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Status Paper

Status and perspective analysis of exotic vegetables for health, nutrition and entrepreneurship in India

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Abstract

The exotic vegetables have emerged as a profitable venture, providing a sustainable source of livelihood for farmers and playing a crucial role in enhancing nutritional security. The increasing demand for diverse and high-value crops has fuelled the expansion of this sector. Additionally, globalization has brought significant changes to developing nations, influencing dietary preferences and dietary components. Exotic vegetables, commonly known as "English vegetables" are increasingly become a vital component of consumers' balanced diets, addressing dietary deficiencies and promoting better health outcomes. The demand for exotic produce is rapidly increasing in both domestic and global markets and India, with immense potential, is strategically positioned to compete in both these markets for exotic vegetables. Recent advancements in cultivation of exotic vegetables include development of new varieties, use of protected structures, mulching, hydroponics, tissue culture, and organic farming. These technologies can prove to be significant with focus on nutrition, farmers income and youth entrepreneurship.

Keywords: Breeding methods, exotic crops, hill agriculture, export oriented farming, youth entrepreneurship.

A significant segment of the population still relies on agriculture for their livelihoods, yet small farms are facing declining profitability. Consequently, a strategic shift towards ensuring both nutritional security and income stability is still needed (Madhur 2016) to improve the livelihood of marginal and smallholder farmers. As per capita incomes rise and lifestyles evolve, factors such as location, quality, and food safety are becoming increasingly important to Indian consumers, driving a growing demand for exotic vegetables. The term "exotic vegetables" refers to those varieties that have been introduced to India over the past few decades and are commonly known as English vegetables. These vegetables originate from cooler climates and are typically cultivated during winters in the northern India or in hilly areas. Exotic vegetables are consumed by the higher socioeconomic classes and have high market value. These are high price vegetables and emerging as one of the fastest-growing option with substantial profit margins. These vegetable crops have gained substantial presence in diets of metro cities even in regions non-traditional for the cultivation of these crops (Navya and Nagnur 2022).

In India, the demand for exotic produce is increasing at an annual rate of 15 to 20 percent. The exposure of people to global cuisines through visits, relative or social media influences also contributing in increased use of exotic vegetables in speciality food preparations. The exotic vegetables like lettuce, broccoli, Brussels sprouts, Chinese cabbage, celery, parsley, red cabbage, asparagus, cherry tomato, and coloured capsicum, once considered niche, are now widely cultivated across various regions of the country. The cultivation of these vegetables, particularly in hilly regions, has seen considerable growth in recent years. These areas, which include states such as Himachal Pradesh, Uttarakhand, and parts of Northeast India, are characterized by favourable agro-climatic conditions that support the growth of various non-native

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vegetables like broccoli, lettuce, bell peppers, and asparagus. The cooler temperatures, higher altitudes, and distinct growing seasons in these regions closely resemble the natural habitats of many exotic vegetables, making them particularly suitable for cultivation. The rising interest in exotic vegetables is also fuelled by increasing consumer demand for diverse and nutritious food options for consumers and higher economic returns for growers.

The exotic vegetables market is projected to grow at an accelerated rate, driven primarily by the expansion of the organized food service sector and increasing consumer demand. Although India has a naturally favourable environment for cultivating high-value vegetables, the country faces challenges due to insufficient export facilities and underdeveloped local marketing infrastructure (Rao and Mrunalinisasanka 2015). Several private companies, such as Siddesh English Exotic Vegetables (Mumbai), PMS Agrotech Trading Company (Nagpur), and Indogreen Nature Farm Private Limited (Bangalore), are engaged in exporting exotic vegetables like cherry tomatoes, lettuce, leek, red cabbage, and baby corn. In the coming years, key forces are expected to drive the growth of India's exotic vegetable market: rising incomes and shifting lifestyles on the demand side, and increased production by farmers, corporate investments, and the expansion of e-retailing platforms offering direct marketing channels on the supply side. Therefore, the present review aims to examine the status, challenges and opportunities for exotic vegetable cultivation particularly in hill regions, emphasizing the importance of indigerzation breeding and production technologies for inclusion of promising exotic vegetables in India's common culinary preparations.

Exotic vegetables in India

In India, exotic vegetables are imported from countries viz., Korea, the USA, Italy, France, the Netherlands, and Thailand, while domestic production takes place in hilly region of Himachal Pradesh, Tamil Nadu, Uttarakhand, Maharashtra, Karnataka, and Andhra Pradesh and plains of north India. The exotic vegetables entered in the country through institutional, industry and individual routes. Different institutions and private seed companies played key role in introduction of exotic vegetables but, later individual growers also contribute in diversifying the Indian vegetable basket by introducing new exotic vegetable crops from different parts of the world. In the New Policy on Seed Development (1988), the import of the selected seeds is permitted under Open General Licence (OGL), with the aim to make available farmers high quality seeds to farmers to maximize yield, increase productivity and farm income. It allows imports of seeds of exotic vegetables also through identified categories of importers including growers with the recommendations of the Directors of Horticulture/ Agriculture in the state. The OGL contributed a great extent in entry of several exotic vegetables through private sector and the growers mainly in urban areas. Presently, many exotic vegetables can be seen in India as listed in Table 1.

Hills and mountain ecologies are considered fragile due to being subjected to various kinds of land degradations such as erosion. Further, the problem of land degradation is aggravated due to inappropriate land uses i.e., without considering the suitability of soils for certain specified land uses. Moreover, hilly areas used for vegetable cultivation, most of which is erosion permitting barring few erosions resisting vegetable crops. Thus, promotion of vegetable cultivation in hill and mountain regions need adequate soil conservation plans. In this context, land/soil suitability evaluation strategies such as qualitative approaches and quantitative approaches such as Analytic hierarchy process and Fuzzy AHP is frequently used methods (Ramamurthy *et al*. 2024).

Exotic vegetables in Hill region in India

The hill regions of India have been divided into three categories based on height and prevailing climatic conditions: foot-hill regions (below 1200 m), mid-hill regions (1200-3500 m), and high-hill regions (above 3500) (Kumar 2017). Around 7.08 lakh square kilometers hill region in India predominantly spread across Jammu and Kashmir, Ladakh, Himachal Pradesh, Uttarakhand in north region and Sikkim, Assam, Manipur, Meghalaya, Arunachal Pradesh and Tripura in north-eastern region (Figure 1). The hill regions have significant area and production of vegetable crops. The climatic situation and know-how about vegetable cultivation favours promotion of exotic vegetables in the region. The Himalayan region

Table 1. List of exotic vegetables suitable for hill ecology in India

Exotic vegetables	Scientific name	Family	Chromo. No. (2n)	Exotic varieties/ hybrids	Indigenous varieties/ hybrids	Seed requirement (per ha)	Spacing (cm)
Broccoli	*Brassica oleracea* L. *italica*	Brassicaceae	18	Fiesta, Express	Pusa KTS-1, Palam Samridhi, Palam Haritika, Palam Kanchan, Palam Vichitra, Punjab Broccoli 1, Pusa Purple Broccoli 1	400-500 g	45 x 45 cm 60 x 45 cm
Brussels sprouts	*B. oleracea* L. *gemmifera*	Brassicaceae	18	Jade Cross, Bubbles, Oliver, Royal Marvel, Prince Marvel, Rubine	Hills Ideal	200-500g	60 x 45 cm
Kale	*B. oleracea* L. *acephala*	Brassicaceae	18	Dwarf Green, Dwarf, Moss, Dward Blue, Moss Curled, Curled Scotch, Hamburger Markey, Karamsag	Pusa Kale-64, Karam sag	350-400 g	45 x 30 cm
Kohlrabi	*B. oleracea* L. *gongylodes*	Brassicaceae	18	White Vienna, Early Purple Vienna, Large Green, King of North, Sultan, Quick Star Hybrid Quick Shot Hybrid, Winner, Priya Hybrid	Pusa Virat, Palam Tender Knob, G-40		
Chinese cabbage (heading)	*B. rapa* subsp. *pekinensis*	Brassicaceae	20	Tianjin Qingmaye	Palampur Green, Solan Band Sarson, Solan Selection, Chinese Sarson No. 1, CITH-CC-33	500-750g	Early: 30-40 x 30-40cm Late: 70 cm x 55cm
Pak choi (leafy)	*B. rapa* var. *chinensis*	Brassicaceae	20	-	Pusa Pak Choi-1, Chinese Sarson No.1	500g	70 cm x 55cm
Savoy cabbage	*B. oleracea* var. *sabauda*	Brassicaceae	18	Perfection (Syn. Chieftain), Drumhead Savoy	-	200-500g	45 – 60 x 45-60 cm
Red cabbage	*B. oleracea* var. *rubra*	*Brassicaceae*	18	Premiero	Red Rock, Red Drum Head, Kinner Red, Solan Band Sarson	200-500g	45 – 60 x 45-60 cm
Horse radish	*Armoracia rusticana*	Brassicaceae	32	Big Top Western, Bohemian, Common, Swiss, Variegata, Wildroot, Czechoslovakian	-	15,000 - 22,500 sets	30 x 45 -60 cm
Romanesco	*B. oleracea* var. *botrytis* 'Romanesco	Brassicaceae	18	Caesar	-	100–200 g	50 x 50 cm
Collard	B. *oleracea* L. *acephala*	Brassicaceae	18	Georgia, Georgia Blue Max, Champion, Morris Heading, Heavie Crop, Flash, Hi-Crop, Bulldog, Tiger and Top Bunch	-	350–400 g	90 x 45 cm; 60 x 30 cm
Rocket salad	*Eruca sativa*	Brassicaceae	22	-	-	5–6 kg	20 x 5 cm

Mustard sag	*Brassica juncea*	Brassicaceae	36	-	Pusa Saag 1	3.5 kg	45 x 10 cm
Swiss chard	*Beta vulgaris* L. var. *cicla*	Amaranthaceae	18	**White-stemmed-** Fordhook Giant, Lucullus and Silerado **Coloured -** Pink Passion, Burgundy, Orange Fantasia, Golden Sunrise, Bright Light, Rhubarb, Ruby Red and Rainbow chard **Perpetual -** Perpetual and Verde Da Taglio	-	7-9kg	60 x 30 cm
Celery	*Apium graveolens*	Apiaceae	22	Golden, Florida Golden, White Grove Giant, Fort Hook Emperor and Standard Bearer, Green Giant	-	100-125g	60 x 20 cm; 45x 10 cm
Parsley	*Petroselinum crispum*	Apiaceae	22	Hamburg, Dark Green Italian, Paramount, Extra Triple Curled, Triple Curled, Evergreen and Moss Curled	-	250-300g	60 x 45 cm
Asparagus	*Asparagus officinalis* L.	Asparagaceae	20	Perfection, Mammoth White, Mary Washington, Violet Touch, White German, Paradise, Jersey Giant, Jersey Knight, Jersy King, Jersey Supreme, Jersey Queen, Lara, Mira	Sel 831, UC-72, UC-66	2-3 kg	90 x 60 cm; 75 x 50 cm
Snow pea	*Pisum sativum* var. *saccharatum* Ser.	Fabaceae	14	Sylvia,	Arka Sampoorna, Arka Apoorva, Him Palam Meethi Phali-1, 2, JP 19	70-80 kg	45 x10 cm
Snap pea	*Pisum sativum* var. *macrocarpon*	Fabaceae	14	Tendersweet, Super Sugar Snap, Sugar Daddy, Cascadia		70-80 kg	45 x10 cm
Gherkin	*Cucumis anguria*	Cucurbitaceae	24	Ajax, Calypso, Diamante, Adam, Chopin, Levina, Vokal, Octopus	-	800 g	20 × 10 cm
Baby corn	*Zea mays* L.	Poaceae	20	Rangsit-1	VL-42, MEH-14 and Golden Baby, SOLAN SUGAR BABY, Vivek,hybrid 27, hM-4	30-40 kg	60 x 15 cm
Sweet corn	*Zea mays* convar. *saccharata* var. *rugosa*	Poaceae	20	-	Parkash, Kesari, Solan Sugar Baby, Cobc 1	25-40 kg	45 × 25 cm
Lettuce	*Lactuca sativa* L.	Asteraceae	18	Great Lakes, Imperial 859, White Boston, Dark Green Boston, Ton Thumb, Butter Crunch, Red Butter Head Chinese Yellow, Slobolt,	Punjab Lettuce No. 1, Solan Kriti, Shalimar Lettuce-2	400–500 g	30 × 25 cm

				Black seeded Simpson, Golden Ball, Little Gem, Iceberg, Paris Cos, Wonderful			
Paprika	*Capsicum annuum*	Solanaceae	24		Arka Abir, KTPL-19		
Cherry tomato	*S. lycopersicum* var. *cerasiforme*	Solanaceae	24	Tiny Tim, Sweet 100, Sungold, Italian Ice, Yellow Pear, Black Pearl	Pusa Cherry Tomato-1, Pusa Golden Cherry Tomato-2, VL Cherry Tomato 1, Hybrid CTH 1, Punjab Red Cherry, Punjab Sona Cherry, Punjab Kesar Cherry, Him Palam Cherry tomato-1, Him Palam Cherry Yellow	125 g	90 × 60 cm
Coloured capsicum	*Capsicum annuum*	Solanaceae	24	Orobelle (yellow), Bomby (red),	Arka Basant, Arka Gaurav, Indra (red), Swarna (yellow), Natasha (red)		
Leek	*Allium porrum*	Alliaceae	32	Londan Flag, American Flag, Renova, Miner, Splendid, Giant Winter, Hannibal, Mammoth Blanch, Atlantic	Palak Paushtik,PPL-1	5-7 kg	40 x 10 cm
Bunching onion	*Allium fistulosum*	Alliaceae	16	Santa Clause, Red Beard, Shimonita, Yoshima, White Lisbon, Evergreen White Bunching and Winter Over	Pusa Soumya	8-10 kg (Rabi)	25 × 15 cm15 × 10 cm
Shallot	*Allium cepa* var. *aggregatum* Syn. *A. ascalonicum*	Alliaceae	16	Ambition F_1, Prisma, Banana, Golden Gourmet, Jermor, Longor, Mikor, Red Sun, Topper, Pikant, Atlantic, Atlas, Dutch Yellow, French Shallots, Frog Leg Shallots, Giant Red, Grey Shallot, Odetta's White Shallot, Pink Shallots and Success.	-	8–10 kg	30 × 20 cm
Chive	*Allium schoenoprasum*	Alliaceae	16, 24, 32	Curly Mauve, Forescate, Marsha, Pink Giant, Profusion, Snowcap and Album	-		10 × 10 cm
Rhubarb	*Rheum rhabarbarum*	Polygonaceae	44	Victoria, Macdonald, Crimson Cherry, Timperley Early, Champagne, Ruby Red, Cherry Red Strawberry Rhubarb	-	18000 crowns	120 × 45 cm
Vegetable soybean	*Glycin max*	Fabaceae	40	-	Himsu 1563, Swarna Vasundhra	75 kg	40 x 25-30 cm

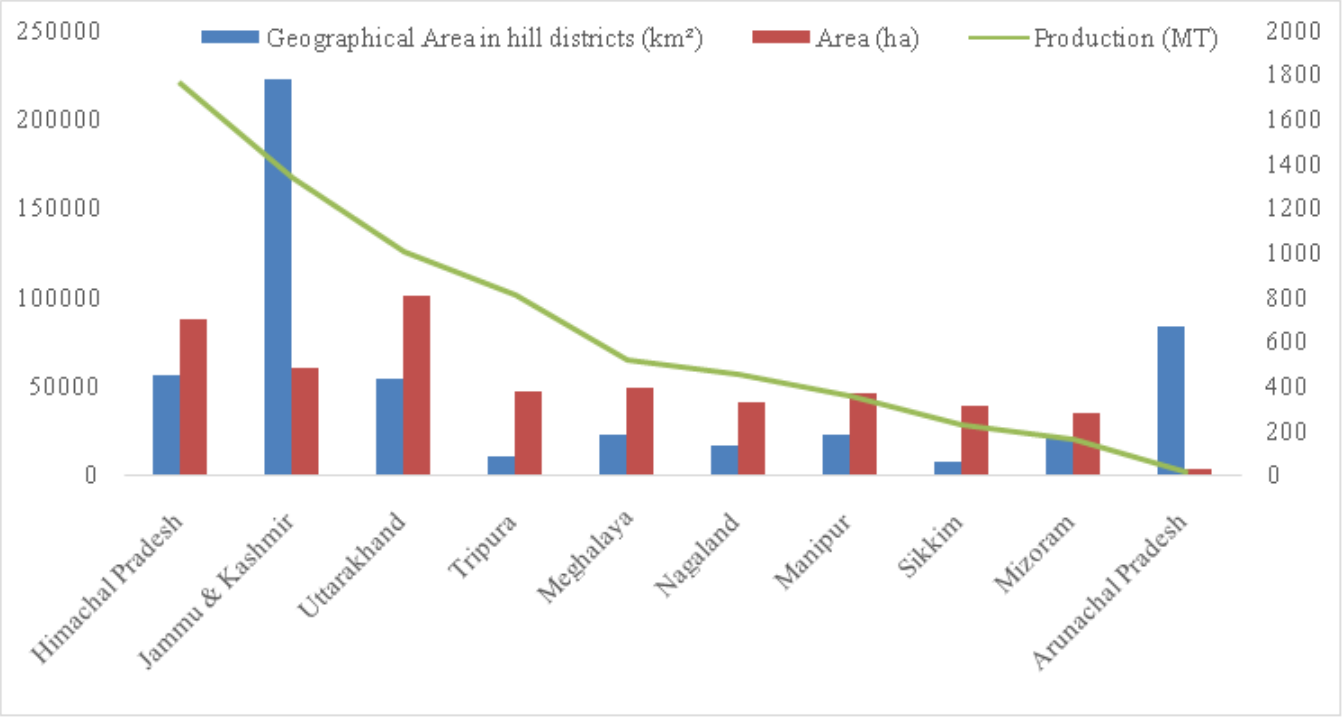

Figure 1: Vegetable scenario in the hilly regions of India

is predominant for exotic vegetable cultivation and their seed production. Hill ranges in southern region of the country also cultivate exotic vegetables. The region has small landholdings, steady slope, irregular vegetation, prone to erosion and transport challenges for growing and marketing of perishable vegetables. However, the seed production of exotic temperate type crops has great scope because of the vernalization requirement and premium price of the seeds. Besides, winter season in north India is most suitable for exotic vegetables since these crops predominantly originated or evolved in the European region. Thus, the northern plains mainly the peri-urban areas are cultivating these crops to supply the metro cities. These crops are moving to other parts of the country for their taste and commercial reasons.

Nutritional and health value of exotic vegetable crops

While numerous studies have demonstrated the health benefits of specific phytochemicals, these benefits cannot be attributed to a single component or one vegetable alone. Rather, the year-round consumption of a variety of vegetables provides consumers with the full range of health advantages. The exotic vegetables are rich source of various dietary minerals (Table 2). Paprika, Brussels sprout, Sweet Corn and Chive are rich in protein; Paprika, Kale and Sweet Corn in fat; Paprika, Parsley, Horse Radish in ash content. The rich sources of dietary fiber are Paprika, Brussels sprouts, Kale and for total Sugars (mg) are Gherkin, Paprika and Horse radish. These vegetables are also a good source of essential minerals like Kale, Collard and Paprika are rich in calcium, Paprika and Lettuce and Parsley are rich in iron, Paprika, Swiss Chard and Parsley are rich in magnesium. The phosphorous is highest in Paprika, Lettuce and Sweet Corn, Potassium is highest in Paprika, Parsley and Brussels sprout, sodium is higher in Gherkin, Horse radish and Swiss Chard exotic vegetable crops. The exotic vegetables like Paprika, Parsley, Horse- radish are rich source of zinc, Paprika, Lettuce, Asparagus, Chive, Swiss Chard, Mustard sag are rich in copper, Paprika, Kale, Collard are rich in manganese and Paprika, Horse radish and Broccoli are rich in selenium. These vegetables are also serve as a good source of vitamins with Parsley, Colored capsicum and Kale rich in vitamin C and Paprika, Parsley and Lettuce are rich in vitamin A.

Exotic vegetables are valued not only for their culinary appeal but also for their health benefits, as they are often rich in vitamins, minerals, and antioxidants. These vegetables are almost similar to

Table 2. Nutritional composition of exotic vegetables suitable for hill ecology in India

Exotic vegetables	Moisture (g)	Energy (KJ)	Protein (g)	Total fat(g)	Ash(g)	CHO (g)	Dietary fibre(g)	Total Sugars (g)	Ca (mg)	Fe (mg)	Mg (mg)	P (mg)	K (mg)	Na (mg)	Zn (mg)	Cu (mg)	Mn (mg)	Se (µg)	Vit C (mg)	Vt A (IU)
Broccoli	89.3	141.0	2.8	0.4	0.9	6.6	2.6	1.7	47.0	0.7	21.0	66.0	316.0	33.0	0.4	0.0	0.2	2.5	89.2	623.0
Brussels sprouts	84.4	185.0	4.3	0.5	1.5	5.1	4.3	2.2	42.0	1.4	23.0	69.0	389.0	25.0	0.4	0.1	0.3	1.6	85.0	754.0
Kale	89.6	148.0	2.9	1.5	1.5	4.4	4.1	1.0	254.0	1.6	33.0	55.0	348.0	53.0	0.4	0.1	0.9	0.9	93.4	4810.0
Kohlrabi	91.0	113.0	1.7	0.1	1.0	6.2	3.6	2.6	24.0	0.4	19.0	46.0	350.0	20.0	0.0	0.1	0.1	0.7	62.0	36.0
Pe-tsai(heading)	94.4	67.0	1.2	0.2	1.0	3.2	1.2	1.4	77.0	0.3	13.0	29.0	238.0	9.0	0.2	0.0	0.2	0.6	27.0	318.0
Pak choi (leafy type)	95.3	55.0	1.5	0.2	0.8	2.2	1.0	1.2	105.0	0.8	19.0	37.0	252.0	65.0	0.2	0.0	0.2	0.5	45.0	4470.0
Savoy cabbage	91.0	113.0	2.0	0.1	0.8	6.1	3.1	2.3	35.0	0.4	28.0	42.0	230.0	28.0	0.3	0.,062	0.2	0.9	31.0	1000.0
Horseradish	85.1	201.0	1.2	0.7	1.8	11.3	3.3	8.0	56.0	0.4	27.0	31.0	246.0	420.0	0.8	0.1	0.1	2.8	24.9	2.0
Romanesco																				
Collard	89.6	133.0	3.0	0.6	1.3	5.4	4.0	0.5	232.0	0.5	27.0	25.0	213.0	17.0	0.2	0.0	0.7	1.3	35.3	5020.0
Rocket salad	91.7	105.0	2.6	0.7	1.4	3.7	1.6	2.1	160.0	1.5	47.0	52.0	369.0	27.0	0.5	0.1	0.3	0.3	15.0	2370.0
Mustard sag	90.7	114.0	2.9	0.4	1.4	4.7	3.2	1.3	115.0	1.6	32.0	58.0	384.0	20.0	0.3	0.2	0.0	0.9	70.0	3020.0
Swiss chard	92.7	79.0	1.8	0.2	1.6	3.7	1.6	1.1	51.0	1.8	81.0	46.0	379.0	213.0	0.4	0.2	0.4	0.9	30.0	6120.0
Celery	95.4	57.0	0.7	0.2	0.8	3.0	1.6	1.3	40.0	0.2	11.0	24.0	260.0	80.0	0.1	0.0	0.1	0.4	3.1	449.0
Parsley	87.7	151.0	3.0	0.8	2.2	6.3	3.3	0.9	138.0	6.2	50.0	58.0	554.0	56.0	1.1	0.1	0.2	0.1	133.0	8420.0
Asparagus	93.2	85.0	2.2	0.1	0.6	3.9	2.1	1.9	24.0	2.1	14.0	52.0	202.0	2.0	0.5	0.2	0.2	2.3	5.6	756.0
Snow pea	88.9	42Kcal	2.8	0.2	0.0	7.6	2.6	4.0	43.0	2.1	24.0	53.0	200.0	4.0	0.3	0.1	0.0	0.7	60.0	54 µg
Snap pea	-	41Kcal	2.4	0.0	0.0	7.1	2.4	3.5	44.0	2.4	-	—	200.0	-	-	-	-	-	-	-
Gherkin	-	107Kcal	0.0	0.0	0.0	28.6	0.0	25.0	-	-	-	-	-	607.0	-	-	-	-	—	-
Baby corn	-	27.0	1.5	0.0	0.0	4.6	2.3	1.5	0.0	0.3	-	-	-	169.0	-	—	-	-	-	-
Sweet corn	76.0	360.0	3.3	1.4	0.6	18.7	2.0	6.3	2.0	0.5	37.0	89.0	270.0	15.0	0.5	0.1	0.2	0.6	6.8	187.0
Lettuce	95.0	62.0	1.4	0.2	0.6	2.9	1.3	0.8	36.0	13.0	29.0	194.0	28.0	0.2	0.0	0.3	0.6	0.6	9.2	7400.0
Paprika	11.2	1180.0	14.1	12.9	7.7	54.0	34.9	10.3	229.0	21.1	178.0	314.0	2280.0	68.0	4.3	0.7	1.6	6.3	0.9	49300.0
Cherry tomato	-	111.0	1.6	0.0	-	4.9	1.6	3.3	33.0	1.2	-	-	-	61.0	-	-	-	-	9.3	738.0
Coloured capsicum	92.2	111.0	1.0	0.3	0.5	6.0	2.1	4.2	7.0	0.4	12.0	26.0	211.0	4.0	0.3	0.0	0.1	0.1	128.0	3130.0
Leek	83.0	61Kcal	1.5	0.3	-	14.2	1.8	3.9	59.0	2.1	28.0	35.0	180.0	20.0	0.1	0.1	-	1.0	12.0	83 µg
Bunching onion	89.8	32Kcal	1.8	0.2	-	7.3	2.6	2.3	72.0	1.5	20.0	37.0	276.0	16.0	0.4	0.1	-	0.6	18.8	50 µg
Chive	90.6	126.0	3.3	0.7	1.0	4.4	2.5	1.9	92.0	1.6	42.0	58.0	296.0	3.0	0.6	0.2	0.4	0.9	58.1	4350.0
Rhubarb	93.6	88.0	0.9	0.2	0.8	4.5	1.8	1.1	86.0	0.2	12.0	14.0	288.0	4.0	0.1	0.0	0.2	1.1	8.0	102.0

Source: USDA database

indigenous vegetables but in another country. They are used and maintained by these local people of those countries for their specific taste, flavour and texture in culinary preparation. These vegetables are also rich source of antioxidants and colour compounds which contribute in their health beneficial properties. A list of such health benefits from available literature is presented in Table 3.

Novel exotic traits in common vegetables

In addition to introduction of exotic crops, certain novel traits of economic use were introgressed in well-acclimatized crops through indigenous efforts. A list of such traits and crops are listed in Table 4. White cauliflower is common among consumers but it provides only glucosinolates (19.5-42.6 mMol/g) while purple cauliflower also provides anthocyanin (48 – 375 mg/100g FW). Purple cauliflower (Var. Graffiti) is rich source of anthocyanin (375 mg/ 100 g fw). IARI RS, Katrain also developed Pusa Purple cauliflower-1 (43.7 mg/100 g fr. wt) purple cauliflower in snowball group. This *Pr* gene has been introgressed in tropical or Indian type cauliflower also. The advance progenies show intense purple curd (anthocyanin: 76 mg/100g FW), curd formation in October – November months and flowering and seed setting in December – January months. Further, a new genotype of purple cauliflower 'PC-1' was also registered in NBPGR, New Delhi. Further, orange cauliflower hybrids also seen in Indian markets and one orange cauliflower line Pusa Kesari VitA-1 was developed by IARI, New Delhi. Further, new promising hybrids of orange cauliflower were found for further testing and commercial release. Broccoli is rich in health beneficial glucosinolates (64.6 mMol/g; glucoraphanin 18.4 mMol/g) and purple broccoli varieties provide anthocyanin such as 'Pusa Purple Broccoli' (30.31 mg/100g). Red cabbage contains total glucosinolates in range of 39.9 to 89.9 mMol/g and provide anthocyanin (182 mg/100g fw) which is a strong antioxidant and good for health.

Black carrot is one of the richest sources of anthocyanins, which vary from 13 to 283 mg/100 g FW among carrot genotypes. The yellow and orange varieties of the carrot contain carotenoids in the range of 0.47 to 0.56 mg/100 gm and 5.99 to 12.52 mg/100 gm, whereas dark orange contains carotenoids in the range of 26.55 mg/100 gm, respectively (Ikram *et al*. 2024). Red colour of carrot is due to the presence of lycopene, thus, it also provides a strong antioxidant for health benefits of consumers. The black to red colour of radish is due to anthocyanins, varied from 47 to 530 µg/g FW (Guisti *et al*. 1998; Singh *et al*. 2017). Thus, providing additional phytochemicals to add its health value. Similar was the case of tomatoes, where introgression of exotic traits improved the native varieties for dietary nutrients and lycopene. Further, total anthocyanins in the whole ripe fruit of Sun Black variety of tomato was 1.2 mg/g dry weight (DW); 7.1 mg/100 g fresh weight (FW) (Blando *et al*. 2019).

Breeding methods for exotic vegetable crops

Exotic vegetables such as disease susceptibility, heat sensitivity and the need for specific soil and climate conditions. Breeding plays a critical role in addressing the challenges faced by developing improved varieties and hybrids with better adaptability, disease resistance, and enhanced yield potential. A combination of traditional and advanced breeding methods are important approaches.

Pureline selection has been used develop new varieties in exotic crops like lettuce, Chinese cabbage and parsley. Lettuce breeding in India has focused on selecting varieties that can withstand higher temperatures and resist common diseases like downy mildew and bacterial leaf spot. Breeding efforts in Chinese cabbage focus on creating high-yielding varieties with resistance to pests and diseases, using hybrid breeding and pureline selection (Feng *et al*. 2014). Parsley breeding has been geared towards improving flavour, leaf texture, and disease resistance. Development of parsley varieties is still in nascent stages in India, with trials underway. Dhaliwal and Jindal (2017) bred Punjab Red Cherry using interspecific cross between *Solanum lycopersicum* and *S. pimpinellifoilum* following the pedigree method of selection. Coloured capsicum breeding programs focus on improving fruit quality, increasing yield, and developing resistance to pests and diseases. 'Indra', 'Bomby', and 'Orobelle' are prominent varieties of sweet pepper. Breeding of cherry tomato and red cabbage also hybrids also resulted a number of indigenously bred varieties. Mutation breeding has potential to create variability for indigenous breeding.

Table 3. Nutritional composition of exotic vegetables suitable for hill ecology in India

Exotic vegetables	Active compounds	Anti-nutrients	Heath benefits
Broccoli	Glucosinolates (glucoraphanin, sulforaphane) and isothiocyanates	Oxalic acid, phytic acid, saponins, goitrogens, protease inhibitor	Anticancer, antioxidant, antimicrobial anti-inflammatory, and antihypertensive activities
Brussels sprouts	Glucosinolates and isothiocyanates	Oxalates, phytates, goitrogens, phytoestrogens,	Improving bone health, managing diabetes, preventing cancer, Maintaining vision
Kale	Glucosinolates, flavonoids (glycosylated flavonols), and phenolic compounds	Oxalates, tannins, and phytates	Lowering the risk of type 2 diabetes, protecting against heart disease, and helping prevent constipation
Kohlrabi	Glucosinolates and isothiocyanates	—	Ending off cancer, diabetes, and high cholesterol while improving liver and kidney function
Pe-tsai (heading type)	Thiocyanates, indole – 3 – carbinol, lutein, zeaxanthin, sulforaphane and isothiocyanates	—	Protection from cancer, Bone health,Blood pressure, Heart Health, Inflammation, Type 2 diabetes
Pak choi (leafy type)	Thiocyanates, indole – 3 – carbinol, lutein, zeaxanthin, sulforaphane and isothiocyanates	—	Protection from cancer, Bone health,Blood pressure, Heart Health, Inflammation, Type 2 diabetes
Savoy cabbage	Glucosinolates, vitamin C, carotenoids, and polyphenols	Phytates, oxalates, tannins	Reduce constipation and has also been used as a laxative, as an antidote to mushroom poisoning, or as a treatment for hangovers and headaches
Horse radish	Sinigrin, allyl isothiocyanate, phenolic compounds	-	Antibacterial, anti-inflammatory, antioxidant, anticarcinogenic properties
Romanesco	Glucosinolates, chlorophyll	Progoitrin	Anto-cancer, antioxidants
Collard	Antioxidants, flavonoids, glucosinolates, and phenolics	Phytic acid, tannic acid, and oxalic acid	For anemia, heart disease, constipation, diabetes, an eye disorder that causes damage to the optic nerve, high cholesterol, loss of vision, and weight loss
Rocket salad	Sinapic acid, ferulic acid, and 7-hydroxycoumarin	Nitrates, glucosinolates	Help the body's cardiovascular, nervous, and digestive systems
Mustard sag	Glucosinolates, phenolics, phytic acid, and various phytosterols	Oxalates	Heart health, blood sugar regulation, and bone health
Swiss chard	Betalains, flavonoids, ß-carotene	Oxalates	Decreases the risk of obesity, diabetes, heart disease
Celery	Apigenin and furanocoumarins	Oxalates	Prevent cardiovascular diseases, reduces glucose, blood lipids, and blood pressure
Parsley	carotenoids, phenols, flavonoids, non-flavonoids and vitamin C	Oxalates	Carminative, gastro tonic, diuretic, antiseptic of urinary tract, anti-urolithiasis, antidote, anti-inflammatory
Asparagus	Asparagine, arginine, tyrosine, flavonoids	Phytate, tannins, trypsin inhibitor	Diuretic effect and promote defecation

Snow pea	Alkaloids, flavonoids, glycosides, isoflavones,	Phytic acid	Controls Diabetes, Promotes Digestion, Bone Health and Bolsters Immune System
Snap pea	Flavanols, flavan-3-ols, and anthocyanins	Trypsin inhibitors and lectins	Helps heal cuts and wounds, blood clotting and bone health
Gherkin	Cucurbitacins, cucumegastigmanes I and II, cucumerin A and B,	Oxalates	Anti-carcinogenic, anti-hyaluronidase, anti-elastase, anti-inflammatory, anti-hyperglycemic, diuretic, amylolytic, antimicrobial, and analgesic effects.
Baby corn	Total phenols, flavonoids and ascorbic aci	Phytate and oxalates	Prevents anemia, Controls cholesterol, Improves digestion
Sweet corn	Phenolic acids (ferulic acid, coumaric acid, and syringic acid), carotenoids and flavonoids (anthocyanins)	Phytates, tannins, and protease inhibitors	Lowers the risk of developing chronic diseases such as cardiovascular disease, type 2 diabetes, and obesity and improves digestive health
Lettuce	Folate, β-carotene, lutein, and phenolics.	Nitrates and Phytates	Reducing low density lipoprotein, cholesterol and blood pressure, reducing risk of diabetes by improving glucose metabolism, lowering risk of colon cancer
Paprika	Beta-carotene, zeaxanthin, capsanthin and lutein	-	Treatment of rheumatoid arthritis and osteoarthritis to anemia prevention
Cherry tomato	β-carotene, lycopene, lutein, vitamin C, vitamin E, rutin, kaempferol, caffeic acid, and chlorogenic acid	Phytate, glycoside, saponin and tannin,	Help protect against cancer, heart disease, and skin damage. But you may want to avoid cherry tomatoes if you have acid reflux or certain allergies.
Coloured capsicum	Capsaicinoids, phenolic compounds, carotenoids (provitamin A), and vitamins (C and E)	Phytates and oxalates	Antibacterial, antifungal, immunosuppressive, and immunostimulant properties, and antidiabetic, antitumoral, and neuroprotective activities
Leek	Naphthalene, cycloisolongifolene, 3– methyl– 4 isoprophylph-enol, thymol, and caryphyllene	Oxalate	Reduce the risk of cataracts and age-related macular degeneration.
Bunching onion	Flavonoids and sulfur-containing compounds such as dipropyl sulfide, dipropyl disulfide, dipropenyl sulfide, and dipropenyl disulfide	Oxalate and tannins	Anticancer, antidiabetic, antioxidant, antiplatelet, antihypertensive, and antidepressant effects and neuroprotective, anti-inflammatory, and antiparasitic effects
Chive	Thiosulfinates, e 3,5-dihydroxy-6-methyl-2,3-dihydro-4H-pyran-4-one, glycolipid		Anti-inflammatory and anticancer effects, abdominal pain, diarrhea, hematemesis, and asthma, bactericidal activity, Antihypertensive activity, Anthelmintic activity
Rhubarb	Anthraquinone glycosides	Oxalate	Chronic constipation (Purging action)

Source: Online available published information

Table 4. Novel exotic traits introgressed in commercial vegetables in India

Exotic vegetables	Novel exotic traits	Local varieties
Cauliflower	Purple cauliflower and orange cauliflower	Pusa Purple Cauliflower-1 (Anthocyanin)
Cabbage	Red cabbage (anthocyanin)	Pusa Red Cabbage Hybrid-1Kinner Red
Carrot	Baby carrot, Pale carrot	Pusa Rudhira, Pusa Nayanjoti, Pusa Asita, Pusa Prateek
Radish	French radish, Chinese pink, coloured radishes (lycopene)	Pusa Sagarika, Pusa Jamuni (Anthocyanin), Pusa Gulabi (Lycopene), Chinese Pink, Rapid Red, Pusa Mridula (lycopene)
Tomato	Cherry tomato- Red (lycopene), Orange (β -carotene)	Pusa Cherry Tomato Hybrid-1, Pusa Golden Cherry Tomato-2,
Capsicum	Yellow Wonder, Red (lycopene)	Arka Basant (Cream and Red), Arka Gaurav (yellow fleshed), Arka Mohini (red), Orobelle (yellow colored), Bomby (red colored)
Sweet potato	Orange flesh (β-carotene)	Varsha, Kamal Sundari, Sree Vardhini, Sree Ratna, Sree Kanaka, Pusa Sunehri, Pusa Bharati, CO-1,3, Gouri, Gouri Shankar
Broccoli	Coloured types (anthocyanin)	Pusa Purple Broccoli-1, Palam Vichitra

In India, the breeding of exotic vegetables has advanced significantly, with a range of methods tailored to local needs. Introduction contributed in maximum varieties in these crops such as knol khol, Brussels sprouts, Lettuce, celery, parsley, asparagus etc. Recurrent selection also resulted in varieties in crops such as broccoli (Pusa Purple Broccoli-1). The exotic vegetables are well investigated in European countries for biotic and abiotic stresses and genomic information from these studies can be easily utilized in Indian condition. The marker-assisted breeding and tissue culture have contributed to the development of varieties that are disease-resistant, high-yielding and better suited for India's diverse agro-climatic regions. The successful cultivation of exotic vegetables in India hinges on developing varieties that are adaptable to the country's diverse agro-climatic zones. Through methods like hybrid breeding, mutation breeding, and marker-assisted selection, Indian agricultural institutes and universities have made significant progress in releasing varieties and hybrids that not only improve yield and quality but also address challenges like heat tolerance and disease resistant.

Entrepreneurship opportunities with exotic vegetables:

In India, the market for exotic vegetables is still in its early stages compared to international markets. The primary buyers include high-end retail chains like Spencer's, Reliance Fresh and More, online platforms like star hotels, Big Basket, quick service restaurants such as Subway and McDonald's as well as hospitals, offices and social events. The exotic vegetables provide opportunity to create entrepreneurship opportunities through (i) high throughput production centers, (ii) processing for domestic and export markets, (iii) seed business- production, import, export, (iv) cold chain infrastructure- refrigerated trucks, transit cold storage facility, (v) transport facilities for domestic markets and to air cargo/ports, (vi) edible colour extraction, (vii) functional compound extraction, (viii) services – production, processing, transport, consumer behaviour and market intelligence (ix) Organic production of exotic vegetables, and (x) input production/procurement and supply (Figure 2). Some of these options are discussed below:

1. **Seed business of exotic vegetables**

   The seeds of exotic vegetable crops is very important and potential economic activity for the reasons such as (i) almost seed supply of exotic vegetables is import dependent, (ii) hills are ideal for seed production of temperate exotic vegetables, (iii) local production individually or FPO for domestic market and export, (iv) import/procure and supply to local growers, (v) low volume – high-cost seed, demand is less but

Figure 2: Different entrepreneurship options through exotic vegetables

the margin is high, (vi) diverse platforms of marketing: direct sale, seed store, online and (vii) present trend is faulty since no major attention to quarantine.

2. **Harnessing export potential of exotic vegetables**

   Export potential during winters in Europe and tropical adjoining countries from northern plains of India and in spring and summer seasons from the hill region give advantage of cultivating these exotic vegetable crops. Because the European region remain frozen during winters and have to spend huge money to grow crops locally (Table 5). Further, the India's domestic markets also increasing for winter loving crops during spring and summer season which give additional advantage to hill region. However, it requires ecofriendly and soil conserving practices for growing the crops.

3. **High Throughput Production Centers**

   Modern high throughput production centers are transforming agricultural practices through advanced methods like hydroponics, now widely used, and aeroponics, which is targeted at select crops. Vertical gardening has gained significant traction in urban areas. These centers focus on an integrated approach, utilizing standardized technologies, optimizing supply chains, and minimizing energy consumption. The high level of automation ensures cost-effectiveness and efficiency.

4. **Hi-tech Nursery Production of Vegetables**

   This technique is particularly beneficial for exotic crops, with seedlings nurtured in polyhouses or net

Table 5. Temperature profile of India, Europe and Tropics with reference to exotic vegetables

Country/Region	Summer	Autumn	Winter	Spring
	June-August	Sept-Nov	Dec-Feb	March-May
India	34-39 °C/27-28 °C	28-34 °C/28-34 °C	23-25 °C/8-11 °C	30-40 °C/16-26 °C
Europe	High 22-30 °C/ Low 13-17 °C	11-20 °C/ 5-10 °C	1-7 °C/ -6 to 0 °C	11-18 °C/ 2-7 °C
Tropics	25-30 °C	25-30 °C	22-30 °C	26-32 °C

houses. Low-cost polyhouses offer beginners a viable entry point while controlled environment leading to high returns with minimal investment.

5. **Microgreens from Exotic Vegetables**
   Exotic vegetables are among the best option for in-store farms to, leafy greens, and Microgreens on-site. The concept of portable farms and roadside plant factories is also gaining momentum in urban environments.
6. **Processing, value addition and export facility for Exotic Vegetables**
   This is sector is emerging option for young entrepreneurs. Minimal on-farm processing methods, facilities for grading, sorting, and packaging help to streamline the process, ensuring these products are ready for the market are much in demand. Value addition provides options such as sauerkraut, frozen items etc. and cold Chain Infrastructure for Exotic Vegetables to transport metro cities in different regions of the country. The natural colorants derived from food products are in high demand both domestically and internationally, carrots and sweet potatoes provide orange hues, while cabbage, purple cauliflower, black carrot, beetroot, and broccoli contribute purple tones, and cherry tomatoes offer rich red shades. Besides, the services such as Production, Processing, Transport, Consumer Behavior, and Market Intelligence, Input Supply Line for Exotic Vegetables are options to tech-savvy young entrepreneurs.

However, crop prioritization for entrepreneurship is essential to make it successful. For this, the following factors can be considered: (i) local geographical conditions and crop requirement, (ii) geographical advantage – 'natural glasshouse', (iii) market research– domestic & export, (iv) economic competitiveness with other growing areas– volume & value, (v) input requirement, (vi) sustainability of production and demand, (vii) ease of doing crop practices and (viii) technologically advanced practices.

Government in entrepreneurship development:

Policies that promote the inclusion of exotic vegetables in school feeding programs, advocate for their role in sustainable diets, enhance food aid with nutritious exotic options, and provide subsidies for their cultivation and marketing can significantly encourage their utilization. The MSME sector focus on enhancing employability of the youth through skill development and provide opportunities through various schemes and subsidies even for doing entrepreneurship with exotic vegetables. Udyog Aadhar Memorandum is aimed to promote ease of doing business and employment exchange for industries and ASPIRE scheme (Promoting innovation and rural entrepreneurs) and APEDA for export promotion of agricultural commodities. Institutions such as Indian Institute of Entrepreneurship (IIE), National Horticulture Board (NHB), Farmers-Producers Organization (FPO) and Small Industries Development Bank of India (SIDBI) are supporting the promotion of youth entrepreneurship in agriculture also. Ministry of Agriculture and Farmers Welfare (MoA&FW) has established a new Horticulture Cluster Development programme to boost the country's horticulture sector's worldwide competitiveness. The MoA&FW has identified 55 horticulture clusters, of which 12 have been selected for the pilot launch of the Programme.

Conclusion

The introduction and cultivation of the exotic vegetables presents immense opportunity to youth and farmers particularly in hill region. However, promotion and mainstreaming of these have several challenges, including the availability of quality seeds, the need for specific agronomic practices with specialized knowledge, inputs, advanced post-harvest handling, market access and marketing strategies, which can pose significant barriers for smallholder farmers. Consequently, the success of exotic vegetable farming in these regions is largely reliant on the support provided by agricultural research institutions, government initiatives, and extension services, which are essential for providing farmers with improved seed varieties, training in best practices, and insights into market dynamics. This transition not only boosts earnings from the same piece of land but also permits the land to be used twice during the cultivation season, due to the shorter growth cycle of exotic vegetables.

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