 2017 owing to farmers fetches stable prices (Chen, 2018). In Thailand, the main planting areas are located in the

lowlands of Central Plains around Bangkok. Hence, orchards with raised furrow and ditch system are surrounded by soil barrier to prevent flooding during rainy season (Saradhuldhat, 2018). The production and area under dragon fruit is also increasing in other south Asian tropic countries *viz.,* Malaysia and Philippines. The commercial dragon fruit production is also introduced in USA, Cambodia, Australia and South Africa in recent decades (0.5%). During 2017–18, dragon fruit production of India is about 4,200 tons, which is only 0.2% of the world production.

2.2. Global leading suppliers, market, export & imports

2.2.1. Major dragon fruit supplier countries

World major supplier countries of dragon fruit can be broadly divided into following three main hubs (Fig. 3).

1. **Asia:** Vietnam, China, Thailand, Taiwan, Indonesia, Malaysia, Philippines, Cambodia, India and Sri Lanka.

2. **Middle East and Europe:** Israel, Switzerland and EU.

3. **America:** Mexico, Colombia, Ecuador, Guatemala and Costa Rica.

At present, Vietnam is the largest dragon fruit supplier in the world, accounting the highest share in Asia, Europe and sometimes in the United States. Vietnam dragon fruit has been a long trademark of Asian Americans. Particularly in Asia; Vietnam is a leading supplier to the Chinese market. Other market *viz.* Hong Kong, Taiwan, Thailand and Malaysia are also trying to establish their trade in Asian markets. According to American consumer's website, Vietnam's red dragon fruit is generally bigger than other types of dragon fruit, with a nice and impressive appearance, but it is light in colour not as crispy and sweet as yellow dragon fruit. In contrast, the red dragon fruit of Vietnam, although not highly evaluated in form, but is rated to have superior flavour compared to other red dragon fruit.

Israel and Thailand are known major dragon fruit suppliers for European countries. In the US market; Mexico, Central and South America are the biggest competitors to Asian dragon fruit suppliers owing to geographical advantage. In Central America, Nicaragua are major producers and suppliers of red dragon fruit to USA, Canada, Europe and Japan. Colombia is the leading supplier of yellow dragon fruits and highly valued for their taste and form in the US market, as they are the sweetest and most vibrant of the dragon fruit varieties. In addition, this dragon fruit has seasonal advantages to capture the markets when other types of dragon fruits, do not arrive as it is usually harvested in November to February every year. Ecuador produces both yellow and red dragon fruit. Guatemala, El Salvador, Honduras, Costa Rica produce dragon fruit in small scale particularly in the garden (dragonfruit.net.vn).

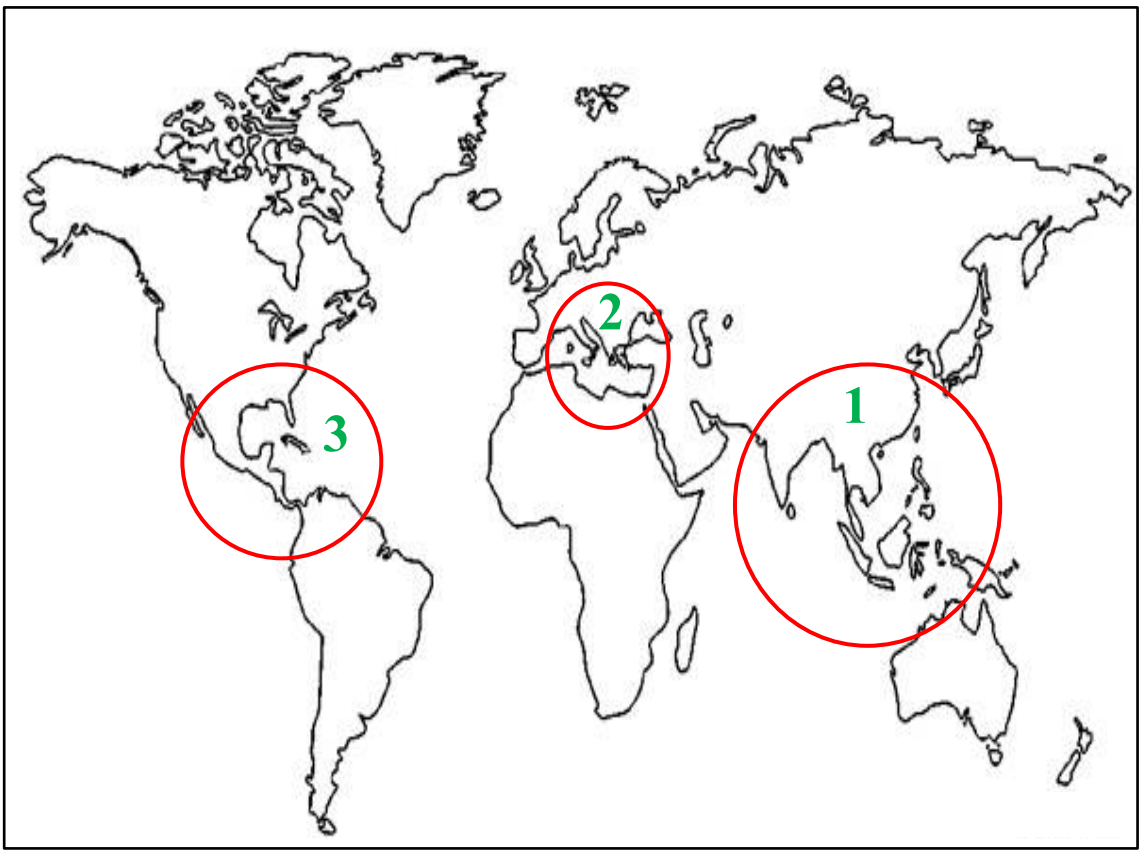

Fig. 3. World three major hubs of dragon fruits.

2.2.2. Demand of dragon fruit in the world markets

Recent estimates show that the demand for dragon fruit is growing consistently all over the world. According to world dragonfruit.net.vn website, demand in different global markets is highly dependent on the marketing information related to its nutraceuticals properties and health benefits in addition to the price and level of sweetness of fruit.

a) **Asia market:** Asia has the largest numbers of consumers of dragon fruit, especially in the Chinese community, due to the belief in the good fortune brought by the dragon fruit's name, shapes, and colours. Consumers in Asia, particularly China, buy dragon fruit mainly for fire-worship, so they often focus on the form of dragon fruit. However, Japanese does not like the big dragon fruit; they value the flavour more than the size.

b) **European market**: The European market is the world's leading importer of fresh fruits and vegetables, and quite open to new products. Therefore, although the dragon fruit is a relatively new and not widely advertised, the price is high, but still very promising and attracting more and more consumers in the continent. With reduction in the cost and further enhancement in the nutritional value, dragon fruit will certainly reach most of the population in European countries.

c) **US market**: Dragon fruit is traditional good for Asian consumers in the US. Due to the high Asian and Vietnamese communities, demand for dragon fruit is relatively high. For other ethnic groups, dragon fruit is relatively new and only known in the high–end market segment. However, analysts say this is a fast–growing market in the near future, as farm owners in Florida and California have begun planting dragon fruit to meet market demand.

According to a recent report (Mordar Intelligence (2020), the global market of dragon fruit is projected to register a CAGR of 3.7% over period of next five years. The global market of this crop is growing at a robust rate, owing to the increasing demand for fresh dragon fruit. Dragon fruit is primarily grown for the fresh market trade and is often sold through specialty stores and farmers' markets in all countries. However, some of major exporting countries like Vietnam are developing of modest post–harvest preservation technologies for processing this fruit into exportable products (Hein, 2018).

2.2.3. World export and import

A worldwide dragon fruit is traded >40 different countries and territories. Apart from the traditional markets *viz*., Vietnam, China, Thailand, Indonesia, Malaysia, Netherlands and Taiwan, dragon fruits are exported fastidious markets of US, Australia, New Zealand, Chile, EU, Japan Korea, Singapore and India (Hein, 2018). This is the fifth most imported tropical fruit from Asia and exported to China after lychee, longan, banana and mango. The estimated export volumes and values of dragon fruits are presented in Table 2.

Table 2. Estimated export quantity and value of dragon fruit of major countries during 2017–18.

Major Importers	Quantity (tons)	Value (lakh US$)
Vietnam	5,11,000	3,940
Malaysia	4,256	20
Taiwan	111	3.1
Indonesia	92	2.6
Philippines	Negligible	-

Source: Ahmed et al. (2019); Chen (2018); Hein (2018); Muas et al. (2019)

China is the biggest consumer and importer while Vietnam is biggest exporter of the fresh dragon fruit (mostly white flesh). Official figures show China's dragon fruit imports have remained steady over the past three years at over 500 thousand metric tons (t) worth nearly US$ 400 million (MZMC, 2020). As per the Ministry of Industry and Trade of Vietnam, 80% of the dragon fruits produced in Vietnam is exported to China, while 99% of dragon fruits in the Chinese market are imported from Vietnam. China consumes 70% of dragon fruit produced from Vietnam apart from their own production. The high demand for the Vietnamese dragon fruit is mainly due to its sizable production and high economic importance. In 2018, China imports from Taiwan were valued at US$ 2.2 lakhs, while small quantities were also imported from Philippines, Malaysia, and Thailand. Taiwan largest export destination is

Mainland of China with a volume of 60.19 t, followed by Hong Kong 44.42 t (Chen, 2018). About 36% of Malaysian dragon fruit is for export mainly to Singapore, Taiwan and Hong Kong with average export value of US$ 20 lakh for the past five years (Ahmed et al., 2019). Indonesia exports about 92 t of dragon fruit of worth US$ 2.6 lakh to other countries like Singapore, Malaysia, Vietnam, Hong Kong, China, Thailand, Japan, United Arab Emirates, Saudi Arabia, Timor Leste, Kuwait, Qatar, Oman and Germany (Muas et al., 2019). As per the recent estimates more than 20,000 tons of dragon fruits of valued US$ 3.00 million are being imported annually into India from the Vietnam, Thailand, China, Switzerland, US and Indonesia.

3. National Status

3.1. Dragon fruit production in India

In India, dragon fruit was introduced during the late 1990s (Arivalgan et al., 2019). Thereafter, area under its cultivation was gradually increased from 4 to 400 ha in different states during 2005–2017 (Table 3). Initially cultivation of dragon fruit was started by the farmers from Karnataka, Maharashtra, Gujarat, Kerala, Tamil Nadu, Odisha, West Bengal, Andhra Pradesh, Telangana and Andaman & Nicobar Islands (Fig. 4). Nowadays, its cultivation has extended to Rajasthan, Punjab, Haryana, Madhya Pradesh, Uttar Pradesh and North Eastern States. According to recent estimates, India's dragon fruit production increased drastically to more than 12,000 tons over an area of 3,000–4,000 ha in 2020 (Table 4). These estimates are based on the first–hand information collected by the ICAR–NIASM, Baramati from progressive growers, entrepreneurs, consultants and officials of state agricultural departments across the country.

Table 3. Year wise estimated area (ha) under dragon fruit cultivation in India.

Years	Area (ha) under cultivation
1990	Introduced in India (0.5)
2005	4.0
2010	12.0
2012	15.0
2014	35.0
2017	400.0
2020	3,085.0#

Source: Digital and printed information available in public domain. #data collected by ICAR–NIASM.

The rise in production and cultivated area are mainly because of states like Karnataka, Maharashtra, Gujarat, Telangana, Andhra Pradesh and West Bengal, which have taken initiatives to promote commercial production after 2018 onwards. Out of total 3,085 ha, more than 80% area (2,468 ha) is under new cultivation with less than 18 months old plantation. Further, average

productivity of these areas is ranging from 1.5 to 3.1 t/ha. While remaining 20% cultivation area (617 ha) is already well established and attained its full maturity level with average productivity of 8–13.5 t/ha. Indian farmers, who follows good cultivation practices under drip irrigation, can get up to 4.5 tons of fruit per ha in the first year after planting, up to 7.5–10 t/ha in the second years and 16–24 t/ha on third year onwards.

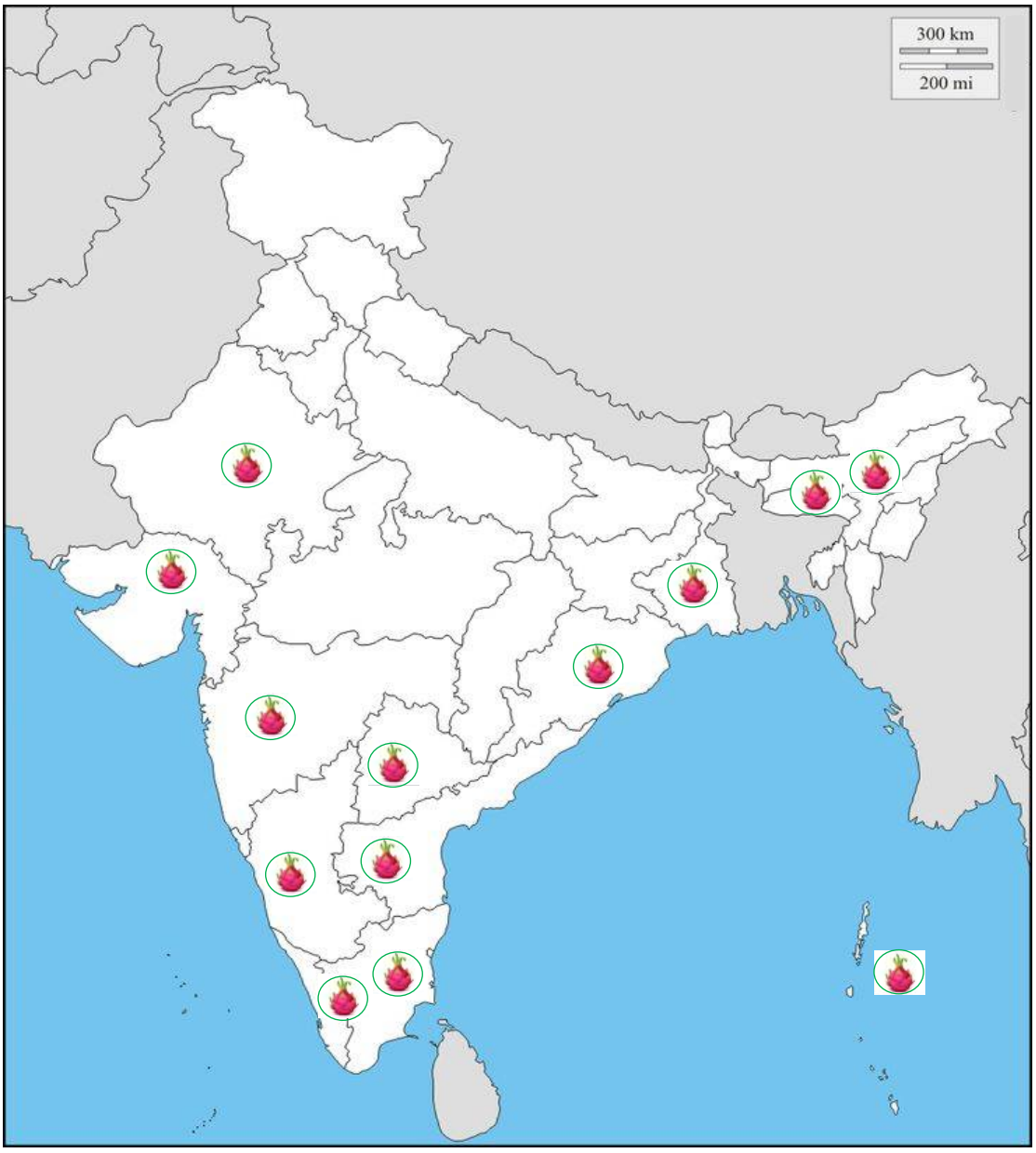

Fig. 4. Major dragon fruit producing states of India.

Gujarat, Karnataka and Maharashtra are the leading producers contributing about 70% of India's dragon fruit production (Fig. 5). The water scarce areas of Kutch in Gujarat, Northern Karnataka and Western Maharashtra are major dragon fruit growing regions of the country. Overall, southern and western states are contributing a major share for the production of dragon fruit since they have been growing dragon fruit during last 5–8 years. For example, more

than 600 farmers from Karnataka alone have taken up dragon fruit cultivation in the last five years after seeing the performance of the fruit. In Karnataka, area under dragon fruit cultivation was about 8–10 ha during 2012, amplified to about 500 ha in 2020 and it is likely to reach around 5000 ha in next five years. Presently over 200 farmers in Gujarat's Kutch are cultivating this fruit in approx. 800 ha of land.

Table 4. Major dragon fruit producing states (Estimated area, production and productivity, 2020).

Major States	Total Area (ha)	New area (ha) 80%, A1*	Productivity of A1 (t/ha), P1	Production in A1 (t), Y1	Old Area (ha), A2	Productivity (t/ha) of A2*, P2	Production in A2 (t), Y2	Total production (t) (Y1+Y2)
Andhra Pradesh	140.4	112.3	1.5	168.5	28.1	10.2	286.5	455.0
Telangana	80.9	64.8	1.8	116.6	16.2	10.0	161.9	278.4
Tamil Nadu	121.4	97.1	2.2	213.7	24.3	12.0	291.4	505.1
West Bengal	303.5	242.8	2.1	509.9	60.7	11.0	667.7	1177.7
Maharashtra	323.8	259.0	3.1	802.9	64.8	13.5	874.1	1677.1
Karnataka	485.6	388.5	3.0	1,165.5	97.1	12.4	1,204.4	2,369.9
Gujrat	1,214.1	971.3	2.2	2,136.8	242.8	8.0	1,942.5	4,079.3
Rajasthan	38.4	30.8	1.5	46.1	7.7	8.0	61.5	107.6
Meghalaya	174.0	139.2	2.8	389.8	34.8	11.4	396.8	786.6
Other	202.3	161.9	1.5	242.8	40.5	10.7	433.9	676.7
Total/ average	**3,084.6**	**2,467.7**	**2.2**	**5,792.6**	**616.9**	**10.7**	**6,320.7**	**12,113.4**

Note: A1* newly cultivable area after 2018–19; A2*well established cultivable area with more than 4 years old plantation

The cultivation of dragon fruit increased to more than 400 ha in other parts of Gujarat state. Similarly, it can estimated that about 250 farmers in Maharashtra growing dragon fruit over 200 ha areas in Western Ghats regions and remaining 100 farmers over 125 ha area in the rest of Maharashtra that includes Marathwada, Konkan and Vidharbha regions. Similarly, agriculture departments and SAUs of the few states *viz*., Andhra Pradesh, Telangana, West Bengal, Tamil Nadu and Meghalaya (Singh and Singh, 2017) are in the ways of popularising this crop in water scarce regions. There are several success stories of farmers indicating that dragon fruit already gaining popularity in different parts of India. This is also evident from the fact that many nursery owners have started propagation of planting material of dragon fruit. Most widely grown and commonly available cultivars of dragon fruit in India are the red skin-white flesh (93%) followed by red skin-purple/red flesh (6.5%) and yellow skin-white flesh (<0.5%). Overall, it is fast returning perennial fruit crop with economic production in the first year after planting, and full production within three to five years. It was also noted that after first years onwards desirable cultural

management practices are highly essential. Although the initial investment is relatively high, profit is substantial within 4–5 years. The linear equation (y= 508.33 x – 1000000, R^2=0.84) was used to estimate the projected area for the next five years up to 2025. These projection shows that the area under dragon fruit cultivation is expected to rise more than ten times i.e. ~ 30, 000 ha in next five years (Fig. 6). Further, this rise in projected trend will depend on the market demands, consumer acceptability and government policies.

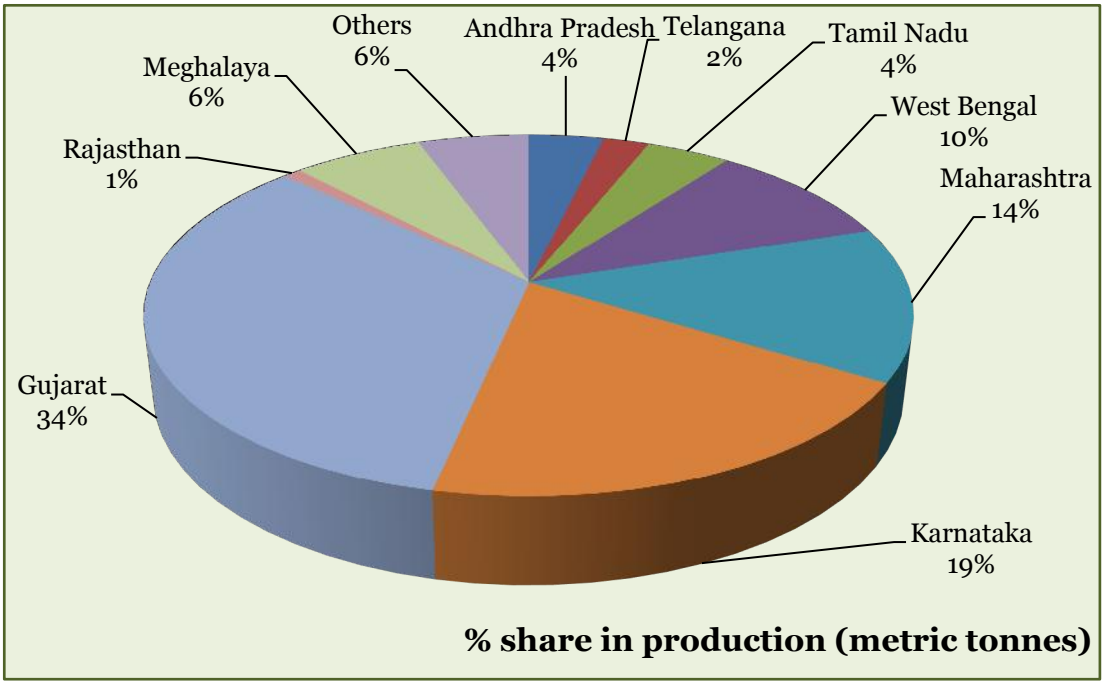

Fig. 5. Estimated production of dragon fruit (% share state wise), India.

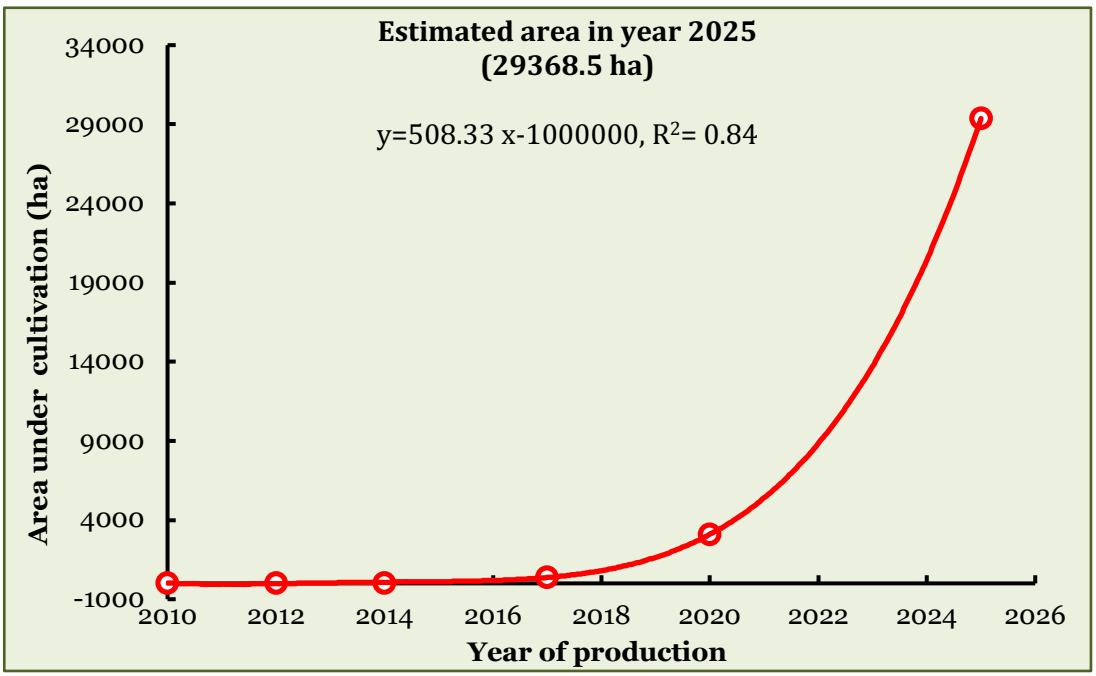

Fig. 6. Projected area under dragon fruit cultivation for next five years (2025).

3.2. Marketing, export and import in India

3.2.1. Marketing channels and prices

As far marketability concerned, there is assured market of dragon fruit in India at present and expected to reach greater peak because of limited number of commercial producers and high demand. In future also its demand and awareness likely to increase mainly due to its taste, nutritional and medicinal properties. In Indian retail market, dragon fruit is often sold as a fresh product. Domestic and international market channel of dragon fruit is depicted in Fig.7. In general marketing chain of domestic dragon fruit grouped into simple path of 4–5 components namely farmers, small traders/collectors, whole sellers, retailers and consumers. At farm level, the growers can either sell dragon fruit to small traders/collectors or whole sale retailers directly. In this situation, all these private agents and retailers play significant roles of middle men's between farmers and consumers since the industrial players for processing and export are missing completely. In certain places, growers could also sell their produce directly to consumers through mobile/digital markets or farmers markets (Mandi) or even nearby road sides to the farm. At present, wholesaler act as key player to the supply of domestic and imported fruits into retail market *viz.,* super market in Mumbai, Delhi, Kolkata, Chennai, Pune, Hyderabad and Bengaluru and small market/grocery stores in town and rural areas. The market prices ranged from INR 55–250/kg depending on weight based three grades (A> 400 g, B between 200–400 g and C <200 g) prevailing in market. During offseason, prices persisted as high as INR 300–450/kg for Indian dragon fruit. Even huge numbers of health conscious consumers in cities paying up to INR 500–600/kg for dragon fruit imported from Vietnam and Thailand.

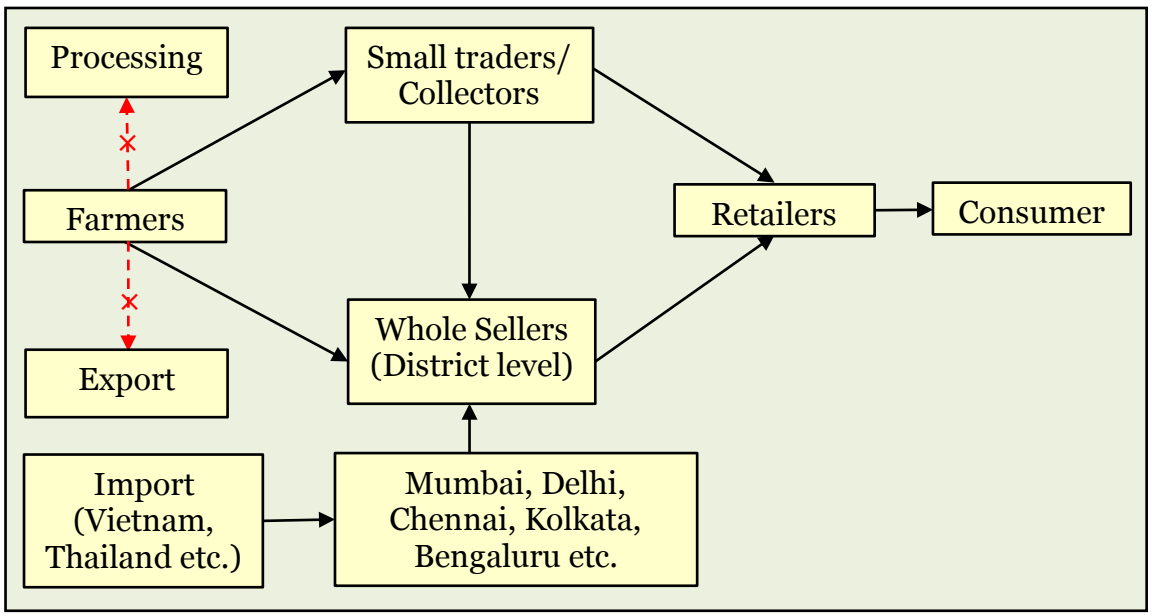

Fig. 7. Marketing channel of dragon fruit in India.

Like other fruits and vegetables, dragon fruit is highly perishable having shelf life of 5–7 days at ambient Indian conditions. In case of any market glut due to excess production, dragon fruit can be turned into various value added products *viz.*, jams, juice, freeze-dried chips or cookies (Ahmed et al., 2019). Thus, there is a strong need to explore the avenues of value addition through processing, so that the production will continuously increase and surplus produce can be diverted for processing (Arivalagan et al., 2019). However, apart from continuously rising demand, there is lack of information about consumer requirement in Indian markets. In conclusion, until the market gets stabilised it is better to avoid large-scale production of dragon fruit. The production should be demand–driven and sustainability should be the main concern.

3.3.2. Import and export trade in India

Presently, production of dragon fruit in India is far less than the same imported from Thailand, Malaysia, Vietnam and Sri Lanka etc. Freely available import data (2015–16) of dragon fruit provided by Seair Exim Solution, New Delhi and Infodrive India, New Delhi were analysed. As per data about 23, 166.4 metric tonnes (MT) of fresh dragon fruits of worth US ($) 2.99 million (INR 205 million) were imported in India during December 2015 to November 2016 (Table 5). Vietnam (99.74%) and Thailand (0.24%) are the major countries importing dragon fruit into India (Table 6).

Table 5. Import of dragon fruits to India (total quantity and values) in 2015–2016.

Month	Total quantity (tons)	Value (INR, million)	Value (US$, million)
December	175.2	11.9	0.13
Jan	312.7	18.4	0.27
Feb	236.6	12.2	0.18
March	276.0	15.4	0.23
April	334.7	20.2	0.30
May	102.2	6.1	0.09
June	71.6	5.1	0.07
July	159.0	11.5	0.17
August	260.4	17.1	0.25
September	135.7	9.7	0.14
October	597.7	41.9	0.62
November	20,504.6	36.4	0.54
Total	**23,166.4**	**205.8**	**2.99**

Source: Seair Exim Solution, New Delhi and Infodrive India, New Delhi.

After excluding 20, 000 MT surplus amount of dragon fruits received from Vietnam in November 2016, more than 35% supply of these fruits was noticed in three months *viz.*, April, November and December i.e. at the initial and peak season either due to higher prices in Indian market or glut production in the importing countries (Fig. 8). Presently more than 20,000 MT of dragon fruits are being imported annually into India from Vietnam, Thailand and China.

Table 6. Country-wise import to India during 2015–2016.

Country	Quantity (Metric tonnes)	% Share
Vietnam	22,932.2	99.74
Thailand	55.9	0.24
China	2.09	0.009
Switzerland	0.56	0.0024
US	0.48	0.0020
Indonesia	0.033	0.0001

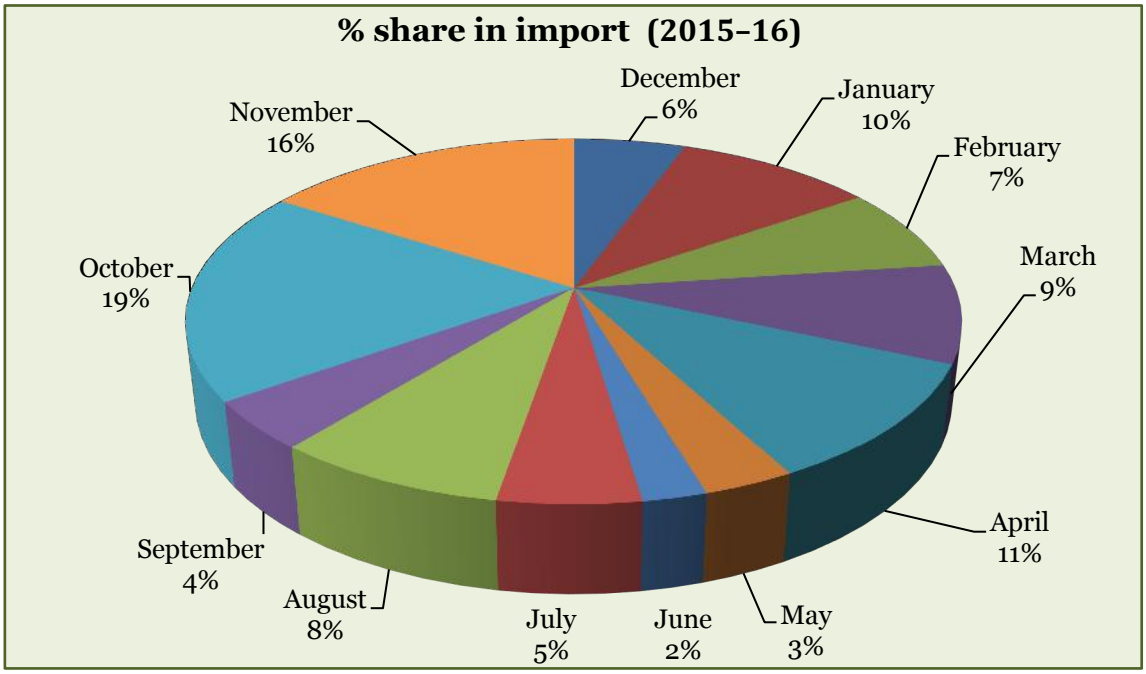

Fig. 8. Import of fresh dragon fruit (% share) in India during 2015–2016.

India is nowhere in the list of global exporter of dragon fruit. However, considering present expansion of dragon fruit cultivation, India has great scope in a near future for large-scale export to meet global market demand particularly market at *viz.*, North America, Europe, Asia–Pacific, South America, and the Middle East and Africa etc. Hence, India has to promote dragon fruit farming in the form of large clusters in barren/dry land areas, which can ensure quality supply in bulk quantity. All other infrastructure for post-harvest management can be created if there is clustered approach for cultivation. To begin with dragon fruit clusters, it can be developed in drought prone and hilly areas of Karnataka, Maharashtra, Gujarat, Andhra Pradesh, Telangana, Tamil Nadu and North eastern states. India has to initiate similar steps as adopted by the Vietnam for successful dragon fruit cultivation and for exports imports after fulfilling own demand.

4. Potential areas for dragon fruit cultivation in India

4.1. Degraded lands and rainfed areas

The challenge of providing food security to ever–increasing Indian population is most difficult task though not impossible. This must be addressed in the context of changing consumption patterns, climate change inducible abiotic and biotic stresses and degradation of the limited land and water resources. There is an urgent need for enlarging area under arable lands, by the approach of reclamation of degraded land for sustainable intensification of agriculture, in which crop yields can be augmented without penalising the environments and area under forests. As per estimates of ICAR–NBSS & LUP, about 120.8 million ha (Mha) land constituting 36.5% of total geographical area are degraded in India (Maji et al., 2010) through different water, wind, physical and chemical agents. The extent of area under water and wind erosion is 82.6 Mha, and 12.4 Mha respectively. Chemical degradation comprises salinity/alkalinisation (6.7 Mha) and acidification (17.6 Mha). Other categories include mining, industrial waste and waterlogging, occupying 1.07 Mha (Fig. 9). The details of land degradation by various physical, chemical and biological factors is given in degradation map of India generated using LISS–III data (ISRO) of 2015–16 (Fig. 10).

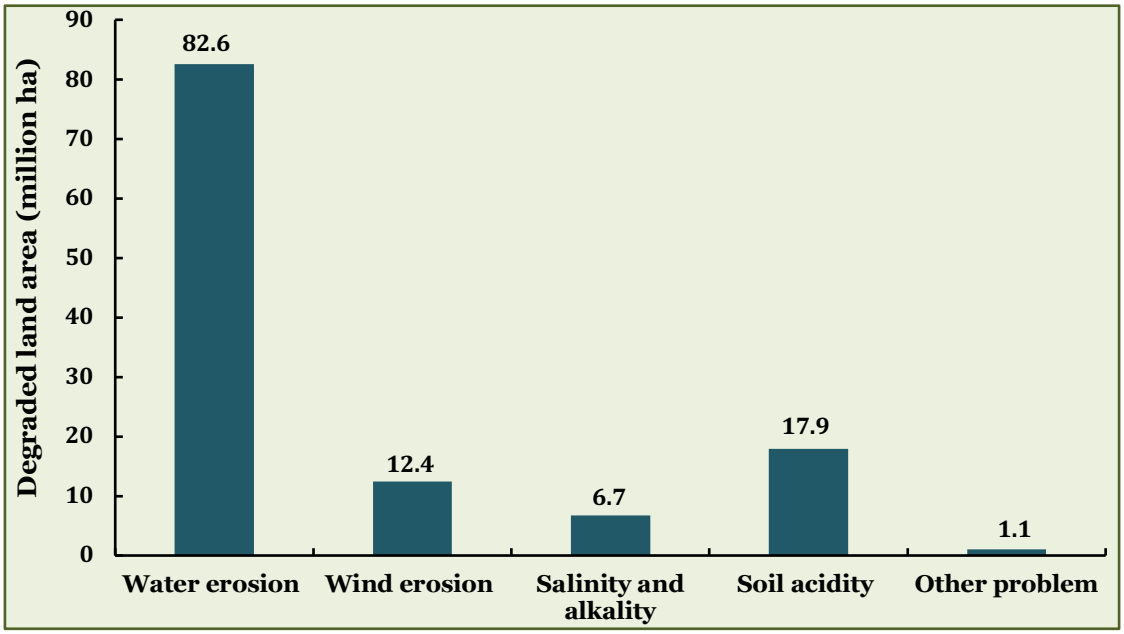

Fig. 9. Statistics of degraded and wastelands of India. **Source:** Maji et al. (2010)

Climate change aggravate the stresses *viz.,* mineral content, drought, acidity, sodicity, waterlogging that continue to deteriorate the soils, and drastically reduce the crop productivity of these degraded land regions. In addition, unfavourable climatic factors like erratic rainfall, high evaporation and severe droughts contribute to the increasing water scarcity in 58% (80 Mha) of net shown rain-fed areas. Projections indicate that by 2050, agricultural sector would require additional 45% water whereas its share is expected to decline by 10% with increasing demand for water resources from all sectors. Hence,

rainfed agriculture is featured by significant year–to–year fluctuations in production, market volatilities, distress of primary producers and end–consumers.

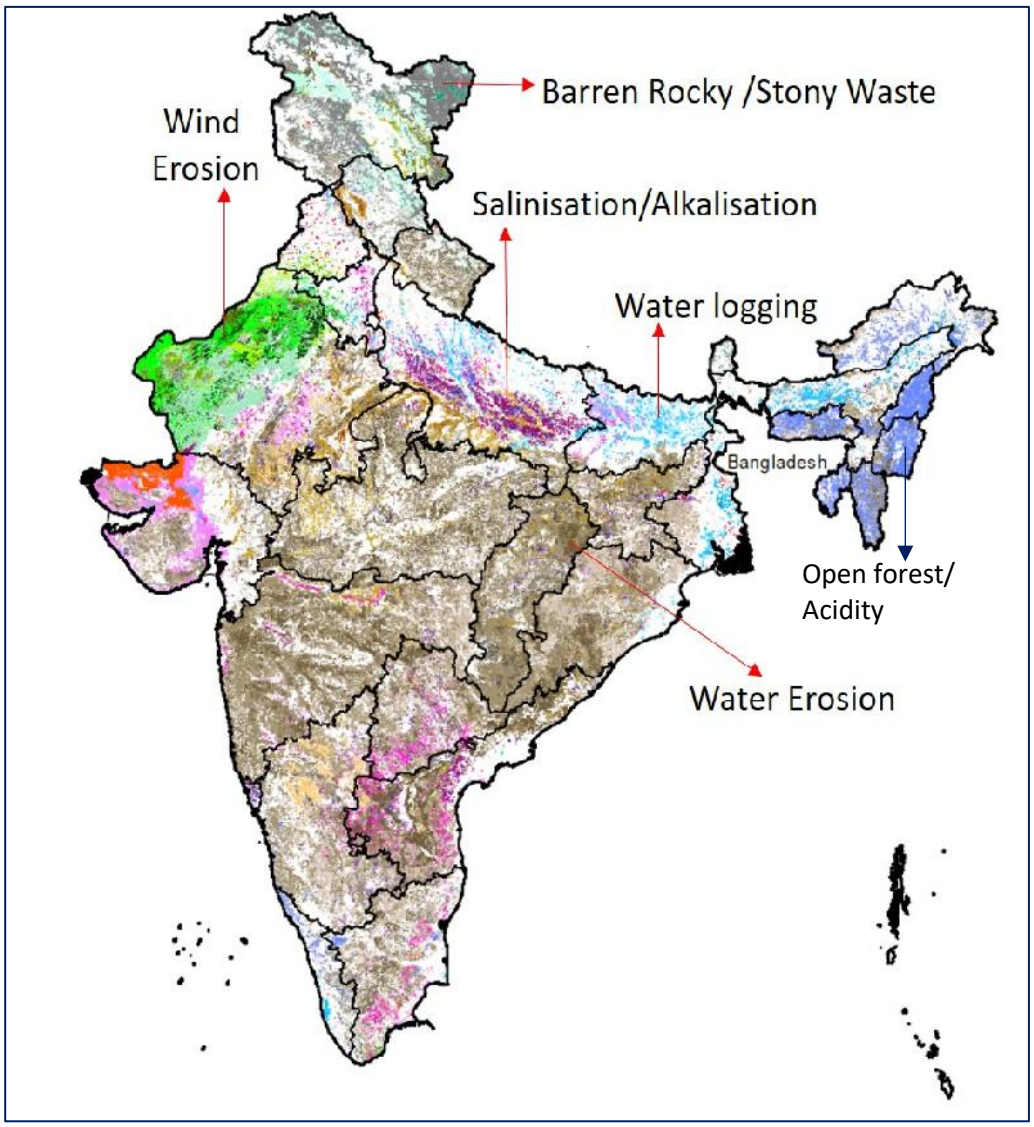

Fig. 10. Degraded land of India (Source: ISRO, 2015–16).

There is limited scope for bringing more area under cultivation with speeding urbanizations. Adequacy of irrigation water is also a challenge. These constraints will continue for the coming years, and the challenging task is to increase agricultural output of all these degraded and rainfed areas with limited resources without compromising sustainability of the agro-ecosystems. Therefore, technologies interventions are need to be developed for enhancing agricultural output and mitigate abiotic stresses with best compatible cropping patterns and soil and water conservation techniques, yet the large yield gaps exists. Under this situation, exploration of potential and beneficial exotic crops and their introduction to present crop genetic resource base seems to be an easiest way and could be a key for addressing number of issues faced by Indian agriculture particularly in the near future. Dragon fruit can be one such

potential crop that can be cultivated in large parts of the rainfed and degraded land of country considering its various benefits as discussed in section 1.

4.2. Dragon fruit–a viable option for degraded/ rainfed land in India

Being a fruit of cactus family, dragon fruit has potential to grow in various agro–climatic regions of northern, southern, western, eastern, central and north–eastern India, and is tolerant to extreme weather conditions, except for water logging, often faced by degraded lands (Fig. 10). Positive side is that its cultivation has already been started in tropical and subtropical regions in almost 20 states of India including Andaman and Nicobar Island. Thus, it provides plenty of opportunities to take up cultivation in diversified climate and soils of India and could be viable options to extend its cultivation to abiotic stressed regions and waste lands, coastal soils, soils having shallow depth, soils with high gravel content, low water retention capacity and low fertility status owing to multitude of stress handling plant characteristics.

With respect to total geographical area, the five major states of Rajasthan (20.0 Mha), Uttar Pradesh (14.4 Mha), Madhya Pradesh (14.09 Mha), Maharashtra (9.73 Mha) and Karnataka (8.1 Mha) have the highest area of lands under degradation, accounting to 55% (out of India's total 120.4 Mha degraded land) while all the other states including Andhra Pradesh and Telangana each have less than 4% of degraded lands (Maji et al., 2010). Most of parts of these states falls under rainfed and drought prone regimes. Being a moderately drought tolerant, the water requirement of dragon fruit is as low as 120 to 150 mm, hence provision of micro irrigation and rainwater harvesting could be viable options for dragon fruit farming in these areas. Whereas, it is necessary to protect the crop from extreme temperature particularly during summer season to avoid problem of sun burn in these regions.

As stated earlier, dragon fruit can be grown in wide range of soils but it should be well drained. However, the loamy soil, rich in organic matter is good for its commercial cultivation. It is very shallow rooted crop; mostly the roots confined up to 40 cm, therefore, depth of soil may not be problem for the cultivation. Taking advantage of this trait, cultivation of dragon fruit can be extended to shallow soils particularly in hilly areas. It prefers slightly acidic soil of pH 5.5–6.5 for its optimum growth. Thus, an area around 5.0, 5.7 and 7.1 Mha falling under exclusively acid soils (pH ≤5.5), acidic soils under erosion and open forest can be used for rigorous cultivation of dragon fruit. More than 50.9% of the total 17.9 Mha acidic soils falls in North–eastern region of India endowed with rich diversity of agro–climatic conditions which could provide enough scope for enhancing dragon fruit cultivation. Thus, it may be a potential fruit for this region also, particularly for Assam, Arunachal Pradesh, Nagaland, Manipur, Mizoram, and Tripura states. Further, its cultivation can be extended to acidic soils of the Kerala (13.5%), Chhattisgarh (13.1%), Jharkhand (4.1%), Tamil Nadu (2.4%) and other states of country.

Dragon fruit is tolerant to moderately saline soils. Hence, its cultivation can also be extended to over 3.85 Mha saline soils particularly having problem

of moderate to slight salinity. Thus, dragon fruit can be grown in saline areas of the major states of Gujarat (1.5 Mha), West Bengal (0.4 Mha), Maharashtra (0.16 Mha), Odisha (0.13 Mha) and Rajasthan (0.11 Mha). There is limited chances of cultivation of dragon fruit in high saline/sodic soils since cacti will not tolerate sodic or waterlogged conditions. However, effort can be made to bring the 3.7 Mha low lying and sodic soils areas of country contributing Uttar Pradesh (1.32 Mha), Gujarat (0.54 Mha) Maharashtra (0.42 Mha), Tamil Nadu (0.35 Mha), Andhra Pradesh (0.19 Mha), Rajasthan (0.18 Mha) and Haryana (0.18 Mha) with help of advanced cultivation technologies and varietal development.

Dragon fruit cultivation can also be extended in non-conventional agro–ecological occurred in some parts of degraded lands with the aid of protective agriculture technologies. Dragon fruit has enormous potential in protected cultivation also owing to its short stature, response to pruning, potential to provide quick returns on investment etc. Dragon fruit under protected cultivation could open new avenues of income generation and agricultural entrepreneurship development to meet out the goals of self–reliant India in low and high temperature, frost and erratic rainfall areas. Throughout–year supply of dragon fruit which fetches premium price in the markets can also be ensured through protected agriculture technologies. Further, because of ease of cultivation and management, production of dragon fruit can also be extended to smallholder or marginal cultivators, entrepreneurs of small medium and large scale plantations through development of high density or ultra–high density orchards and also in backyards, on terraces or as garden fruits. In conclusion, all these clues indicate the there is a great possibility to extend its cultivation in wider parts of the country.

5. Constraints in dragon fruit cultivation

Although dragon fruit is a fast growing, perennial vine like cacti that widely thrives in tropical diverse agro–ecologies because of its tolerance to drought, heat, poor soils and cold, it can be damaged by several environmental factors, improper cultivation and management practices. Hence, even in the most ideal conditions, issues related with dragon fruit may still plague the gardener. Therefore, in this section an attempt is made to enlist some of major constraints in dragon fruit cultivation based on the feedback of scientists, consultants and growers from India. The information on these constraints is certainly useful for addressing researchable and policy issues for successful cultivation of dragon fruit in the future.

5.1. Nursery and varietal improvement related problems

- Lack of awareness and expertise about preferred nursery practices related to dragon fruit among the nursery owners and farmers particularly in degraded land and rainfed regions.
- Apart from easier propagation through stem cutting, inferior quality of sapling materials supplied by the private nursery owners mostly from nearby cities.

- High cost and non–availability of quality sapling materials. The stem sapling materials can be available in three different forms *viz.,* fresh cut, rooted sapling without soil bags and rooted sapling with soil bags for easer transportation and cost reduction depending on distance, soil types and climatic conditions (Fig. 11).
- Lack of nursery standards and choice of sapling of different varieties particularly for diversifying dragon fruit in drought prone /degraded areas. Presently saplings of one or two varieties i.e. red skin–white flesh and red skin–red flesh are available with nursery owners. Hence, preference should be given to prepare saplings of other varieties in nearby dragon orchards of villages.
- Lack of sapling material of high yielding varieties suitable for processing, value addition and marketing purpose.
- Identification and development of new varieties for overcoming problem of irregular flowering & pollination.

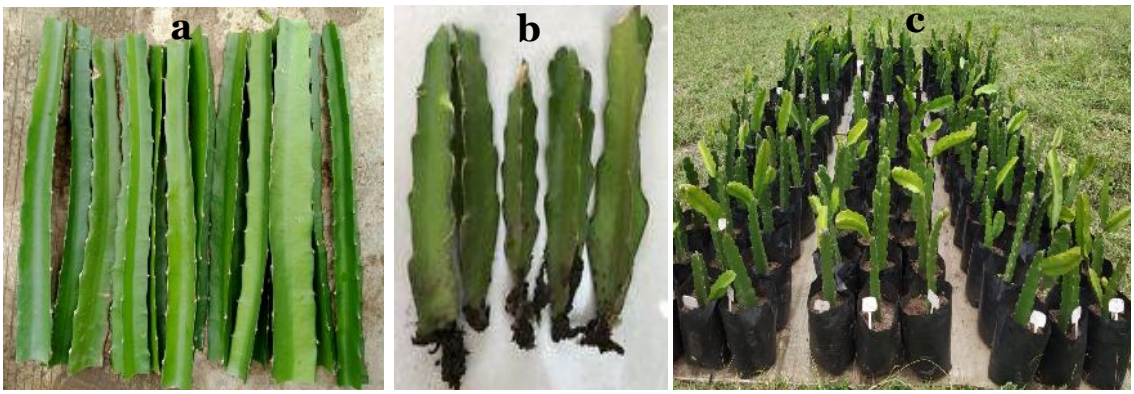

Fig. 11. Dragon fruit stem sapling material (a) fresh cut (b) rooted cut and (c) rooted sapling with soil bags.

5.2. Orchard establishment and training system

- Lack of awareness among the growers about ideal plantation practices and seasons for initial establishment of orchards. Sometimes, it may leads to complete damage of dragon fruit saplings if planted during offseason or prior to extreme weather conditions. The growers must be well aware about site selected for orchard *viz.*, soil types, slope, drainage, runoff and water logging pattern.
- High initial investment of orchard establishment (INR 6.5–7.5 lakhs/ha) is the biggest constraint of dragon fruit cultivation at marginal and small farmers levels. It includes cost of sapling materials, installation of drip irrigation and trellis system (concrete pole, iron/concrete ring, continuous pyramid, 'T' stands and iron wires and ladder etc.). This cost can be reduced to some extent by using locally available trellis materials depending on its durability (Fig. 12).
- Standardisation and selection of regional specific trellis designs, planting geometry and trellis materials is highly essential for improving yield performance, easy harvesting and achieving high load

bearing capacity in diversified agro–climatic regions (Arivalagan et al., 2019). It is not possible to change the poles in between once after orchard establishment because of the growth and entangled branches of dragon fruit plant. Hence, concreate poles are usually preferred due to its durability.

- Scarcity of trellis materials to meet farmers demands.
- Lack of skilled/trend manpower for establishing the orchards.

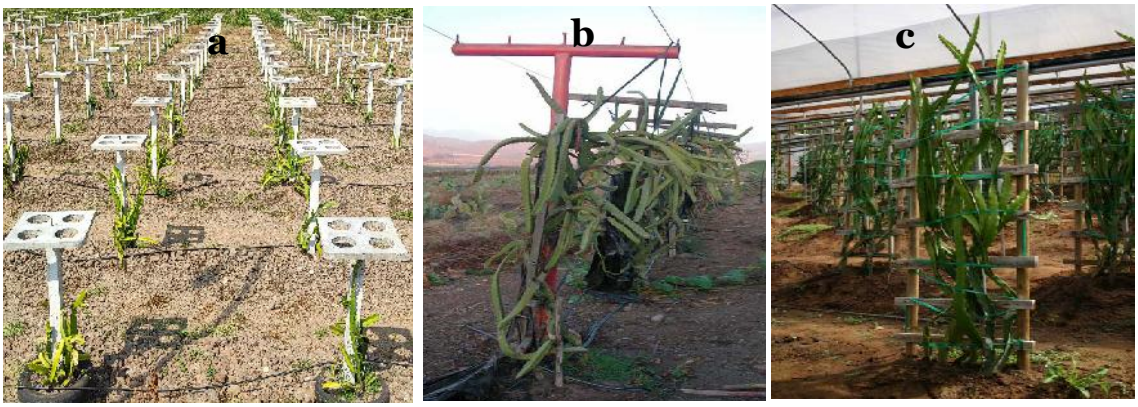

Fig. 12. Different trellis systems namely (a) concrete pole and rings (b) 'T' stand and iron wires (c) wooden ladder for dragon fruit establishment.

5.3. Lack of standard protocols of cultivation practices for diversified agro-climatic regions

An immediate action on developing standard protocol/packages of cultivation practices is obligatory for profitable dragon fruit farming and entrepreneurship in diversified agro–climatic regions. Accordingly some of key cultivation practices *viz.*, water, nutrient, weed, canopy, insect and disease management as suggested below need to be standardised. The issue related to canopy management discussed separately along with disposal of canopy residues.

5.3.1. Water and nutrient management

- Necessity of regional specific optimisation of irrigation practices/ fertigation schedules depending upon soil and climatic conditions. About 2–4 litres of water weekly twice per plant is sufficient during the summer/dry days. However, water requirement may increase or decrease depending upon soil, climate and plant health.
- Development of standard irrigation methods seems to be prerequisite for improving fruit yield, quality and water productivity of degraded and rainfed areas. Installation of drip system could be main practice in orchards of dryland areas. Thus, possibility of finalizing the location of drip lines on surface, middle and top of the poles need to be explored since plant has also a kind of entangled stem roots sometimes floating in air (Fig. 13). Most of the times, roots of dragon fruit spread over top of the soil surface and it might dry up easily resulting in adverse effect on the fruit growth and production. In these situations, sprinkling with water pump mounted behind the mini–tractor could be

immediate solution to overcome the problem. In low land water logged areas, planting beds need to be raised as furrow and ditch system. The aim of furrow is to increase the soil layer for root systems above to protect the plants from waterlogging. Further, to avoid problems of flood water occurred during rainy season, there is need of constructing soil barrier around orchard (Saradhuldhat et al., 2018).

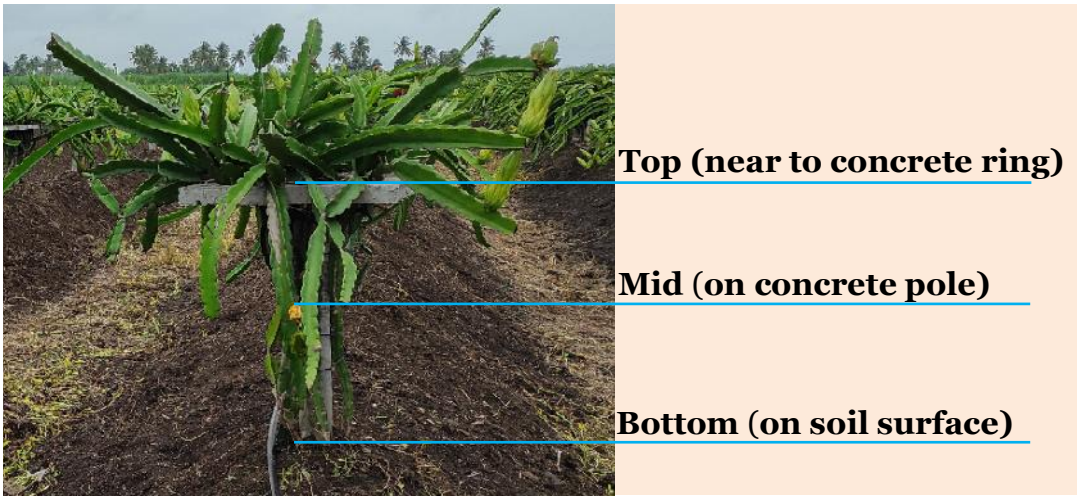

Fig. 13. Various locations of lateral for drip system in dragon fruit orchard.

- Need of standardisation of organic, chemical and micro nutrients management practices/doses being a fruit of low fertile barren land. Optimisation of primary nutrient (N–P–K) in commercial fertiliser under well drip irrigated conditions is very essential in resource poor soils. Orchards in uplands use of organic fertilisers (cow dung, neem cake and chicken manner) in 1–3 times in a year i.e., about 15–20 kg/application/pole before and after the production season is very important. Similar nutrients management practices can be standardised for the drought prone/degraded land areas.

5.3.2. Weed management

- Many of growers in India have reported severe weed problem particularly during and post rainy seasons in all kind of soils. This can be controlled through standardising weedicides/herbicides spray schedules with interval of 10–20 days, intercropping and developing suitable equipment for intercultural operations using mini–tractors (Fig. 14a). The intercropping of cereals like wheat, rice, green manuring and also vegetables crops is possible under irrigated conditions (Fig. 14b). However, flood irrigation must be avoided to reduce the weed population and also excess soil moisture stress is detrimental for dragon fruits.

Fig. 14. Weed management (a) weedicides spraying and (b) intercropping.

5.3.3. Insect, disease, predators and disorders in dragon fruit

Dragon fruit is comparatively free of pests, diseases and disorders. However, there should not be any complacency in measures for protection of dragon fruit orchards.

- Prevalence of insects and pests like ants, nematodes, scale insects, mealy bugs are common in dragon fruit in India and can be easily controlled by application of insecticides.
- Reports similar to those documented by researchers (Athipunyakom et al., 2015; Lin et al., 2016; Masyahit et al., 2009) in other countries, are appearing in Indian context (Arivalagan et al., 2019) with respect to occurrence of some fungal and bacterial pathogens origin diseases such

as anthracnose, brown spots, stem rots and stem canker severely affect yields and quality of dragon fruits (Fig. 15). Excess light makes the plant vulnerable to diseases like bacterial rot. Further, sun burn and calcium (Ca) deficiency aggravates the diseases. Hence, timely detection and necessary precautions are needed at farmers' end to protect the dragon fruit crop.

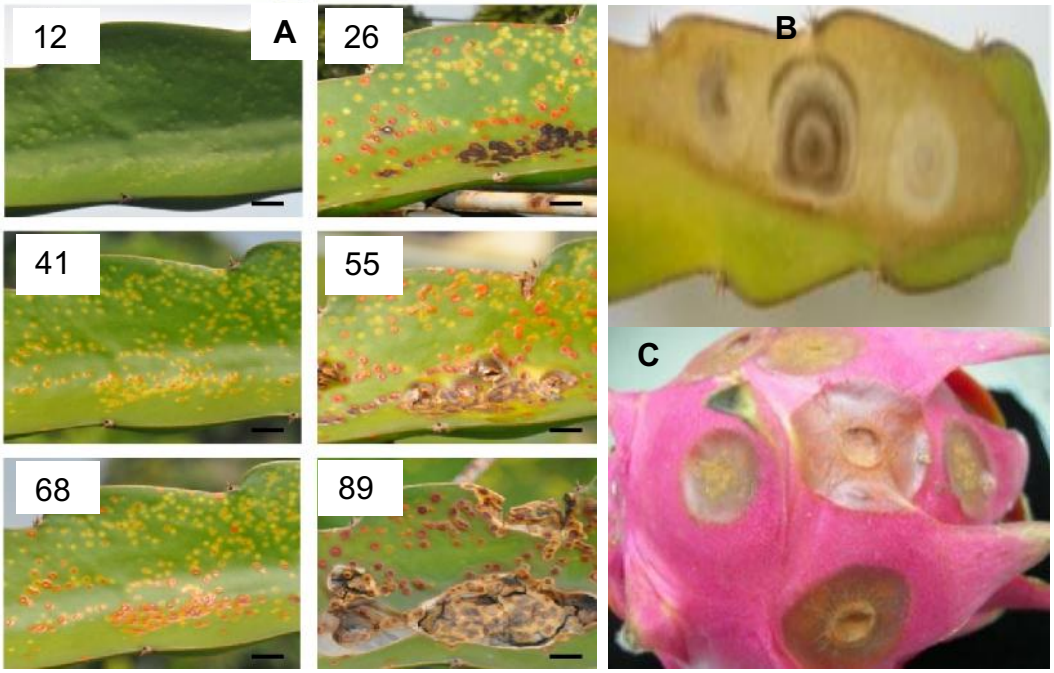

Fig. 15. Various diseases in dragon fruits (a) Stem canker symptom–stages in 12, 26, 41, 55, 68 and 89 days after inoculation (b) stem anthracnose and (c) fruit anthracnose.

- The attack of fruit flies *viz., Bactrocera dorsalis* and *Bacrocera correcta* was reported in some of the farmer's field in India and they cause yield losses up to 35% (Khanh et al., 2016). It is difficult detect their infection even after 3–7 days depending upon fruit stages. However, it changes fruit colour of infected part of fruit particularly at the contact point of skin and flesh just after infection (Fig. 16a).
- Inappropriate proportion of water and soil nutrients supply and extreme climatic conditions can cause several diseases and disorders related to plant and fruits. Disorders related to fruits are manifested through changes in size, shape, colour and taste etc. (Fig. 17a). In India, about 2–5% of dragon fruit farmers have reported formation of white mesh structure inside the fruit body (Fig. 16b). This is a matter of investigation as it is kind of disorder or disease including factor responsible for formation in fruit. Hence, there is a need of designing non–destructive method/instruments for identifying the diseases/disorders inside the fruits.
- Dragon fruit is susceptible to predators like rat and birds during ripening stage and they can cause losses up to 5–8%. Plants need netting to prevent rat and bird damage to fruit (Fig. 17b).

- There is necessity of standardisation, development and implementation of combined package of integrated pest as well as nutrient management practices on priority for enhancing the yield and productivity dragon fruit orchards.

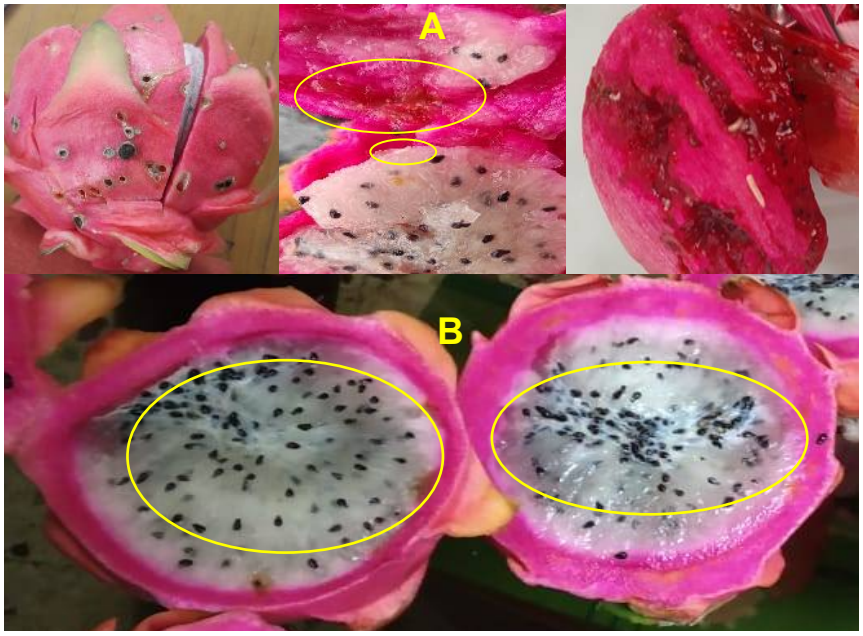

Fig. 16. Infected dragon fruit by the (a) flies and (b) white mesh structure.

Fig. 17. Dragon fruit (a) disorder (Kutch–Gujrat) and (b) bird infection.

5.4. Poor/excess flowering, flower and fruit dropping, yellowing and rotting/dropping owing to excess rainfall and temperature

The problems related to pollination, flowering and yellowing/rotting of fruits are common in dragon fruit cultivation but its intensity varies with rainfall and temperature conditions of particular sub–tropical and tropical regions. It also occurred in Indian diverse agro-climatic regions particularly during summer and monsoon seasons and reduced yield losses up to 40% in a particular harvesting stage. Even some times 70–100% depending upon the frequency, duration and intensity of the rains occurred during night of flowering. It can be resolved through adaptation of standard cultivation, nutrient-water management practices and varietal development programme since dragon fruit is well adapted to semi–humid climates in organic matter rich soils. In summer

season, excess heat combined with water stress is main cause of flower/fruits drop at the initial stage of fruit production (April–June). Use of shade nets and optimal irrigation facilities could be the best solution to avoid flower/fruits drop in summer season. Further, excess rain or moisture during peak fruiting period (July–October) is another key factor responsible for dropping and rotting of flowers/fruits. It can be resolved by keeping flowers dry until the fruits have set and then they can be watered for better fruit establishment and yield improvement.

Preliminary observations reveal that fruit drop in monsoon season occurs in five major steps (i) socking and absorption of rain water/moisture in flower bud (ii) flower dropping (iii) yellowing of flower and fruit remain on plant (iv) fungi attack and (v) cutting of corolla part by larvae's of fruit flies (Fig. 18).

The typical problem of excess flowering followed by flower dropping, yellowing and rotting of fruit was observed during harvesting period of August, 2020 (rainy season) at dragon fruit orchard of ICAR–NIASM (Fig. 19). The recorded field observations indicates about 40–70% fruits were of tiny size (36–49 mm dia.) having yellow to pinkish colour, 15–20% small size fruits (63–68 mm) and remaining 8–10% medium size fruits (79–84 mm) having light to dark pink colour. The tiny fruit cannot be used for any purpose. While, small and medium grade fruits can be used for value addition and fresh consumption, respectively. Flower density management followed by covering of flower into plastic bags to avoid contact of rain water can be the solution of this problem.

Fig. 18. Steps of flower/fruit dropping of monsoon season dragon fruit.

Possible causes of poor/excess flowering and yellowing/rotting of fruits

- Prior cloudy weather conditions/continuous rainfall/heavy rainfall/poor soil nutrients management practices could be the main causes for excess/poor flowering in dragon fruit orchard
- Washing of pollen's, decaying/ spoilage of flowers and small fruits due to excess water absorption by the fruit
- Excess or less irrigation to plant
- Dragon fruit plant does not get sufficient sunlight
- Nutrient management is issue
- Prefer organic nutrient management
- May be due to disease infestation

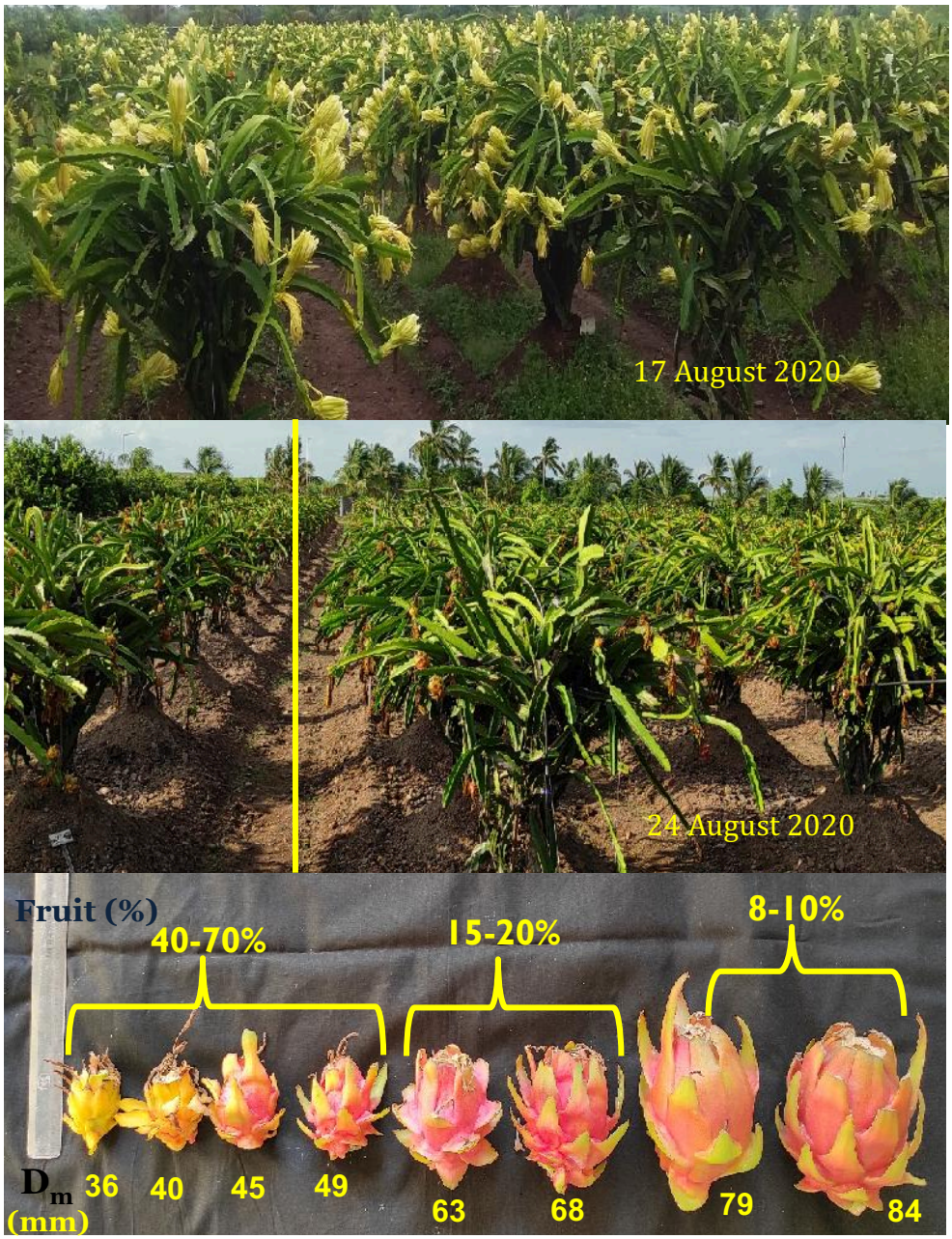

Fig. 19. Dragon fruit excess flowering followed by yellowing/dropping of fruit.

5.5. Stunted growth and sun burning of canopy

Stunted growth and sun burning injuries closely related to heat stress experienced by the several (80–95%) dragon fruit farmers across India. It occurred particularly during summer season in Rajasthan, Gujarat, Maharashtra and Southern India (Fig. 20). The symptom appeared during the month of March and April that witness higher variation in day and night temperatures in regions crosses above 38°C (Arivalagan et al., 2019). The intensity of sun burning on plant leaves and stem varies between 10–50%. Even complete loss of orchard can happen if sun burn occurs at initial phase just after transplantation of sapling material owing to high summer temperature in dry land regions of Marathwada (Maharashtra). To overcome this problem, an attempt has been made on trial basis for growing dragon fruit under shade net house and spraying of anti-transpirants to control the sun burn injury on dragon fruits. Apart from this, some of the progressive growers in Maharashtra started to grow low water requiring crops like drum stick and custard apple as filler crop to control the physiological injury caused by sun burn. However, further research regarding validating the findings of all experiments for improving yield and quality is required.

Fig. 20. Sun burn injuries on canopy of dragon fruit.

5.6. Reduction in fruit size and yield

This is typical problem experienced by several farmers mostly in old orchards (after 5–6 years) at least once in two years particularly during 1st and 2nd harvesting. However, this problem can tackled through good agronomic practices for nutrients and water management.

5.7. Non uniform fruit size

This is common problem starts from initial to the ends of the fruiting season in all kinds of dragon fruit orchards. However, its intensity is higher at first and the last harvesting of dragon fruit. It can be resolved by maintaining appropriate fruit density and soil moisture–nutrients management practices at initial stage of fruiting.

5.8. Canopy and residues management in older orchards

5.8.1. Canopy management

- Lack of standards on canopy management practices for Indian conditions is one of the major concerns of dragon fruit growers.

- Presently, no growers/farmers adopting any kind of canopy management practices such as training and pruning at least for initial 5 years. However, it is very much essential after 5 years (at present very few have started to adopt) for facilitating intercultural operation to obtain higher yields.
- Mostly farmers are not willing to follow standard canopy management practices since crop of dry land areas and its thorny leaves which calls for engineering interventions.
- Collapse of poles/wires due to ever increasing heavy loads of canopy in older orchard is another issue to be addressed through research.
- Better canopy management practices can help to retain the umbrella shape plant structure for sunlight interception (Fig. 21a).

5.8.2. Canopy residue management

- Most of Indian growers are unaware about the importance of pruned out canopy residues, as a lignocellulose rich substrate for preparation of compost (Fig. 21b).
- Composting methods needs to be standardised via microbial inoculation and engineering interventions. Composted substrate can be utilised as alternative to organic fertiliser like cow dung and chicken manure in same orchard.
- Research on rapid decomposing of canopy residues is lacking.

Fig. 21. Canopy (a) pruning of older orchard and (b) residue management.

5.9. Harvesting, cleaning and grading practices

- Fruit harvesting: Generally, fruits are harvested after 30–35 days after flowering when skin colour changes from green to red for better firmness, eating and storage quality. In India, harvesting is carried out manually and accomplished with the help of existing small handheld tools (sickle, cutter and picker). There is a scope for improvement of existing tools or development of novel tools/equipment for harvesting of dragon fruit (Fig. 22a).

- Cleaning, sorting and grading of fruits: At present, these activities are accomplished manually since prices of fruits are determined by different grades depending on fruit size, colour and weight (Grade A, B, C). Therefore, at least common facility of advanced grading should be available at major markets in dragon fruit producing areas (Fig. 22b).

Fig. 22. Dragon fruit (a) harvesting and (b) automated grading of dragon fruit.

5.10. Post–harvest management practices

India consumes largely fresh dragon fruit than the processed products. Hence, focus should be on standardising post–harvest management practices for fresh dragon fruits. Four major physiological disorders namely chilling injury, mechanical injury, animal injury, and water loss reduces the shelf–life of fresh dragon fruit drastically if timely care is neglected (Hsu et al., 2018). Diseases of bacterial (*Xanthomonas campestris*) and fungal (*Dothiorella spp.*) origin affect the storage quality of fresh dragon fruits. Hence, disease management should be controlled in the fields and during the postharvest handling stage. In addition to short shelf–life at ambient conditions; variable fruit size & unique taste of dragon fruit are the key factors to be considered for efficient post–harvest management practices *viz.,* precooling, vapour heat treatment for diseases control, controlled atmospheric storage facility, modified atmospheric packaging (MAP) and use of corrugated boxes for transportation to minimize the yield losses (Paull et al., 2014). During glut production, different value added products *viz.,* jam, jelly, cosmetics in addition to edible colours from the skin and flesh–pulp of dragon fruit can be prepared. Overall, practices that facilitate maintenance of better quality, higher prices, larger markets, constant supply can enhance income of farmers; standardised post–harvest management can effectively address following components of value chain which are often found weaker at Indian scenario for different vegetables and fruits including dragon fruit.

- Need to standardise quality and maturity indices based on size, colour and TSS.
- Lack of ideal pre–cooling, packaging and transportation facilities (Fig. 23).
- Lack of controlled storage facility to prevent the chilling injury, ethylene production, respiration rate, optimum temperature for enhancing shelf life of fresh fruits.

- Dragon fruits are fly host and can be disinfected through irradiation treatment.
- Lack of standardised packing materials like HDPE, polypropylene, polyethylene plastic/corrugated box etc.
- Promotion of small–scale industries to utilise dragon fruit as rich source of vital nutritional ingredients *viz.* carotene, calcium, fiber, vitamin B, vitamin C, and phosphorous. The fruit can be processed into numerous value–added products particularly during glut production (June–November).
- Lack of round the year supply of dragon fruits for continuous operation of processing plant.
- Lack of knowledge on value added products for long-term use.
- Poor marketing infrastructure and network.
- Lack of research, market and policy guidelines for post–harvest management of dragon fruit.

Fig. 23. Post–harvest management practices (grading and packaging) in India.

5.11. Marketing and human resource development

Details about marketing channel and prices of dragon fruit is well explained in a section 3.2.1. However, unstable market prices influenced by seasonal glut production and import from other countries *viz.* Vietnam and Thailand are major challenges to Indian farmers. Further, availability of trained manpower for cultivation, marketing and post–harvest management of dragon fruit is another key constraint.

6. Researchable issues in dragon fruit production

The continuously growing demand for dragon fruit due to its several bioactive and nutraceutical components widened the horizon for research, development and extension for this potential underutilised crop. Although, dragon fruit is introduced as super fruit in India; need arises to convert it as a remunerative crop of degraded land through addressing following major researchable issues.

Genetic improvement:

1. Identification, development and performance evaluation of varieties of dragon fruit for abiotic and biotic stress tolerance particularly for degraded lands.

2. Research for better insights into mechanisms of tolerance to drought, water logging, soil salinity, frost and heat stresses in dragon fruit through modern physiological, microbial and biotechnological approaches, methods and traits for screening stress–resistant genotypes.

Crop production:

1. Region specific research on standardising nursery propagation and orchard establishment techniques.

2. Research on developing standard cultivation practices for diverse agro–climatic regions through multi–location field trials.

3. Research on the soil–plant–water relations under stress conditions in dragon fruit cultivation and their management practices. Focus should be on developing integrated water, soil–nutrient, weed and canopy management practices for abiotic stressed degraded land. The major problems like flower/fruit dropping, pollination and sun burnt can be addressed through optimising the cultivation practices.

Crop Protection:

1. Development of integrated pest management programme for addressing concerns on pest and diseases with main focus on environment friendly control measures.

2. Application of climate resilient engineering interventions *viz.*, precision agriculture, shade net, mechanisation and canopy residues management for minimising impact of abiotic and abiotic stresses in dragon fruit.

Post–harvest management and marketing:

1. Standardisation of harvesting and post–harvest practices for minimising post–harvest losses in dragon fruit. Focus should be on improvement of varieties suitable for processing, value addition and marketing of dragon fruit.

2. Preparation of database of dragon fruit growers, entrepreneurs and associated scientists for collaborative research and extension for popularising the dragon fruit.

3. Research on adopting aggressive marketing strategy and infrastructure development is essential.

7. Policy issues for promoting dragon fruit in India

1. Need to develop policy framework at national level for popularising the dragon fruit in diversified agro–ecological regions since crop is comparatively new in India. There should be strong collaboration between State Govt. and Central Govt.; public and private funding institutions to promote dragon fruit not only for economic returns from degraded/dryland areas but also for medicinal uses.

2. Standardisation of regional specific package of cultivation, harvesting and post–harvest practices for round the year production of dragon fruit.

3. Strengthening research & technical support: Joint efforts of scientists, entrepreneurs, progressive growers and policy makers is highly essential to popularise dragon fruit in a resource poor dryland areas and to enhance farmers' income. The major researchable issues related to natural resource management technologies, cultural practices, disease management, improvement of varieties suitable for processing, processing and value addition and marketing of dragon fruit must be addressed immediately through research organisation supported by Govt. of India/State Government/ private and co–operative bodies.

4. Standardisation of methods for raising develop nursery and trellis system and licence to only authorised owners for ensuring quality and availability of both sapling materials and trellis at reasonable prices to the farmers.

5. Need to develop a database of area under dragon fruit cultivation, production and productivity of crop, dragon fruit farmers, entrepreneurs and associated scientists.

6. Need to develop training module on package of practices for profitable dragon fruit farming and entrepreneurship.

7. Need to establish centre of excellence on dragon fruit farming and entrepreneurship development. Another aim of centre is to disseminate information, education and communication (IEC) materials as part of extension activities.

8. Provision of financial support for marginal or small scale farmers for dragon fruit cultivation in the form of soft loan and subsidy by the government/cooperative organisations/banks, etc. The financial support is highly essential since initial capital investment of dragon fruit cultivation is around INR 6.5–7.5 lakhs per ha.

9. Post-harvest management becoming critical issue to successful marketing of dragon fruit since it is always influenced by cultural needs, harvesting stages, inherent product attributes, ambient environment, transportation and storage needs. Being a perishable fruits with comparatively low shelf life and mostly fresh consumption, attention should be given to minimize post–harvest losses. Therefore, emphasis should be given to standardisation of post–harvest operations (cleaning, grading and packaging) and development of post–harvest infrastructure including cold chain for transportation and storage. During glut production of dragon fruit, small scale entrepreneurs/growers have to be encouraged for development of new products, via value adding technologies for generating additional income.

10. Marketing and prices: At present there is assured market in India because of limited commercial growers and high demand of fruits. The market prices ranged from INR 55–250/kg depending on weight based different grades (A>400 g, B between 200–400 g and C<200 g) prevailing in market. During offseason prices persisted as high as INR 300–400/kg for Indian dragon fruit. Even huge numbers of health conscious consumers in cities paying up to INR 500–600/kg for dragon fruit imported from Vietnam and Thailand. There are report saying that more than 20,000 MT of dragon fruits are being imported into India from Vietnam, Thailand and China every year. Apart from it demand for dragon fruit in rural areas is also increasing, which will give it a wide market reach. It is predicted that production and area under dragon fruit will rise drastically; hence marketing strategies need to be critically examined including fixation of minimal support price. There is also need of developing marketing infrastructures and quality standards in view of exploring potential of future export.

11. Import strategies: There is a strong belief among Indian dragon fruit growers that unrestricted import from countries like Vietnam and Thailand creates biggest market problem as it coincided with seasonal glut production from India that ultimately results in drop in prices and hence loss for farmers. Therefore, there is a need to protect the

interest of Indian farmers' with stringent quality control on imported dragon fruit.

12. Agro tourism: As like other countries need to identify the hot spots for dragon fruit farming in dryland regions *viz.*, Kutch in Gujarat that having potential to attract steady stream of tourists and nature lovers for boosting agricultural tourism in these sites.

8. SWOT Analysis

Strength:

1. Diversified agro–climate condition and strategic geographic location of India, highly suitable for dragon fruit cultivation and marketing across the world.
2. The great scope to bring larger available degraded/barren lands particularly in drought prone and hilly regions of India under dragon fruit cultivation. The Govt. of India offered several incentives and grants for the overall development of farmers of these regions including agriculture.
3. The fruiting starts within 16 to 20 months of plantation, while the plant life is more than 20 years. The yield per hectare can be achieved up to 35 MT. The harvesting season is spread over a period of 5 to 6 months during June to November with at least one large lot every month. There is great potential of off season fruiting via varietal improvement and other cultural practices. Thus there is assured yield of at least 80% even if there are some climatic or other disruptions, making it a source of reliable income for the farmer.
4. Some unique characteristics of dragon fruit *viz.*, simple planting, low water and nutrients requirement, independent growth and flower development irrespective to water availability and potential of round the year fruit production provides opportunity of cultivating the crop in drought prone and hilly regions of India. Further, relatively consistent Indian climatic conditions *viz.,* sunlight and day length throughout years are suitable to accommodate the crop cultivation.
5. The crop has great potential to become popularise among the sugarcane and grapes growers in dryland areas due to its fast and stable income and suitability for inter-cropping.
6. Increasing demands of fresh and processed dragon fruits in rural areas, domestic and global market because exquisite taste, flavour and shape, and awareness of health benefits among the consumers and its round the year availability.
7. The great scope for processing and value addition of dragon fruits, since its ever increasing demands in nutritional and medicinal products, natural food colorants and additives, and cosmetic ingredients.

Weakness:

1. High initial capital investment challenging for marginal and small-scaled growers.
2. Lack of standardised nursery, cultivation and harvesting practices including high yielding varieties of processing causes the crop prone to pest and disease attacks.
3. Poor research, technical and policy supports for popularising crop in barren/degraded lands.
4. Dragon fruit is highly vulnerable to rain particularly during flower pollination and fruiting. The unpredictable weather events hailstorm and excess rains owing to the global climatic change may affect the production.
5. Lack of marketing and postharvest handling infrastructure degrading the fruit quality and affecting its supply chain (harvesting, loading and transportation) at orchards.

Opportunities:

1. High demand in international markets even China being a big competitor importing dragon fruit from South Asian countries. These prospective offer competitive business opportunities for global trade.
2. Some of Indian grower visited to Vietnam and Thailand and have gained high skill, knowledge and experience in dragon fruit cultivation.
3. Some Indian states started to subsidy for dragon fruit farming.
4. Pharmaceutical and food companies have an alternative for medicinal products, natural food colorants and cosmetic ingredients.
5. Well established dragon fruit orchards can be sites for agri–tourism.
6. The dragon fruit sapling material can be sold as ornamental pot plants.
7. Dragon fruit plants can be used fencing material in rural areas for protecting rearing animals from predators.

Threats:

1. The lack of awareness about standard cultivation practices among growers may produce fruits that do not meet the standard quality of grading, global trade, or customer expectations, etc.
2. Unpredictable heavy rain may create moisture conditions particularly in black soil may become more conducive for fungi that could bring higher chance of disease infection and impacting pollination.
3. Need to ensure assured market and supply chain in rural drought prone areas.

4. Unusual attack ants and birds etc. may reduce the production quantity and quality of dragon fruit.

9. Conclusion

Production and marketing data of recently introduced tropical dragon fruit crop is rarely available worldwide. Available evidences suggested the dragon fruit cultivation is continuously increasing in south Asian tropical countries. Vietnam, China, Indonesia, Thailand, Taiwan, Malaysia, Philippines, Cambodia, USA, Australia and South Africa are the major dragon fruit producing countries. While, China is biggest consumer of the dragon fruit. Apart from several health and medicinal benefits; being a hardy crop, it has got potential to grow in degraded and rainfed areas of India under diversified agro–climatic conditions. In a recent five year, many progressive growers started commercial production of dragon fruit (*Hylocereus undatus* and *Hylocereus polyrhizus*) and fetches remunerative market prices. Production and marketability of dragon fruit are expected to rise huge because of high demand and limited commercial producers. Present market trade indicate that import of this fruit is more than the production in India. To meet this demand, possibility of round the year cultivation of dragon fruit including production from degraded and dryland areas, need be explored without affecting other cultivable land areas allotted for other crop. Further, for bridging demand and supply gap various constraints were identified in dragon fruits cultivation *viz*., high initial investment, standardisation of nursery and cultivation practices, attack of insect pests and diseases, sun burnt, yellowing/dropping of flowers and fruits, low yield, short shelf life of fruits and marketing infrastructure problems. Joint efforts of scientists, growers, entrepreneurs and consultants to identify the researchable and policy issues related resource management technologies, improvement of varieties suitable varieties for processing, and marketing of dragon fruits were initiated from some government and private research organisations in India. Effort has started by some of the state agricultural departments, centrally funded organisations and private/cooperative agencies to promote as commercial crop for enhancing income of marginal and small scale farmers in dryland areas. In near future, ample attention should be obligatory for minimising post–harvest losses through standard post–harvest practices and successful marketing of fresh dragon fruit.

The SWOT analysis indicates that India has tremendous scope for all kind of dragon fruit production. There is increasing demand for quality products at competitive rate in domestic and export market. Though dragon fruit production depends on increasing and widening domestic market in future, export market will be equally attractive. To be successful in both domestic and International market it is essential to produce quality dragon fruit of organic origin and processed products to avoid pesticide residues and at competitive rate from underutilised degraded land. It is important to set policy guidelines and standards for cultivations, post–harvest and marketing of dragon fruit. It is also equally significant to commercial utilisation of established orchard sites for agro-tourism, the excess leaves as sapling material for ornamental pot plants, fruit peels for pharmaceutical uses and canopy residues left after cultivation for manure and vermicomposting for generating

additional income and enriching soil organic matter of degraded land. Overall it can be concluded that dragon fruit cultivation can become a turning point for assured income to marginal and small scale farmers and other enterprising entrepreneurs in draught prone areas.

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Appendix– I

List of dragon fruit varieties available in different countries.

Adunta–4	George's White	Malaysian Red	S9
Alice	Godzilla	Manila Red	San Ignacio
American Beauty	Golden Dragon	Maria Rosa	Scotts Purple
Apollo Yellow	Green Skin Red Flesh	Maui Dragon	Seoul Kitchen
Armando	Green Skin White Flesh	Mexican Red	Shayna
Asunta–1	Guatemalan – 2	Mexicana	Sin Espinas
Asunta–2	Guatemalan Pink	Michelle	Sugar Dragon
Asunta–3	Guatemalan Red	Moroccan Red	Sweet 21
Asunta–5	Guyute	Mr. Woo	Taiwan Pink
Australian Red	*H. Stenopterus*	Natural Mystic	Taiwan Red
Ax	*H. Broxinsis Blue*	Neon	Tex Sweet
Bien Hoa Red S	*H. Costaricensis*	Nicraguan Red	Thai Dragon
Bien hoa White	*H. Guatemalensis*	Nietzel	Thai Red
Bilu	Halley's Comet	Orejona	Thai white S
Black Dragon	Hana	Paisley	Thai yellow
Bloody Mary	Harpua	Palora	Thompson
Bruni	Hawaiian Orange	Pepino Dulce	Townsend Pink
Capistrano Valley	Hawaiian Pink	Peruvian Orange	Tricia
Caribbean Pink	Hawaiian Red	Peruvian Yellow	Trish red
Cebra	Houghton	Phoenix Red	UCLA
Chameleon	*Hylcereus Ocamponis*	Physical Graffiti	Undatus
Columbian Supreme	*Hylocereus Peruvianus*	Pineapple Cactus	Valdivia Raja
Condor	Isis Yellow	Pink Diamond	Variegata
Connie Mayer	Jacky Lee Red	Pink Flesh	Varigated white
Cosmic Charlie	Jade Red Flower	Pink Panther	Varigated yellow
Costarican Sunset S	Jade White Flower	Purple 8	Venus
Country Roads	Jala	Purple Haze	Vietnam King
Dark Star	Jc01	Rainbow	Vietnamese Giant
David Bowie	Jc02	Red Crystal	Vietnamese Red
Delight	K–1	Red ES –1	Vietnamese White
Desert King	Kathie Van Arum	Red giant	Vivid Purpurea
Desert Princess	Korean White	Red Jiana	Voodoo Child
Edgar	LA Girl	Rixford	White King
Edgar's Baby	La Verne	Rosa	White Sapphire
El Grullo	Lake Atitlan Red	Royal Red	Yellow Cross 68
Florida Red Sweet	Lemonade White	Rubra	Yellow Dragon
Frankie's Red	Lisa	Ruby Red	Yellow Thai
G2	Makisupa	S8	Zamorano

Appendix– II

Global market overview of value-added products of dragon fruit.

Table 1. Export and imports status of value added dragon fruit in global market (% share and value in US$) during 2019.

Country	% share	Export value (US $), Million	Country	Import value (US $), Million
China	14.7	513.69	**USA**	1412.09
Thailand	8.1	283.15	**Japan**	309.69
Mexico	7.7	266.51	**Netherlands**	233.81
United states	6.8	236.31	**Canada**	203.26
Netherlands	6.7	235.08	**China**	202.11
South Korea	4.3	151.23	**Germany**	198.61
Germany	3.7	129.72	**France**	196.2
France	3.7	128.80	**United Kingdom**	134.99
Canada	3.6	125.23	**South Korea**	95.54
Philippines	3.6	124.31	**Spain**	78.82

Source: https://www.tridge.com/products/canned-dragon-fruit

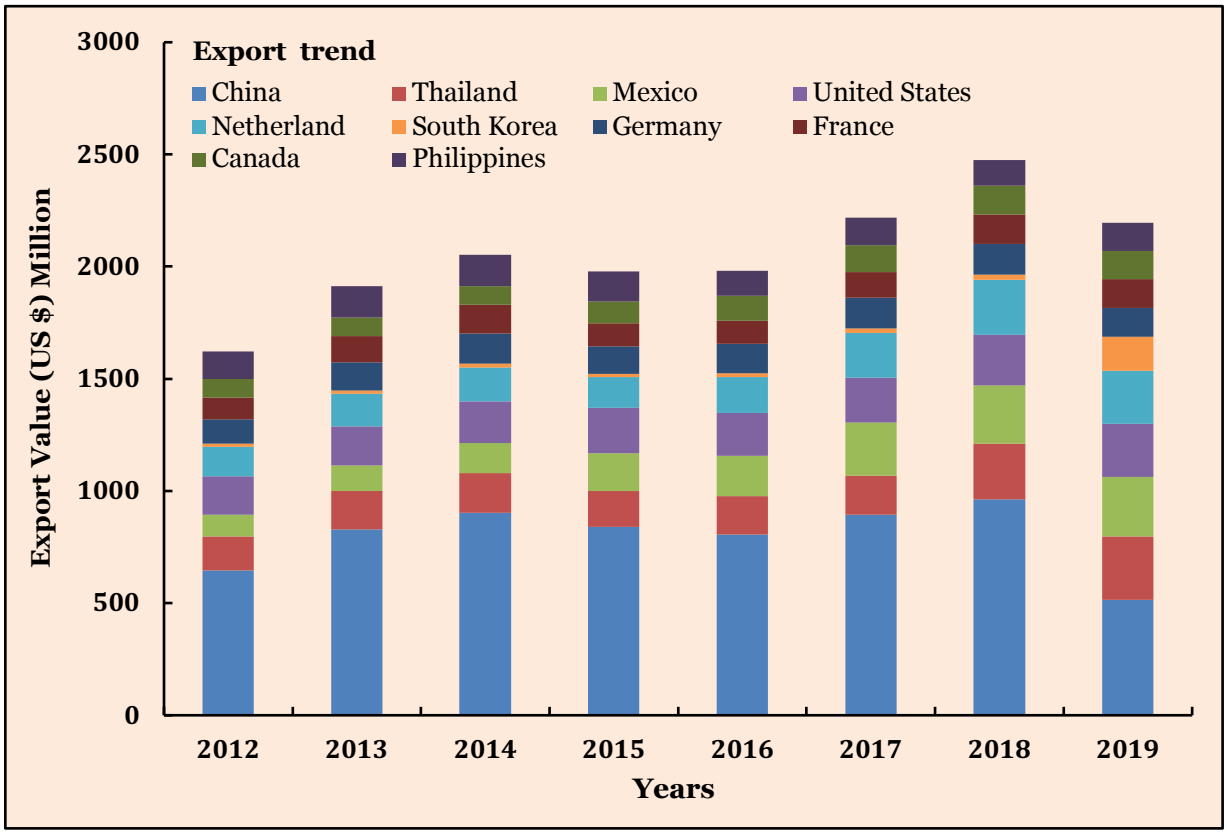

Fig. 1. Global export trend of value added dragon fruits.

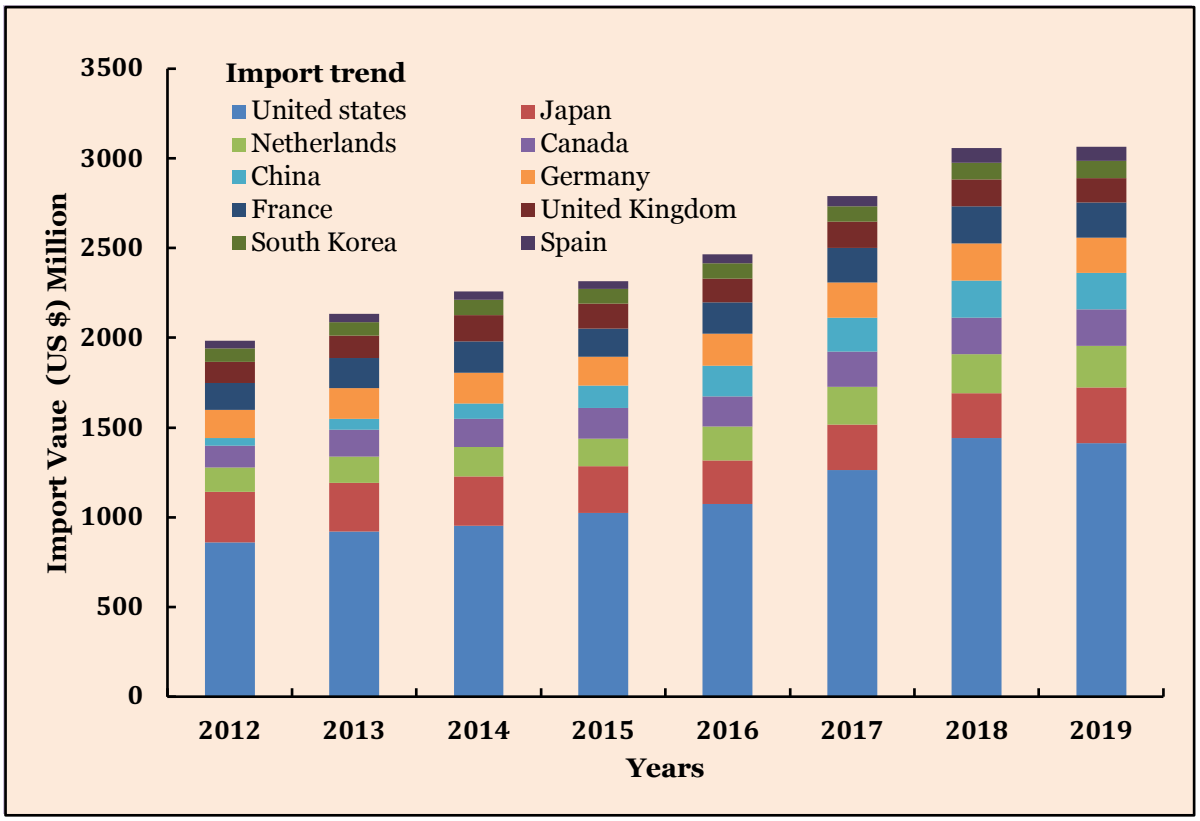

Fig. 2. Global export trend of value added dragon fruits.

Important value-added products of dragon fruits in global market

Dry dragon fruits

Dry dragon fruit-Chips

Free dried powder

Dragon fruit cubes

Dragon fruit frozen yogurt

Yogurt- Greek style

Canned dragon fruit

Frozen dragon fruit puree drink

Aloe Vera-dragon fruit pulp juice

Pure dragon fruit juice

Dragon fruit smoothie

Dragon fruit bakery (baguette)

Dragon fruit jelly

Dragon fruit flavoured -RTS

Dragon fruit energy booster(Vit C)

Dragon fruit jam

Dragon fruit cosmetic (face mask)

Dragon fruit colorant

Appendix– III

Frequently asked questions (FAQ) about dragon fruit farming.

Q.1	**What is dragon fruit and where it can be grown?**
	Dragon fruit, Pitaya and Strawberry pear is a cactus vine of the genus *Hylocereus*, tolerant to the various abiotic and biotic stresses. It is native of Central America and commercially cultivated as tropical fruit in south-east countries. It grows in almost all kind of subtropical and tropical environmental and soil conditions. It has potential to bring the India's most degraded land under cultivation.
Q.2	**What are health benefits of consuming dragon fruit?**
	It is grown for nutraceutical and edible usages as rich source of nutrients and minerals *viz.,* vitamins, protein, amino acids, fat, carbohydrate, crude fibre, carotene, phosphorus and iron etc. The dragon fruit regulates digestive process, prevent colon cancer, diabetes, neutralize toxic substances, reduce cholesterol levels, high blood pressure and can help against asthma and cough.
Q.3	**What are the ideal temperature, rainfall, water requirement and soil conditions for dragon fruit cultivation?**
	Dragon fruit is CAM plant with xerophytes' characters grown in wide range temperature, rainfall and soils. The regions of 20–30°C temperature, 500–1700 mm rainfall and slightly acidic soils with pH of 5.5–6.5 are considered as ideal for successful cultivation of dragon fruit. Generally, well drained *murrum* soil is prepared for dragon fruit cultivation in India. Dragon fruit can be also grown in the regions of excess rainfall (1730–2540 mm/year). The water requirement of dragon fruit is as low as 120 to 150 mm with micro–irrigation. In irrigated area about 1 inch of water is required weekly to plants so that soil doesn't get dry completely. About 2–4 litres of water weekly twice per plant is sufficient during the summer/dry days.
Q.4	**What is life span of the dragon fruit orchard?**
	Dragon fruit is perennial crop and produce the marketable yield up to 20–30 years depending upon agronomic management practices.
Q.5	**What is initial cost of establishing dragon fruit orchard?**
	The initial cost for establishing dragon fruit is INR 2.5–3 lakhs/acre. The cost is coverable within 2–2.5 years after plantation of dragon fruit.
Q.6	**How to propagate the dragon fruit plant? What is cost of dragon fruit plant or sapling material?**
	Dragon fruit plant is propagated through seed and vegetative propagation methods. The vegetative method i.e. stem cutting (fresh/rooted) is most common, faster and economical. The mature step segment of 15–30 cm treated with fungicides is used for plantation. Rooted cutting ready for

	transplantation in orchard after 30–40 days of nursery rising. The cost of dragon fruit materials varies between INR 15–40/plant and must be procured from authentic private/govt. nurseries
Q.7	**What are different varieties of dragon fruit available in the market?**
	Worldwide, more than 150 varieties of dragon fruit are available. However, four main types of varieties (i) red skin–white flesh (*Hylocereus undatus*) (ii) red skin–red flesh (*Hylocereus polyrhizus*) (ii) red skin–purple flesh (*Hylocereus costaricencis*) and (iv) yellow skin–white flesh (*Hylocereus (Selenicerus)* megalanthus) are preferred for commercial production in world market. In India mostly red skin–white flesh (93%) followed by red skin–red flesh (6.5–7%) are cultivated for market purpose.
Q.8	**Which is the most suitable season for dragon fruit plantation? When flowering and fruiting will be started after plantation? What is fruiting season?**
	Summer monsoon (June–August) is most preferable season for dragon fruit plantation. Plant growth is paused in remaining months of the year. Usually fruiting will start one year after plantation. Sometimes fruiting start within five months of plantation. Flowers bloom followed by fruiting occurs in July–October in a 6-8 flushes of market quality fruits. In some cases early flowering occurs in April month. Dragon fruit bears fruit for five month in years. It has potential to produce round the year fruits.
Q. 9	**What is impact of excess rainfall or excess temperature on flowering/ fruiting/stem of dragon fruit?**
	Dragon fruit is comparatively tolerant to water and temperature stress. However excess rainfall creates problems of flower/fruit dropping/rotting during rainy season. Excess temperatures causes problem of sun burning in stem of dragon fruit.
Q.10	**Why is training/trellising practiced in dragon fruit orchard? What are different types of trellis system used in dragon fruit orchard?**
	Dragon fruit as cactus vine plant, its basic requisite is to provide training to climb along wooden posts, fences and walls for support. Since plant grow very fast and its braches start spreading on ground surface as result of it creates hindrance in healthy flowering and fruiting. To prevent this damage different trellising system are being practiced for establishing dragon fruit orchard with common thump rule of allowing main vine stem to trellis and pruning other lateral stems. It includes four major trellis system *viz.,* single pole with concrete/iron ring, continuous pyramid stands, 'T' stands and wooden ladder. Amongst, concrete pole of 2 m height (buried in 40 cm in soil) with concrete ring is most commonly used in India**.**
Q.11	**What should be planting spacing for dragon fruit? How much quantity of poles and plants required for establishing one acre of orchard?**
	Planting spacing mainly depends on variety, slope and types of trellis system used for establishing orchard. Most recommended spacing of 4.0 m (row) × 3.0 m (plant) provides better air circulation and reduces chances of disease

	infection. While, in low fertile areas denser plant population with spacing of 3.0 m × 3.0 m is preferred to compensate the yield reduction. Plantation of four plants per pole is common recommended practice. About 300 to 400 concrete poles and 1200 to 1600 plants are required for establishing 1 acre dragon fruit orchard.
Q.12	**How much amount of fertiliser required for dragon fruit plant?**
	The recommended dose of fertiliser application varies with soil type and location of plantation. In general, 10–15 kg FYM or organic manure and 100 g SSP/plant is compulsory at the time of plantation of dragon fruit. About 300 g N, 200 g P and 200 g K is essential per plant each year for the initial two years. The mature plant should be given 540 g N, 720 g P and 300 g K in four equal split doses with interval of 3 months.
Q.13	**What are the common diseases, pests and predators in dragon fruit orchard? How they can be controlled?**
	In general dragon fruit is tolerant to major pests and diseases. Few important diseases of fungal and bacterial pathogens origins *viz.,* anthracnose, brown spots and stem rots affect dragon fruit crop. Heavy rainfall and overwatering or waterlogged conditions predispose the crop for these diseases. Anthracnose can be prevented by spraying with Chlorothalonil / mancozeb at 2g/L and curable by spraying with carbendazim at 1g/L. Rotting diseases are vulnerable to excess sun light and it can be controlled through copper oxychloride (at 0.2%). Fruit are occasionally infected with ants, scale insects, mealy bugs, slugs, nails, bores, caterpillars, termites, nematodes, fruit flies, bats, rats and birds. It can be easily managed by some control measures like agronomic and crop hygiene, chemical control using copper sulphate, fruit bagging, soil amendment and sterilization.
Q.14	**What is expected yield from a dragon fruit orchard?**
	In general dragon fruit yield varies with varieties, soil and climatic conditions. Actual commercial yield started after second year onwards of planting. It is estimated that about 2.5-3 tonnes of dragon fruit (with average fruit weight of 350 g) can be produced from one acre land. With excellent management the fruit yield can be extended to 7.2 to 8.00 tonnes (350-850 g/fruit) from one acre land.
Q.15	**When and how to harvest dragon fruit?**
	Most ideal harvesting period for dragon fruit is June–October in India. Usually outer bright green skin of immature fruit gradually turns into red at the end of ripening process. Only ripened fruit should be selected for harvesting so that harvesting can be done twice during week. Fruits are harvested manually using pruning knives without getting damaged. Then, harvested fruits should be immediately shifted into shades before packaging or being transferred to storage room.
Q.16	**Is it canopy management is essential dragon fruit? When?**
	Yes, canopy management is very essential in dragon fruit particularly in older orchards after 4–5 years onwards

Q.17	**What is market price of dragon fruit?**
	Dragon fruit prices varied with demand, supply and market grades. The estimated average price of dragon fruit in the local market is ranged from INR 55–250/kg depending on weight based grades (A> 400 g, B between 200–400 g and C < 200 g). During offseason prices persisted as high as INR 300–450/kg for Indian dragon fruit. The market prices for imported dragon fruit is INR 500–600/kg in a cities.
Q.18	**What is shelf-life of dragon fruit? What are ideal storage conditions for dragon fruit after harvest?**
	The shelf life of freshly harvested dragon fruit varies between 3–4 days at ambient conditions. Fruits shows decrease in weight and shrivelling after 7–8 days of harvest. No extra storage facility required for storage if fruit sold in local market immediately after harvest. Usually storage condition varies with variety and climatic conditions. The fruits are generally stored in perforated bags at 8°C for 25–30 days. Sometimes storage temperature of 15–20°C and relative humidity of 85–90°C is preferred fresh market delivery. The shelf life can extended up to 45 days during storage at 7–10°C with relative humidity of 90-98%. The yellow varieties can be stored up to 28–30 days at 10°C temperature.
Q. 19	**What kind of packages used for transportation and marketing?**
	For short term transport into local market, perforated plastic carats of ~20 kg capacity, commonly designed for other fruits and vegetables are used for dragon fruit. The corrugated boxes of 10 kg capacity is usually used long term transportation and marketing. The dragon fruits of different grades (A, B, C) were packed into corrugated boxes.
Q.20	**Can dragon fruit processed into valued added products?**
	Dragon fruit mostly consumed in fresh from. Pulp of dragon fruit can processed into various valued added juice, jam, jelly, candy, syrup, and wine etc. Different pharmaceutical products, colorant and cosmetics can be prepared from seed and peel of the dragon fruits
Q.21	**What are major markets of dragon fruits in India and abroad?**
	Presently, dragon fruit is popularising in domestic urban and rural markets of India. Delhi, Mumbai, Kolkata, Bengaluru, Chennai, Pune are major domestic markets of dragon fruits. Vietnam is biggest producers and exporter dragon fruit in world market. While China, is biggest importer and consumers of dragon fruit.