Chapter 2
Production Technology of Underutilized Crops of Alliaceae Family

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Introduction

Regardless of huge achievements toward vegetable production globally, still food security is a big challenge for India. According to UNICEF (2019), every second child below 5 years is affected by some form of malnutrition. Underutilized *Allium* is rich in micronutrients such as zinc, iron, vitamin C, and provitamin A, which help protect people against lifestyle diseases like diabetes, heart disease, constipation, obesity, and cancer. *Allium* genus is one of the major genera in monocots, including more than 800 species (Fritsch et al. 2010) and popular vegetable crops, such as garlic and onions (Traub 1968). Additionally, minor and underutilized *Allium* viz. chive (*A. schoenoprasum*), bunching onion (*A. fistulosum*), Chinese chive (*A. tuberosum*), rakkyo (*A. chinense*), and leek (*A. porrum*) have also cultivated from the last few decades. The majority of the 850 species in the *Allium* genus have been identified as a rich source of micronutrients and secondary biological active metabolites (Khanum et al. 2004). *Allium* species' bulbs and leaves have been extensively proven to be antioxidants, antifungals, and antimicrobials (Bernaert et al. 2012; Mohammadi et al. 2012). Although some aqueous solvent aggregates contain antioxidants such as ascorbic acid and other organic acids, they lack non-growing *Allium* species in their profiles (Carocho and Ferreira 2013; Seabra et al. 2006). In several places (Picchi and Pieroni 2005; Tardío et al. 2006; Al-Qura'n 2010), and even in India, the bulb and leaf stalk with petioles are consumed as vegetables or condiments. As a vegetable, it is often eaten raw but more usually boiled, fried, sautéed, or combined with olive oil (Tardío et al. 2006; Dogan 2012). In South India, it is consumed as a special ingredient of Sambhar. In many restaurants, shallots are commonly offered in the condiments tray together with sauces and papads

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(Santosh et al. 2020). Underutilized *Allium* species have a very old and traditional heritage of treatment not only for various ailments (Osbaldeston 2000) but also for their presumed antihypertensive, diuretic, and anthelmintic characteristics, as well as ethnobotanical qualities (Guarrera and Savo 2013). As antagonistic bacteria and antifungal chemicals by *Allium* are produced, soil suppressiveness against fusarium wilting fungi also plays an important function (Nishioka et al. 2019).

Origin and Distribution

The genus comprises over 800 species, almost all distributed in the North. In Eurasia and a minor part of America, the majority of *Allium* species are present. The Mediterranean Basin covers Central Asia and neighboring nations with extraordinarily high species richness. A secondary center for a variety of *Allium* occurs in the western part of North America. Ecological diversification has followed the evolution of the genus. In sunny, open, and fairly humid regions, the majority of species grow. The details of the underutilized vegetables are given in Table 2.1.

Ploidy pressure in onion, shallot, garlic, and many other diploid species has not changed at home. Only seldom during selection was the introduction of additional

Table 2.1 Underutilized *Allium* crop species majorly grown worldwide

Common name	Scientific name	Area of cultivation
Shallot, potato, onion, multiplier onion	*A. ascalonicum* auct. hort.	Nearly worldwide
Ever-ready onion	*A. cepa* var. *perutile* Stearn	Great Britain
Onion	*A. cepa* ssp. cepa/var. *cepal*	Global
Garlic	*A. sativum* var. *typicum*, *A. sativum* var. *sativum,*	Global
Garlic	Regel *A. longicuspis* Regel	Central to the south and east Asia
Kurrat	*A. kurrat* Schweinf. ex Krause	Egypt and adjacent areas
Leek	*A. ampeloprasum* var. *porrum* (L.) J. Gay; *A. porrum* L.	North America and Europe
Great headed garlic	*A. ampeloprasum* var. *holmense* (Mill.) Aschers. et Graebn.	Eastern Mediterranean region
Bunching onion, Welsh onion	*A. fistulosum* L.	Europe, temperate Japan, East Asia, America
Rakkyo, Japanese scallions	*A. bakeri* Regel	Japan, China, Korea, South-East Asia
Chive	*A. sibiricum* L.	Worldwide in temperate areas
Top onion, tree onion, Egyptian onion, Catawissa onion	*A. cepa* var. *proliferum* (Moench) Alef.	North-East Asia, North America, Europe

Source: Rabinowitch and Currah (2002)

species of a function. However, *A. chinense* (Rakkyo) cultivated lines containing diploids, triploids, and tetraploids.

Nutritional Importance and Uses

As a basic component of human food, onions and other unused species, either raw or cooked in other vegetable recipes, have been widely used since ancient times. The health benefits of *Allium* sp. in treating many different major and minor disorders have been proven.

Allium porrum *L. (Leek)*

Leeks provide great vitamin C and folate quantities as well as valuable vitamin B, vitamin A, calcium, and iron portions (Table 2.2).

In addition, leeks were discovered to possess somewhat high specific carotenoids in the leaves (Heinonen et al. 1989). Two kaempferol glycosides in leek had been demonstrated to suppress blood-platelet aggregation (Fattorusso et al. 2000).

Allium ascalonicum *(Shallot)*

Shallot is a type of onion that grows in clusters and has a distinct tapered shape. Cloves are copper brown or reddish and have a sweet onion and garlic flavor. It has a morphology that is similar to both onion and garlic. The bulblets resemble garlic and their texture and color with onion. Further, it was also adopted in Ayurveda as a medicinal herb. Vitamin B6 is the primary core nutrient in shallots. Shallots contain a fair amount of vitamin C even if they are not present at levels as high as other *Allium* species. Shallots can include several other micronutrients in small but valuable quantities (Table 2.3). Shallots include saponins and high quercetin, isorhamnetin, and glycosides of quercetin (Fattorusso et al. 2002).

Table 2.2 Nutrient contents in leek

Nutrient	Content	Nutrient	Content
Energy (kcal)	77	Vitamin A (mg)	30
Moisture (g)	79	Calcium (mg)	50
Protein (g)	1.8	Iron (mg)	2.3
Fat (g)	0.1	Carbohydrates (g)	17.2

Source: USDA National Nutrient database

Table 2.3 Nutrient content in shallot

Nutrient	Content	Nutrient	Content
Energy (kcal)	72	Vitamin A (mg)	13
Moisture (g)	3.2	Calcium (mg)	3
Fat (g)	0.1	Carbohydrates (g)	17
Protein (g)	2.5	Iron (mg)	6

Source: USDA National Nutrient database

A. fistulosum *L. (Welsh onion)*

Vitamins B3 (284. 3 mg/100 g), B6 (5.4 mg/100 g), B2 (1.3 mg/100 g), B9 (2.2 mg/100 g), and iron (20. 8 mg/100 g) are all abundant in Welsh onion (Sung et al. 2014). Colds, influenza, abdominal pain, headaches, constipation, diarrhea, sores, and ulcers have all been treated with it in the past (Chen et al. 2000). *A. fistulosum* contains quercitrin, campesterol, isoquercitrin, *p*-Coumaric acid, stigmasterol, and allicin (Vlase et al. 2013).

Allium schoenoprasum *(Chive)*

Chives have medicinal properties similar to garlic but are weaker; the light effects may be the primary reason for their limited use as a medicinal herb when compared to garlic. Chive has a beneficial effect on the circulatory system due to the presence of allyl sulfides and alkyl sulfoxides. They can have moderate antiseptic, diuretic, and stimulant properties. Chive is rich in vitamins (A&C), minerals (calcium and iron), and a little amount of sulfur.

Agronomic Practices

In sandy, heavy clay, clay, or organic soil, *Alliums* are grown in all sorts of soils. Sandy loams are therefore the most suited soils for loams with decent organic content and a solid soil structure. Climatic requirement of underutilized *Allium* is similar to onion viz. open, dry, and sunny sites in humid and arid areas. Major cultivated *Allium* crops require low temperature for bolting including shallot (Krontal et al. 2000), chives (Poulsen 1990), bulb onion (Rabinowitch 1985), and Japanese bunching onion (Inden and Asahira 1990). In addition, for inflorescence initiation and further differentiation, some *Allium* crops need a long photoperiod; they include leek (Van der Meer and Hanelt 1990), Chinese chives (*A. tuberosum*) (Saito 1990), and rakkyo (*A. chinense*) (Toyama and Wakamiya 2020) (Table 2.4).

Table 2.4 Propagation method, varieties, and edible parts of major underutilized *Allium* species

Crop	Propagation method	Varieties	Edible part
Chive	Seeds or division of clumps	Grolau' Chives, Nelly' Chive, Staro' Chives, Kobold	Bundle of leaf sheaths (scapes)
Tree onion	Bulbs or sett Bulblets and also by seeds	MDU-1, CO-4, CO-3, CO-2, CO-1	Bulblet, bulbil
Welsh onion	Clumps and seeds		Bulbs, shoots, and leaves
Leek	Seeds	Palam Paushtik, PPL-1, American Flag, King Richard, Pandora, and Primor	Bulbs and lower parts of the shoots

Postharvest Management

Curing

Curing is required to store the bulbs for a long time by maintaining bulb quality. It removes extra moisture from the outer skin, neck tissue, and root of harvested *Allium* crop. This technique increases the quality and decreases the chances of disease infection during storage (Thompson et al. 1972; Petropoulos et al. 2017). The dry scales give mechanical protection (Maw and Mullinix 2005) and an aesthetic look of *Allium* (Maw and Mullinix 2005; Downes et al. 2009). Good ventilation and heat require during curing with low humidity, which dries out the neck and two to three outer scales of the bulb. The curing process is completed when the neck becomes tight and the outer scales also become dry enough to rustle (Hoyle 1948; Vaughn et al. 1964). During this process, *Alliums* have lost 3–5% of their weight (Anonymous 2016a). Immature bulbs have few outer layers and very high moisture; therefore, they require more extensive care during the curing than mature *Allium* (Anonymous 2016b). *Allium* curing can be done by natural convection of air or artificial hot air.

Storage

Allium can be best stored in well-ventilated rooms with lots of sunlight and aeration. Under a controlled atmosphere with a very low oxygen concentration of 0.5–2.0% and 3% CO_2, turning off the bulb and reducing rotten and sprouted bulbs is critical during storage (Adamicki 2004). *Allium* can be stored at a temperature of 30–35 °C with 65–70% of relative humidity (RH) for 6 months to avoid causing disease infection and rotting of bulbs (Saraswathi et al. 2017). Freezing injury occurs at temperatures below 2 °C, and rotting can occur at temperatures between 2 and 25 °C with more than 75% humidity (Saraswathi et al. 2017). Various pathogens, such as *Aspergillus*, *Alternaria*, *Botrytis*, *Rhizopus*, and others, attack *Allium* spp. during

storage, causing economic losses as well as pathogens that are harmful to people's health (Fink-Grernmels 1999). Various chemicals such as mancozeb, carbendazim, salicylic acid, sulfur are used to control the pathogens (Kumar et al. 2015).

Grading

Generally, in India, *Allium* is performed manually grading as well as machine grading. *Alliums* are graded in three grade scales: A grade, B grade, and C grade scales. A grade scale should have more than 60 mm diameter of *Allium*, while B and C grade scales have 50–60 and 35–50 mm diameter of *Allium*, respectively (Tripathi and Lawande 2003). In addition, the price of *Allium* is differentiated significantly according to its graded size. Graded *Alliums* are more attractive to consumers and improve the graded *Allium* quality standard, showing uniformity in the size. Graded *Allium* will attract the consumer to buy the *Allium* at a given or higher than normal price (Aher et al. 2019).

Packaging

Allium crops can be packed in jute bags and wooden baskets for packaging. The nylon net bags can also be used for packaging due to the excellent ventilation provided to packed *Allium* (IIFPT). For easy handling of *Allium* during transportation, packaging should be made with small and suitable packaging materials that protect against physiological (mass), physical (firmness), and pathological (decay) deterioration (Saraswathi et al. 2017).

Marketing Strategies to Promote Underutilized *Allium* Species

Indonesia is the leading producer of leek, other alliaceous vegetables in the world producing 590.6 thousand tons of product in 2019, followed by Turkey and China, 234.1 and 167.0 thousand tons, respectively (Fig. 2.1). These countries also dominate the majority of the export. India has very little production of leek and other vegetables of the Alliaceae family.

In India, for *Allium* crops, majorly production and consumption data are available for onion and garlic. These two are the major crops largely produced and consumed worldwide. So the volume of production and marketing is also available in these two cops. If we consider the state-wise production of onion and garlic, we can see one or two-state dominance in production.

In India, Maharashtra is the highest producer of onion and produces 8854.09 thousand tons of onion every year and holds the share of 38.09% (Fig. 2.2). Madhya Pradesh is next to that, producing 3701.01 thousand tons and holding 15.92% of the

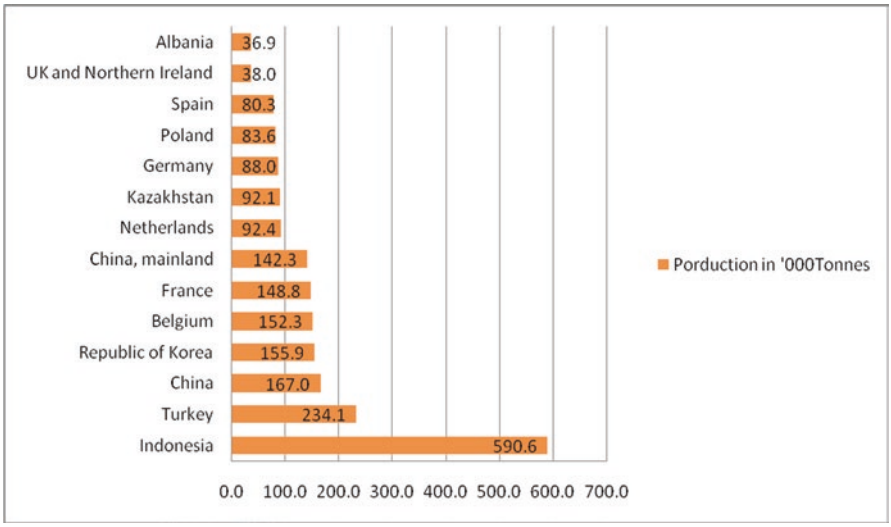

Fig. 2.1 Production of leeks and other alliaceous vegetables in the year 2019 in the top 14 countries in the world. (Data source: FAOSTAT (2021))

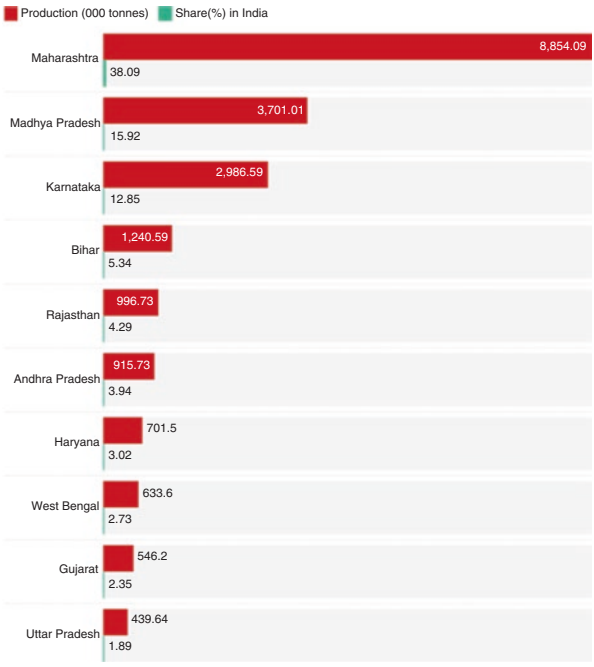

Fig. 2.2 Major onion producing states in India and their production share. (Data source: National Horticulture Board (NHB) Year 2017–18)

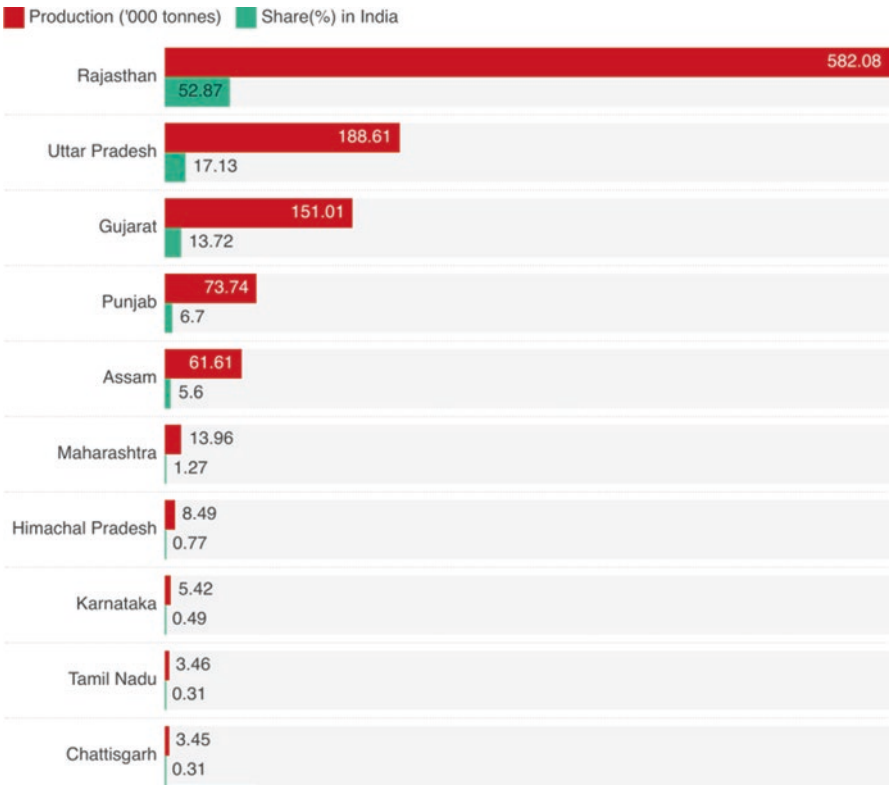

Fig. 2.3 Major garlic producing states in India and their production share. (Data source: National Horticulture Board (NHB) Year 2017–18)

share. Karnataka is the third state producing 2986.59 thousand tons of onion every year and holding 12.85% of the share. In total, these three states are producing two-thirds of the total production in India. These states dominate the entire marketing of onion. Interstate transportation is the way of trade (Fig. 2.3).

As consumption is a concern worldwide, the onion consumption in India per capita per annum is 14.7 kg. As garlic is concerned, the annual consumption is 5.86 kg per person in India (Fig. 2.4). Much data is not available for other *Allium* crops such as chives, leek, shallot, and Welsh onion. These crops are popular in China and other southwest Asian countries. In India, with increasing continental food preferences the pattern of consumption is increasing.

The above data indicate the potential of the underutilized *Allium*. There is massive potential for these nutrient-rich crops to meet the current demands of nutrient-rich foods.

Marketing strategy makes market chains more sustainable for minor *Allium* crops. They target campaigns for public awareness, select high-quality items, and promote certain features or attributes of species or variants. Marketing is essential for enhancing the profitability of farmers (Kumar et al. 2018). For onion and garlic,

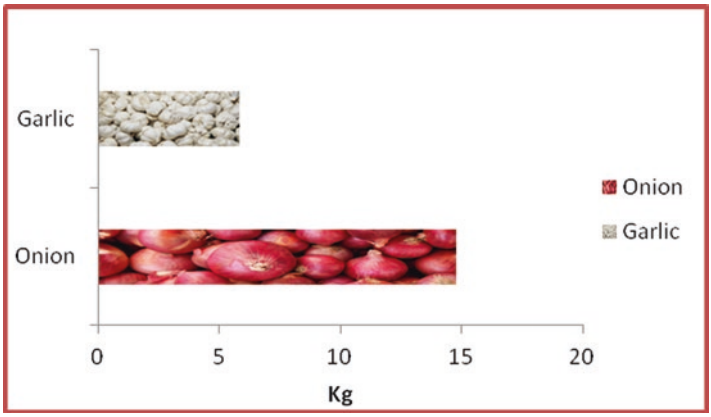

Fig. 2.4 Annual consumption of onion and garlic per person per annum in India. (Data source: Garlic, statista.com (2012); Onion, helgilibrary.com (2017))

the supply chain is well established but it is missing in the case of minor *Allium* as lack of sizable demand. Farmers can individually sell their low use of *Allium* crops through the local market and so even achieve a slightly higher price for their products (Kruijssen et al. 2008). However, growers indicate that they prefer to deliver to society as this is less time-consuming and secure. More demand for *Allium* crops in the market should make products based on *Allium* crops like pest powder flakes, etc. and such platforms like a store, malls, supermarkets, etc. can be more attractive to sell well-packed *Allium* and branded *Allium* products. In India, forming Farmers Producer Organization (FPO), particularly in these underutilized *Allium* crops, can be beneficial. It will be a win–win situation for farmers as well as the consumers. It has been reported from recent studies that FPO has been applicable in enhancing farmer's income (Mukherjee et al. 2018) and livelihood security in different sectors like dairy (Mukherjee et al. 2020a), poultry (Mukherjee et al. 2019), and traditional foods (Mukherjee et al. 2020b). For marketing of minor *Allium*, FPO can be made to market their product to processing industries and tie up with hotels and restaurants (IIFPT).

Physiological Disorders

Bolting

Most of the minor *Alliums* are biennials in nature. The emergence of the seed stalk before the formation of vegetative growth adversely affects the formation and development of bulbs. Bolting is premature flower head development, usually occurring in the first year of growth. Bolting can also result in small and poor vegetative development. It can be rectified by changing the transplanting time.

Bulb Splitting

Adverse environmental conditions and imbalanced nutrient supply cause the splitting of bulbs. *Allium* crop splits of the basal plate and the affected bulb's secondary growth can occur as protrusions from the weakened base. This damage can allow the invasion of microorganisms, contributing to bulb decay. Watering extensively, when plants have been under severe drought stress, raises vulnerability. Incidence can be severe by damage to the root base from other secondary pathogens.

Chimera

In this disorder, variegated leaf tissue usually appears longitudinally around the leaf in yellow and/or white strips. Extreme temperature causes this problem in some minor *Allium*.

Hail/Heavy Rain Damage

Some minor *Alliums* are sensitive to excessive rains or hail damage resulting in distinctive white marks, generally on one side of the leaf only. If serious, holes in the leaves may be punched or leaves may be torn off.

Thick Necks

This disorder occurs when immature bulbs are harvested, before proper bulbing. Phosphorous deficiency can increase incidence during development. It was common in low-population bulb crops or where bulb stimulation is weak, particularly in cold, wet summers.

Watery Scale and Leathery Skin

It is a very common disorder of bulb crops; it mainly occurs when harvested after heavy rain. Affected bulbs produce external water-soaked scales (thick scale). During storage, thick skins limit the absorption of oxygen and carbon dioxide into and out of the bulb scales resulting in reducing the postharvest life.

Conclusion

The better option for large-scale agriculture appears to be the cultivation of underutilized *Allium* crops on a huge scale. *Allium* species have the potential to provide food security, nutrition, health, and income generation. Due to the lack of competition from other crop species in the same agricultural environment, farmers and consumers are using these crops less. The underutilized *Allium* crops are a good option for the region because it is one of the richest reservoirs of genetic variability and diversity, with plant types, morphological and physiological variations, disease and pest reactions, adaptability, and distribution all present. Because these crops have the potential to directly alleviate hunger by increasing food production in difficult environments where major food crops are severely limited daily. The potential for agricultural–rural development, food and nutrition security, and the realization of the importance and uses of these underutilized *Allium* crops can be unlocked, enhancing nutrition, dietary and culinary diversification, health, and income generation.

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