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Chia (*Salvia hispanica* L): A Nutri-rich Potential Crop, its present Scenario and Future Perspectives in India

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Abstract

Chia (*Salvia hispanica* L.) was used as a super food from ancient times. In recent days with increase in the health awareness throughout the world, it demands for healthy food, using chia seeds in daily diet may prevent many diseases (diabetes, obesity and cardiovascular). Chia was domesticated almost 4,500 years ago in Mesoamerica and it was used as food and medicine. Chia seed is composed of high dietary fibre (18-30%), ash (4-5%), protein (15-25%), fats (30-33%), lipids (31-35%), carbohydrates (26-41%), minerals, vitamins and a high amount of antioxidants. It is having higher concentration of PUFAs (Poly Unsaturated Fatty Acids) of omega-3 (58-64% of the total lipids) and omega-6 essential fatty acids. Notably, chia seeds are free of gluten. It may be added to other foods as topping materials. Nutritional composition and health benefits of chia are presented here to create awareness. In recent years, India is one of the major producers and exporters of chia. Karnataka alone occupies more than 50 per cent of area of our country. Research on chia is gaining momentum for increasing productivity, but crop improvement research is lacking because of limited germplasm in this crop. Chia seeds are among the majorly exported commodities as the production of the commodity is limited to a few geographies. However, the COVID pandemic has increased the health consciousness among consumers, which has opened an opportunity for super foods, including chia seeds. This factor is anticipated to propel the market during the 2020-26. The Global Chia Seeds Market is projected to grow at a significant rate of 8.86 per cent from 2019 to 2024 to reach a market value of USD 450 million by the end of 2024. Information contained in this review can be useful for health conscious people who want to be healthy through natural foods. This paper describes the huge nutritional and therapeutic potential of chia seed to make it the part of an average diet for better health and longevity. Present scenario in the country and future market potential in the country are also reviewed. Successful cultivation of chia crop in India will improve economic condition, living standards and health.

Keywords : Chia, nutrition, Climatic requirement, Area, Production, Present scenario and Future market potential

Chia (*Salvia hispanica* L.) a nutri-rich crop was originated from Mexico and Guatemala and belongs to the mint family Lamiaceae. It was a part of human food for about 5500 years. Traditionally, the seeds were used by Aztecs and Mayas people in the preparation of folk medicines, food and canvases. In pre-historic times in Columbian societies, it was the second main crop after beans (Armstrong, 2004). The word chia is derived from a Spanish word 'Chian' which means oily, it is oilseed, with a power house of omega-3 & omega-6 fatty acids, superior quality of protein, higher extent of dietary fibre, vitamins, minerals and wide range of polyphenolic antioxidants which act as antioxidant and safeguard the seeds from chemical and microbial breakdown (Cahill, 2003). A plant of South American origin, chia a popular nutraceutical is a rich source of Omega-3 fatty acids and is gaining popularity across the world because of its nutritional value. Chia is grown commercially for its seed, a food rich in omega-3 fatty acids since the

seeds yield 25-30 per cent extractable oil, including α-linolenic acid. Typical composition of the fat of the oil is 55 per cent omega-3, 18 per cent omega-6, 6 per cent omega-9 and 10 per cent saturated fat (Ullah *et al*., 2017). Chia seeds are popularly known as '*Sabja*' in Hindi '*Gale*' in Kannada and 'Chia' in English.

Chia seeds contain slightly fewer calories compared to flax. It has more fiber and contains 1.5 - 2 times more of the bone-strengthening minerals calcium and phosphorus as well as slightly more iron. According to the Nutritional Science Research Institute (NSRI), chia seed is considered a Dietetic Nutritional Supplement by the Food and Drug Administration in the United States and qualifies as 'healthy food' by NSRI's standards (Tim and Motis, 2011). Chia has a long history as a food crop both for humans and animals and is being 'rediscovered' for its nutritional value and health benefits.

Chia was domesticated almost 4,500 years ago in Mesoamerica and it was used as food and medicine. However, it became a forgotten crop and remained as unknown crop for many years (Ayerza and Coates, 2007). It is currently cultivated in, Australia, Bolivia, Colombia, Guatemala, Mexico, Peru, Paraguay and Argentina (Busilacchi *et al*., 2013). The largest production centre is located in Mexico and currently exports seeds to Japan, USA, and Europe (Alenbrant *et al.*, 2014). The cultivation of chia is gaining popularity in Africa and Asia because it is considered as a good nutritional and healthy food. In recent years, Indian states also witnessing more area under chia production especially in Uttar Pradesh, Rajasthan, Andhra Pradesh and Karnataka.

The area under cultivation of chia crop is expected to rise in the coming days as it requires less water and is drought resistant, It comes up very well under adverse climatic conditions. In recent time, public health awareness is increasing throughout the world, it demands for functional food with multiple health benefits. The use of medicinal food to prevent diseases such as diabetes, obesity and cardiovascular problems is now gaining momentum in India as well as in the globe. Malnutrition problem in the world is a big threat that is alarming our country too and there is a need to adopt nutritionally secured new diet practices for better health. This problem can be overcome by cultivation and consumption of new super food crop like chia which is nutritionally rich. Chia seeds may be added to other foods as a topping into smoothies, breakfast cereals, energy bars, granola bars, yogurt, tortillas and bread. In 2009, the European Union approved chia seeds as a novel food, allowing chia to be 5 per cent of a bread product's total matter. The gel prepared out of chia seeds may be used to replace the egg content in cakes while providing other nutrients also. The chia oil has superior quality than other oils such as soybean oil, sunflower oil, rapeseed oil and olive oil. Chia is the safest, cheapest and the most sustainable source of PUFA's omega-3, as the intake of 25 to 50 g per day is enough to meet the daily demand (Vuksan *et al.,* 2010). Hence, there is a need to introduce chia seeds into Indian diets because of its numerous positive nutritional characteristics to achieve nutritional security.

Botanical Description

Chia belong to the family Lamiaceae; Genera Salvia, Species hispanica, commonly known as chia, Spanish sage, Mexican chia and black chia (Hentry *et al*., 1990). Plant is an annual herb with a height of about one meter with reverse petiolate and serrated leaves (4-8 cm long 3-5 cm wide) with hermaphrodite flowers, flowering during summer (USDA, 2011). Plant can grow in a wide range of well drained clay and sandy soils with reasonable salt and acid tolerance. It can produce 500-600 kg seed/acre but under appropriate agronomic conditions the yield of 2500 kg/acre has also been reported (Cahill, 2003). In tropical country like India, Chia is an annual herbaceous plant that can reach nearly one meter in height. Its serrated lime-green leaves are oppositely arranged. The plant bears spikes of small blue, purple or white flowers that have a high rate of self-pollination. The small oval seeds are about one mm in diameter and feature a shiny, mottled or speckled seed coat that ranges in colour from dark brown to gray-white. The seeds produce a

mucilaginous gel when soaked in water. It is a desert plant requiring little irrigation and grows well in sandy loam soils, but it is sensitive to frost and day length. The plant resists insect pests and disease and is a good candidate for organic production.

Nutritional Composition of Chia Seeds

Chia seed is composed of high dietary fiber (18-30%), ash (4-5%), protein (15-25%), fats (30-33%), lipids (31-35%), carbohydrates (26-41%), minerals, vitamins and also contains a high amount of antioxidants (Ixtaina *et al*., 2008). The heavy metal content of seeds was within the safe limits with no potentially toxic mycotoxins and gluten (Peiretti and Gai 2009). It is having higher concentration of PUFA's (Poly Unsaturated Fatty Acids) of omega-3 (58-64% of total lipids) and omega-6 essential fatty acids (Valdivia and Tecante, 2015). This fatty acid is found to be very good for heart health. These characteristics help for its rapid increase in its production worldwide. The ALA (Alpha Linolenic Fatty Acid) in Chia seed is the only known essential PUFA omega-3 that the body cannot produce on its own. It can fulfil the needs of human health.

TABLE 1

Nutritional value of chia seeds

Nutrient	Value	
	USDA, 2016	Jin *et al.*, 2012
Energy	486 kcal	562 kcal
Protein	16.5 g/100 g	24.2 g/100 g
Total lipid	30.7 g/100 g	40.2 g/100 g
Ash	4.8 g/100 g	4.77 g/100 g
Carbohydrate	42.1 g/100 g	26.9 g/100 g
Dietary fibre	34.4 g/100 g	30.2 g/100 g
Calcium	631 mg/100 g	456 mg/100 g
Iron	7.7 mg/100 g	9.18 mg/100 g
Magnesium	335 mg/100 g	449 mg/100 g
Phosphorus	860 mg/100 g	919mg/100 g
Potassium	407 mg/100 g	726 mg/100 g
Sodium	16 mg/100 g	0.26 mg/100 g
Zinc	4.6 mg/100 g	6.47 mg/100 g
Copper	0.9 mg/100 g	1.86 mg/100 g
Manganese	2.7 mg/100 g	3.79 mg/100 g

Omega-3 is found in foods such as chia seed, flax seed, flax oil, olive oil, walnuts, sea fish, spinach, cauliflower, broccoli *etc*. Since 2000, India has been witnessing increased use of sunflower oil for consumption purpose, which has resulted in a drastic imbalance of the essential fatty acids with more intakes of omega-6 fatty acids. Recently, chia seed is gaining popularity across the globe because of its higher beneficial nutritional value for health.

The chia oil has superior quality than other oils such as soybean oil (*Glycine max*), sunflower oil (*Helianthus annuus* L.), rapeseed oil (*Brassica napus* L.) and olive oil (*Olea europaea* L.) (Ayerza, 2013), it has a higher percentage of fatty α-linolenic acid, reaching 68 per cent (Ayerza and Coates, 2011). Even if it is not cultivated on a large scale today, chia deserves to receive a great attention due to the universal applicability of its products and derivatives.

TABLE 2

Amino acid contents (per 100 g)

Amino acid	g/100 g seed
Aspartic acid	1.689
Threonine*	0.709
Serina	1.049
Glutamic acid	3.500
Glycine	0.943
Alanine	1.044
Valine*	0.950
Cysteine	0.407
Methionine*	0.588
Isoleucine*	0.801
Leucine*	1.371
Tryptophane*	0.436
Tyrosine	0.563
Phenylalanine*	1.016
Lysine*	0.970
Histidine*	0.531
Arginine	2.143
Proline	0.776

*Essential amino acids

Source : U.S. Department of Agriculture (2011)

TABLE 3
Vitamin contents (per 100 g)

Vitamins	Units	Quantity
Vitamin C (total ascorbic acid)	mg	1.60
Thiamine	mg	0.62
Riboflavin	mg	0.17
Niacin	mg	8.83
Folate	ìg	49.00
Vitamin A	IU	54.00
Vitamin E (á-tocopherol)	mg	0.50

Note : IU = International unit
Source: U.S. Department of Agriculture (2011)

TABLE 4
Concentration of antioxidants in chia seed

Compound	mol/kg
Seed Not hydrolyzed	
Caffeic acid	6.6×10^{-3}
Chlorogenic acid	7.1×10^{-3}
Hydrolyzed	
Myricetin	3.1×10^{-3}
Quercetin	0.2×10^{-3}
Kaempferol	1.1×10^{-3}
Caffeic acid	13.5×10^{-3}

Source : Ayerza and Coates (2001)

Health Benefits

The results of a scientific investigation conducted in St. Michael Hospital in Toronto Canada revealed some key benefits of chia (Vuksan *et al*., 2010), which are listed below:

- Best source of omega-3 fatty acids and gluten free
- Higher iron and fibre content, more calcium and magnesium than milk
- Consumption of 37 g seed on daily basis stabilized blood glucose level in diabetic patients
- Prevents myocardial in fraction and strokes by inhibiting platelets aggregation, Lowers systolic blood pressure up to 6 mm Hg
- Reduction of cholesterol and inhibition of blood clotting
- Prevent stresses and epilepsy, improvement of the immune system
- Eating chia in pregnancy helps in the development of retina and brain of foetus (Fernandez *et al*. 2008)
- The other benefit of feeding chia seed was the reduction of omega-6 in plasma, resulting in a lower omega-6 : omega-3 ratio which has a cardio-protective effect (Ayerza and Coates, 2007).

The results of this study revealed that feeding chia seed greatly decreased the visceral adiposity, decreased triglycerides and decreased LDL cholesterol.

The effect of feeding chia seed (50 g/day) to 12 healthy individuals for 30 days was investigated. The results showed that the diastolic blood pressure decreased from 66.1 to 61.5 mmHg with significant decline in serum triglycerides and no side effect was reported (Vertommen *et al*, 2005).

In an another investigation, Fernandez *et al*. (2008) studied the effect of chia seed on the immune system of 23 days old weanling Alewistar rats, the concentrations of thymus and serum IgE were used as an indicator of immunity. Trial was conducted for one month, rats were divided into three groups, one group was fed on chia seeds 150 (g/kg diet), second group was fed on chia oil 50 (g/kg diet), while the third group was kept control. The results evidenced that no difference in body weight and IgE, when chia was administered in seed or oil form. Concentration of IgE was considerably higher in both the groups as compared to the control.

Inclusion of chia in any form did not induce any symptom of abnormal behaviour, diarrhoea, dermatitis. Supplementation of diets with other sources of omega-3 fatty acids such as flax seed or

marine products usually results in allergy, fishy flavour, problems of gastrointestinal tract, diarrhoea (Ayerza and Coates, 2005).

In a study to determine the likely benefits of topical omega-3 fatty acids, topical products containing chia oil formulated. Five patients with pruritus affected by end stage renal disease and five health volunteers having xerotic pruritus were used in this investigation. A topical formulation was prepared by the addition of 4 per cent chia oil and applied for 8 weeks. Itching indications, trans-epidermal water loss and skin capacitance were measured on a 6 points scale. The results indicated that topical chia seed oil is effective for pruritus and xerosis treatment and is also beneficial for skin moisturization in healthy volunteers with xerotic pruritus, as well as patients with chronic renal failure or diabetes (Se Kyoo Jeong *et al.*, 2010).

Alpha-linolenic acid play a vital role in the formation of vital biochemical compounds such as prostaglandins, leukotrienes and thromboxanes which are encountered in numerous physiological functions (Pawlosky *et al*., 2003). Omega-3 fatty has the capability of blocking calcium and sodium channel dysfunctions, which otherwise can resulting in hypertension (Leaf and Kang, 1998). Omega-3 fattyacids improve the parasympathetic tone, heart rate variability and protect ventricular arrhythmia. Fatty acid composition of chia has been reported in literature (Ayerza and Coates, 2005), the concentration of omega-3 and omega-6 fatty acids in all the studies were consistent with minor variations. Alpha-linolenic acid content of the seed greatly depends upon the developmental stage, a declining trend (23%) in the concentration of alpha-linolenic acid has been reported in the fully matured seed and the similar fashion of decline has also been reported in lignin content (Ingeborg *et al*., 2004) performed a meta-analysis.

Soil and Climatic Requirement

It is a short-day flowering plant, the length of growing cycle (100-150 days) varies based on location and is influenced by elevation also. It hardly needs less inputs or fertiliser. It requires the light to medium clay or sandy soils for cultivation, low maintenance, moderately fertile and well-drained soils but can cope with acid soils and moderate drought. The plants have purple or white, self pollinating flower spikes. Chia grows naturally in tropical and subtropical environments. It is optimally established from 400 to 2500 m above msl but conditions below 200 m elevation are not adequate for its cultivation (Orozco *et al*., 2014). It is intolerant to freezing in all development stages (Lobo *et al*., 2011; Bochicchio *et al*., 2015). Its minimum and maximum growth temperatures are 11 and 36 °C, respectively with an optimum range of 16-26 °C (Ayerza and Coates, 2009). It is considered to be a short-day plant with a threshold of 12-13 hour (Jamboonsri *et al.*, 2012; Busilacchi *et al.*, 2013) and as such, its period of growth and fruiting depend on the latitude where it grows. Jamboonsri *et al.* (2012) indicated that domesticated chia germplasm has a flowering induction photoperiod of approximately 12:12 h. Thus in the Northern Hemisphere chia begins to flower in October and in the Southern Hemisphere in April (Hildebrand *et al*., 2013).

Hildebrand *et al*. (2013) indicated that with existing plant germplasm, distribution of chia for grain production is restricted to 22°55' N to 25°05' S. At higher latitudes, the probability of the crop reaching maturity is low, since plants die due to early frosts (Ayerza and Coates, 2005). With the idea of widening cultivated area to temperate zones and regions such as the Mediterranean basin, efforts to induce chia to flower with day lengths greater than 12 hour have failed (Cahill, 2003).

Jamboonsri *et al*. (2012) demonstrated the existence of new chia varieties with early flowering, which were able to flower with a photoperiod 15:9 h in greenhouse and in the field with a photoperiod of 14 h 41 min. The sowing date is an extremely relevant variable, since it determines the duration of the development period of the crop due to variations in environmental temperature and day length to which it is exposed (Lobo *et al*., 2011). These conditions are mostly responsible for the potential yield and seed quality (Ayerza, 2010).

Fig .1 : Chia seed and crop in the field

Present Scenario of Chia Crop in India

Chia seeds have been available in health and lifestyle stores in the country's metros, having been imported from Mexico. In India, the newly introduced crop is gaining importance in few states of the country *viz.,* Rajastan, Madya Pradesh,Uttar Pradesh, Andhra Pradesh and Karnataka. In Karnataka, on experiment basis, adoptability trial of chia crop was first conducted in All India Co-ordinated Research Network on Potential Crops University of Agricultural Sciences, Bengaluru during 2012-13. Later, it was the team of Ram Rajasekharan, former Director of Mysuru-based Central Food Technological Research Institute (CFTRI) and his colleagues, biochemist Malathi Srinivasan and plant breeder R. V. Sreedhar who introduced chia as a crop among Karnataka farmers. Growing it in the 38 acres in Bengaluru campus of CFTRI, researchers began work on chia seeds in 2012. Crop improvement programme was initiated in CFTRI through pure line selection and developed a pure line with blue flower and white seeds and a high yielding line of white flower and white seeds and have tested them through five generations.

In October 2014, CFTRI organized an all India farmers 'Empowerment program', where hundreds of farmers who had come from different parts of the country were gifted 100g pouches of chia seeds along with information on agronomical practices to be followed. In September 2014 at a farmer training event in Central Food Technological Research Institute (CFTRI), former Agriculture Secretary Srivasta suggested Gopinath to start a Farmer's Producer Company to mitigate farmer distress by income generation. At the event, CFTRI shared 50 grams of premium white chia seeds with Gopinath, which he cultivated in his farm in Belikere village, Mysuru. However, Gopinath Co-founded the Raitha Mithra Farmer Producer Company in 2015 with Kurubur Shantakumar, President of All India Sugarcane Growers Association. Within the first year, the company gained a surplus of Rs.38,000. Today, the company has 526 farmers as shareholders from eight districts of Karnataka and over 1,500 farmers are connected with the organisation through its six branch offices in Karnataka. Raitha Mitra is providing a sustainable business model for farmers by connecting with marketing organisations who buy chia seeds in bulk. Since 2015, Chia farming is currently increasing opportunities for farmers in Mysuru, where the Raitha Mithra Farmer Producer Company has been assuring a buy-back agreement of chia seeds at Rs.15,000-20,000 per quintal which is more profitable than finger millet and other traditional millets.

In recent years, the area under chia crop is increasing every year and it was estimated that chia cultivation in Karnataka alone is more than 5-6 thousand acres with a production of more than 2000 metric tonnes. Many farmers are growing chia crop with buy back agreement with companies *viz.,* Nutri-planet Foods Pvt. Ltd and Quessential India Pvt. Ltd. Situated in Bengaluru and Malur Industrial area respectively.

Research Programmes in the Country

Very limited work has been done on crop improvement of chia as there are limited germplasm available in the country. Though CFTRI, Scientists at Mysore have identified two varieties through pure line selection

viz., Champion 1 (Black seed variety) and another one Champion 2 (White seed variety) during 2016. However, All India Co-ordinated Research Network (AICRN) on Potential Crops, Bengaluru centre have been initiated crop improvement programme by adopting mutation breeding programme to harness the new variability and to identify potential mutants with better productivity and nutritional qualities. Similarly, development of production practice is also being carried out (Anonymous, 2022).

Few research programmes on development of production practices have been carried out at different locations and research outcome is reviewed here. Research study at All India Co-ordinated Research Network on Potential Crops, Bengaluru centre indicated that among the planting geometry, seed yield (1045 kg/ha) was significantly higher spacing of 60cm x 15cm as compared to 45 x 15cm and 75 x 15 cm spacing. However, among the fertilizer levels 40:20:20 NPK kg/ha was found better for higher seed yield (1250 kg/ha) as compared to other fertilizer levels (Anonymous, 2021).

Result of the study at University of Agricultural and Horticultural Science, Shivamogga, Karnataka showed that there was significant increase in number of spikes plant^{-1} and seed yield with spacing of 60 cm x 45 cm (76.01 and 597.59 kg ha^{-1}) and fertilizer level of 90:60:75 kg NPK ha^{-1} (69.39 and 623.60 kg ha^{-1}). Higher number of spikes and yield (88.57 and 676.58 kg ha^{-1}) was obtained in treatment combination of 60cm x 45cm with 90: 60:75 kg NPK ha^{-1} compared to other treatment combinations (Mary *et al*., 2018).

Study conducted by Punyasloka Mohanty *et al*. (2021) at Prayagraj Uttar Pradesh indicated that, among different nitrogen levels the application of 100 kg N/ ha at 50 cm × 20 cm spacing produced significantly superior plant height (151.48 cm) and seed yield (1210 kg ha^{-1}). The highest seed yield produced by the application of 100 kg N ha^{-1} at 50 cm × 20 cm spacing is 49.58 per cent more than control plot (60 kg N ha^{-1} at 60 cm × 30 cm spacing).

A field experiment conducted at research and demonstration block of Research Institute on Organic Farming (RIOF), University of Agricultural Sciences, GKVK, Bengaluru during *rabi* 2020-21 and 2021-22 for two consecutive years to study the effect of different spacings and organic sources of nutrients on growth and yield of chia. The pooled data of two consecutive years indicated that spacing of 75 x 15cm recorded significantly higher plant height (89.12cm), whereas 90 x 30cm spacing recorded significantly higher number of leaves plant^{-1} (55.49) and dry matter accumulation plant^{-1} (151.23 gm). The higher grain yield, haulm yield and harvest index (1099 kg ha^{-1}, 1855 kg ha^{-1} and 0.372, respectively) were recorded with spacing of 90 x 15 cm. Among the organic nutrient levels, application of 100 kg N equivalent ha^{-1} recorded significantly higher plant height (85.88 cm), number of leaves plant^{-1} (54.38), dry matter accumulation plant^{-1} (150.32 gm), grain yield, haulm yield and harvest index (1078 kg ha^{-1}, 1827 kg ha^{-1} and 0.368, respectively). However, interaction of different spacings and organic nutrient levels were found non significant (Chaithanya *et al*., 2022).

A field experiment conducted during *kharif* season-2019 at Agricultural Research Station, Chintamani, Karnataka, indicated that the wider spacing of 60 × 30cm produced significantly higher number of primary branches per plant (22.38), secondary branches plant^{-1} (27.69), dry matter accumulation plant^{-1} (146.09g) and leaf area plant^{-1} (4292 cm^2), number of spikes plant^{-1} (81.68), number of spikelets spike^{-1} (28.50), spike length (14.82 cm), seed weight spike^{-1} (0.23 g), seed yield plant^{-1} (18.62 g), seed yield (1016 kg ha^{-1}), haulm yield (4765 kg ha^{-1}), protein (22.93%) and oil content (29.44%) as compared to 45 × 30cm, 45 × 15cm and 60 × 15cm spacing. Among the fertilizer levels, application of 80:60:60 kg NPK ha^{-1} noticed significantly higher plant height (125.59cm), primary branches (22.47), secondary branches (27.63), dry matter accumulation (131.47g) and leaf area plant^{-1} (4556cm^2), number of spikes plant^{-1} (72.26), seed yield plant^{-1} (12.65g), seed yield ha^{-1} (1020kg ha^{-1}), haulm yield (4125kg ha^{-1}). Significantly higher seed yield (1122 kg ha^{-1}) was

obtained in the treatment combination of 60 × 30cm with 80:60:60kg NPK ha^{-1} compared to other treatments (Singh *et al*., 2023).

Experiment conducted at Central Research Farm, Gayeshpur, Nadia under BCKV, West Bengal during 2019-20 and 2020-21 revealed that crop under direct sowing with closer spacing (50 × 20cm) had the greater number of primary branch $plant^{-1}$ (15.7), primary branch length (38.4cm) and main inflorescence length (25.9cm), thereby reflecting superiority of this treatment combination over others. This treatment combination produced significantly the highest grain (672 kg ha^{-1}), stem (1109 kg ha^{-1}) and husk yield (375.2 kg ha^{-1}), which led to increase harvest index (31.2). The greatest economic response in terms of gross return (228.4 × 10^3 ha^{-1}), net return (166.3 × 10^3 ha^{-1}) and B:C ratio (3.67) was recorded in crop under this treatment combination. Based on quadratic regression equation, the optimum plant density of chia was calculated as 71,428 plants ha^{-1}. Thus, direct seed sowing at a density of 71,428 plants/ha (spacing ~ 55 cm × 25 cm) can be done for chia cultivation during *rabi* season in West Bengal condition (Kundu *et al*., 2023).

The result of the field experiment was carried out at Zonal Agricultural Research Station, V.C. Farm, Mandya during *kharif* 2019 to evaluate the suitable methods of establishment and nutrient management practices on yield and economics of Chia revealed that transplanting method of Chia cultivation resulted in significantly higher seed yield (1043.8 kg ha^{-1}), gross income (Rs.167016 ha^{-1}), net returns (Rs.128542 ha^{-1}) and B:C ratio (4.34) and was on par with line sowing than broadcasting methods of establishment. Among nutrient management practices, application of 60:40:40 NPK kg ha^{-1} + FYM (8 t ha^{-1}) resulted significantly higher seed yield (1120 kg ha^{-1}), gross returns (Rs.179250 ha^{-1}), net returns (Rs.136323 ha^{-1}) and B: C ratio (4.18) followed by application of 40:20:20 NPK kg ha^{-1} + FYM (8 t ha^{-1}), FYM (8 t ha^{-1}) and found significantly superior over other treatments (Manasa *et al*., 2023).

At UAS, Bangalore, germination test of white and black chia seeds was carried out. Raw chia seeds were sprinkled with water, allowed to stand at room temperature, incubated at 24°C for time duration of 18, 24, 36, 48 and 54 hours with distilled water, warm distilled water at 45°C and 2 per cent sugar solution. The highest germination percentage of the treatments was selected for analysis of amylase and vitamin C. The highest content of amylase, vitamin C of specific time interval and sensory evaluation were carried out. The results revealed that different time durations, the treatment with distilled water (T_1) for white chia and with warm distilled water (T_2) for black chia seeds were found to give highest germination percentage and both with T_1 were highly accepted for sensory evaluation. Amylase activity was found to be highest at 36 hour's time duration having 1.24 and 1.20 mg/100g for white and black variety, respectively. Vitamin C content was highest for white and black variety at 36 hours having 80.67 and 66.67 mg/100g, respectively. Findings concluded that germination of chia enhanced amylase and vitamin C content (Jelang *et al*., 2023).

Production Practices of Chia

Propagating Chia Seeds

Chia seeds are propagated from both the seeds and seedlings, growing chia plants from seeds can be the best job. Soil should be well drained and bring it to fine tilth for better germination, sow the seeds over it and cover them with soil. Watering should be done at regular intervals. Chia seeds start sprouting with in 3-5 days. Thinning is to be done when the seedling grows up to 20-30 cm tall with 5-6 pairs of true leaves (Arya and Kumar, 2021).

Sowing and Seed Rate

Cultivation of chia seeds requires light to medium clay or sandy soils. The crop can give good yields in well-drained, moderately fertile soils; it can also resist acid soils and moderate drought. For sowing chia seeds, you need fully moisture soil for seedling establishment, while the maturing chia plant cannot resist wet soils during growth. Traditional cultivation techniques of chia include soil preparation by

disruption and loosening followed by seed broadcasting. In modern commercial production, a typical seed rate of 1.0 kg ha^{-1} and spacing of 60 cm x 15 cm will be optimum (Anonymous, 2022).

Fertilization and Irrigation

Chia can be cultivated under low fertilizer input, using 40-20-20 NPK kg ha^{-1} or in some cases, no fertilizer is used. Irrigation frequency in chia production field may vary from none to eight irrigations per growing seasons, depending on climatic conditions and rainfall (Anonymous, 2022).

Diseases and Crop Management

Crop is not affected by major pests or diseases. Essential oils in Chia leaves make them more resistant to insects, making them suitable for organic cultivation. Virus infections, sometimes transmitted by whiteflies may occur. Weeds can create a major problem during the early growing period of the chia crop until its canopy closes, but because Chia is sensitive to the most commonly used herbicides, mechanical weed control is preferred. Some viruses that infect the genus Salvia are Cucumber mosaic virus, the Broad bean wilt virus, Mung bean Yellow Mosaic Virus, Tomato yellow leaf curl virus, and other putative golden mosaics. These viruses can affect crop production to a greater extent. One has to take necessary measures as soon as the crop is infected with these viruses.

Harvesting Chia Seeds

Harvesting period depends on the days required to dry a plant. Farmers are cutting manually and doing heap until it dries fully. The seeds are separated from the capsules by beating with sticks or machine can also be used.

Seed Yield and Composition of Chia

Yield of chia seeds varies on cultivars, mode of cultivation and growing conditions by geographic region. For example, in commercial fields, the yield ranges from 1,000 - 1,250 kg ha^{-1}. The higher yields can be expected when there is favourable growing environment and cultivar interaction.

Future Global Market Potential of Chia Seeds

Health consciousness among people increases the consumption of chia seeds as it is rich in antioxidants and excellent source of omega-3 fatty acids. However, peoples are prefere to consume organic products as they are free from toxic chemicals, this intern raising the growth of the Global Packaged Chia Seed Market over the period 2021-2026.

Chia seeds are among the majorly exported commodities as the production of the commodity is limited to a few geographies. Hence, the initial COVID-19 lockdown caused disruptions in the logistics system, which affected the supply of the commodity across the world. This led to a decline in the market during the first half of 2020. However, the pandemic has increased the health consciousness among consumers, which has opened an opportunity for super foods, including chia seeds. This factor is anticipated to propel the market during the 2020-26. Chia seeds do not follow the commoditization trend as the market is still small. However, as more consumers are now aware of chia seeds and their benefits, the market is likely to witness tremendous growth in the near future globally. The United States and Australia continue to be the countries with the highest demand for chia seeds and other chia-based products, but there are markets, such as the United Kingdom, Brazil, Chile and Spain, that have shown a substantial increase in their demand. The increased demand for nutritional ancient grains and multi-cereal-based products as functional foods are driving the demand for chia seeds. Chia seeds are gluten-free and have high protein content. The gluten-free property of chia seeds is expected to create a strong demand among consumers suffering from gluten intolerance (celiac disease), or those who simply avoid gluten because of their lifestyle choices (Mordor Intelegence, 2022).

The Global Packaged Chia Seed Market based on Product Type can be further segmented into White Chia Seed, Black Chia Seed and Brown Chia Seed. The Black Chia Seed segment is the major segment generating revenue in 2020. Black chia seed is small

in size and contains more protein that rises the preference for black chia seed among health-conscious people. Moreover, black chia seed are mostly used in food and beverage industry owing to its benefits about health that raising the adoption of chia seeds among consumers. The White Chia Seed segment is estimated to register the fastest CAGR of 7.5 per cent for the period 2021-2026. This is mainly owing to its mild flavor and unique texture that attract consumers for consuming white chia seeds. Moreover, white chia seeds are rich in fiber and helps to improve metabolism rising the demand of white chia seeds among consumers which in turn boosts the growth of Global Packaged Chia Seed market.

The Global Packaged Chia Seed Market based on application can be further segmented into Food and Beverages, Pharmaceuticals, Personal Care & Cosmetics and Others. The Food and Beverages segment registers for the higher Global Packaged Chia Seed market share in 2020. This is mainly owing to the rising consumption of chia seeds in bakery products, peanut butter, breakfast cereals and many more. Moreover, growing trends of consuming gluten free products in food and beverage industry rising the preference of chia seeds. The Pharmaceuticals segment is forecasted to register the fastest CAGR of 8.1 per cent over 2021-2026. This is mainly owing to the fact that chia seeds are used various health benefits such as cardiovascular diseases that increases the production of chia seeds in the form of capsules in pharmaceutical industry and are thus propelling the growth of Global Packaged Chia Seed Market.

North America dominated the Global Packaged Chia Seed Market with major share of 45 per cent in 2020. This is owing to changing lifestyle among consumers that increases the demand of chia seed as it is considered as gluten-free diet. Moreover, rising prevalence of heart diseases increases the consumption of chia seeds which in turn driving the market growth. The American Heart Association recommends adding omega-3 foods in diets as it helps to reduce heart related diseases that increases the consumption of chia seeds among population and are boosting the growth of Global Packaged Chia Seed Market. However, Asia Pacific is estimated to outpace all the regions by clocking the highest CAGR of 3.05 per cent during the forecast period 2021-2026 owing to rising health consciousness among population and changing lifestyle. In India, lifestyle changes increase the prevalence of various diseases such as diabetes, blood pressure, obesity and cardiovascular problems. So, people are adopting gluten free products such as Chia seeds that are further enhancing the market growth. Finally it is estimated that at 6.1 per cent CAGR global packaged chia seed market size worth USD 3700 million by 2026 (sales@industryarc.com).

The growing popularity of chia seeds among consumers and increasing industrial application of chia seeds are the major drivers propelling the growth of chia seeds market globally. The use of Chia seeds in various food & beverages, pharmaceuticals, and personal care products is growing globally and has increased demand for chia seeds growers and helping the entry of new market players. The factors mentioned above are driving the growth of chia seeds market. In addition to that, the popularity of organic chia seeds among health-conscious consumers is expected to fuel the market growth of chia seeds over the forecast period. The Global Chia Seeds Market is projected to grow at a significant rate of 8.86 per cent from 2019 to 2024 to reach a market value of USD 450 million by the end of 2024. However, according to a new report by Market Research Future the global chia seeds market size is expected to reach USD 4.9 billion by 2027 growing at a CAGR of 22.5 per cent (info@market research future.com).

The Chia seeds market is fragmented. Major Key players include Glanbia Nutritionals, Navitas Organics, Vega Produce LLC, Benicia, Nutiva Inc. and Garden of Life among others. Some key players follow a merger and acquisition policy to increase product demand. For instance, in May 2022, Grub Market acquired Vega Produce, one of the largest Asian fruits and vegetable providers in the United States, to expand to Florida and strengthen its global food supply chain. The key players of the global chia seeds market are adopting several innovative

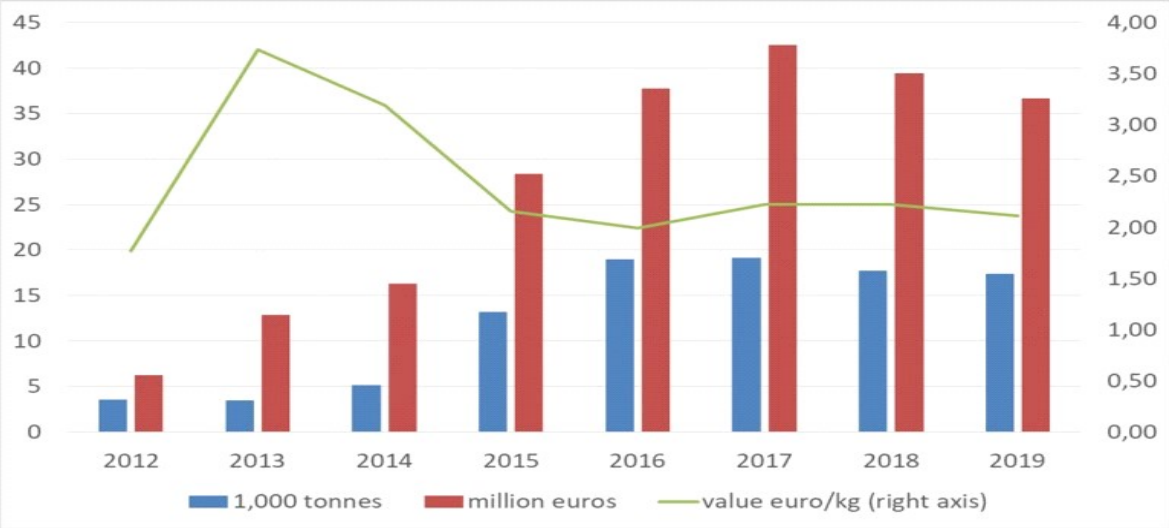

Fig.2 : Indicative chia imports to Europe from the main producing and supplying countries, Paraguay, Bolivia, Argentina, Peru, Mexico, Uganda, Chile, Australia

techniques such as improved product distribution strategies and product launches to stay ahead of each other. For instance, in March 2020, Benicia bets on a seed wellness consumer brand to boost the category. Benicia is one of the early players in chia production. In 2018, the SOW brand launched a chia milk product, Chia pasta, which is high in protein and fiber and chia oil positioned as a salad dressing constituent (Marketresearch.com).

Chia crop being a super food due to its high nutrition profile, using chia seeds in daily diet may help to reduce malnutrition and also it may prevent many diseases (diabetes, obesity and cardiovascular) in the country. In addition to this, chia seed has greater influence on Indian economy as it is having an economic value in national and international market. It is estimated that the global Chia seeds market is projected to grow at a significant rate of 8.86 per cent from 2019 to 2024 to reach a market value of USD 450 million by the end of 2024. Successful cultivation of chia crop in India will improve economic condition, living standards and health benefits to the population. Chia is becoming very popular as super food all around the world with dramatic increase in cultivation and consumption. With high demand in international and Indian market, it can be cultivated as profitable, commercial and health crop. Since, availability of germplasm lines in chia in India is very meagre, crop improvement programme needs to be taken up in collaboration with other international centres.

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