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Welsh Onion (*Allium fistulosum* L.): A Promising Spicing-Culinary Herb of Mizoram

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ABSTRACT

Welsh onion (*Allium fistulosum* L.), known as Mizo-purun in Mizoram, is a spice-vegetable herb of temperate to tropical regions of northern Hemisphere which is used extensively to flavour up the soups, steamed-boils, fries, vegetables, salads, dals and other cookeries. It is used as an ethno-medicinal herb for the treatment of eyesight problems, common colds, headaches, heart problems, wounds and festering sores; reduces fat accumulation and serum lipid concentrations; and the root exudates in soil root-zone have anti-termite, anti-fungal and anti-microbial activities. The Welsh onions are tolerant to abiotic stresses (excess moisture, drought and high humidity), biotic stresses (neck rot, leaf blight, pink root disease, smut, anthracnose, downy mildew, Fusarium basal rot, thrips, onion fly and onion yellow dwarf virus); and good sources of total soluble solids and folic acid content. Being a potential donor for various traits of economic traits and readily crossable with onion, it is most suitable candidate for genetic improvement of onion, especially Kharif onion. Therefore, focus on holistic research approaches such as genetic enhancement to develop high yielding cultivars, efficient production technologies for commercial cultivation to harvest the plants in mass, post-harvest management to minimize marketing loss, and widening of its marketing would be the best strategies to make it as an economically relevant crop.

1. Introduction

Allium fistulosum L. (Welsh onion and Japanese bunching onion) belongs to the family Liliaceae; popularly known as Mizo-purun in Mizoram, India; and widely grown and consumed in East/Southeast Asian countries. It is originated in Asia, probably in the region of Mongolia, Siberia or north western China. The species is not known in the wild form, but the nearest wild relative *A. altaicum* Pall (wild bunching onion, butun in Siberia) seems to be progenitor which is widespread in the parts of Mongolia and Siberia (De Candole 1883; Hanelt 1985; Friesen 1995). Consequently, Friesen *et al.* (1999) in their RFLP and RAPD study confirmed that *A. fistulosum* is of monophyletic origin and originated from *A. altaicum*, making *A. altaicum* a paraphyletic species.

The wild bunching onion was discovered in 1735 near rift Lake Baikal, Siberia by Steller (1740); and its frost-resistant bulbs are locally used as condiment and vegetable in Siberia and Mongolia. The interspecific hybridization between these two *Allium* species occurs easily and hybrids show a high pollen and seed fertility (Inada and Iwasa 1983; Nishitani 1984). The written history of *A. fistulosum* in China dates back to the 300 BCE, while definite characteristics and agronomic practices of *A. fistulosum* were described in a Chinese book of 100 BCE. However, *A. fistulosum* was first mentioned in Japanese literature as early as 720 ACE, probably after its introduction from China (Inden and Asahira 1990). The species was brought into western Europe during or at the end of the Middle Ages (1000-1400 ACE) and from there into Russia. Thereafter, it was further spread to Southeast Asia and Northeast India.

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In China, the fifth-century treatise on agriculture, Chi-min-yao-shu (Essential Arts for the People) by Chia Ssu-hsieh, described the cultivation of *A. fistulosum* along the Red River valley. There are lots of variability occur in East Asia, its region of diversity, where several types are grown (Inden and Asahira 1990). Almost all the plant parts of the *A. fistulosum i.e.* shoots, leaves and non-developed bulbs are eaten raw in salad, boiled as soup, cooked as vegetable or used as healing herbs. Northeast India, including Mizoram, is one of the areas with rich biodiversity of various plants. The warm tropical climate of this region provides the suitable habitat for both cultivated and wild edible species of *Allium*, especially *A. fistulosum, A. chinense* and *A. hookeri*. Mizoram is located at 21º58' to 23º35' N latitude and 92º15' to 93º29' E longitude; having varied altitudes ranging from 21 to 2157 m above the mean sea level; and surrounded by Tripura, Assam and Manipur in North-frontier regions, Bangladesh in West, and Mayanmar in East and South. The undulated topography of Mizoram, named as Lushai hills during British period, endowed with mild-tropical climate; receives annual rainfall of 2000-3200 mm; mean monthly temperature ranges from 14.5 ºC to 29.5 ºC in summer (monsoon); and during winter minimum temperature falls up to 11.8 ºC (Singh *et al.,* 2013).

A. fistulosum has several local/common names in different languages such as Welsh onion, bunching onion, Japanese bunching onion and stone leek (English); cong (Chinese); ail fistuleux, Ciboulette and ciboule (French); zwiebel, Schnittzwiebel and Winterzwiebel (German); cipoletta and cipolla dinverno (Italian); negi and nebuka (Japanese); chung (Taiwan); pa (Korean); lukbatun, luktatarka and ukdudcatyj (Russian); cebolleta and cebolla (Spanish); piplok (Swedish); cebolinha-verde (Portuguese); pijplook and bieslook (Dutch); Pillisipuli (Finnish); ceaps de iarna (Romanian); escallion (Jamaican); vilayati lahsun (Hindi); khorat (Marathi, India); vellulli (Malayalam, India); Mizo-purun (Mizo, India); and ja-uat (Khashi, India). Welsh onion is neither indigenous to Wales nor common in Welsh cuisine (the green *Allium* common to Wales is the leek, the national vegetable of Wales). The word 'Welsh' preserves the original meaning of the old English word 'welisc' or old German 'welsche' meaning 'foreign'. This was probably applied when it was first introduced into Germany near the end of the Middle Ages. The other names those are commonly applied to *A. fistulosum* include green onion, salad onion, scallion and spring onion. These names are ambiguous, as they are also be used to refer to any young green *Allium* stalks, whether grown from Welsh onions, common onions or other similar members of the genus *Allium*.

Taxonomically, *A. fistulosum* belongs to the division Mangoliophyta (Flowering plants), class Liliopsida (Monocotyledons), subclass Liliidae, order Liliales, family Liliaceae (Lily family), genus *Allium* and species *fistulosum* (USDA 2015). Literally, the species *fistulosum* means hollow, named as it possesses hollow leaves and scapes. The genus *Allium* is a large plant taxon comprising about 850 species; many of them have high economic value as spices, vegetables, medicinal plants and ornamentals (Keller *et al.,* 2012) which grow widely throughout the temperate to tropical and arid regions of the northern Hemisphere. Other most common crops of the genus *Allium* are *A. cepa* (onion), *A. sativum* (garlic), *A. schoenoprasum* (chives), *A. ampeloprasum* (great-headed or elephant garlic), *Allium ampeloprasum* var. *porrum* (leek), *A. tuberosum* (Chinese or garlic chives) and *A. chinense* (rakkyo). *A. fistulosum* is a diploid species having 16 numbers of chromosomes (2n=2x=16). Cytogenetically, *A. fistulosum* is very similar to *A. cepa*: both are diploid with similar chromosome morphology, although the *A. fistulosum* chromosomes are considerably smaller (Jones and Rees 1968). Ohri and Pistrick (2001) reported a very wide diversity of genome size (16.93 to 63.57 pg 2C DNA per genome) among 75 *Allium* species belonging to the six subgenera, relatively smaller genome size for *A. fistulosum* (26.64 pg 2C DNA per genome).

Morphologically, there is a strong resemblance between *A. fistulosum* and *A. cepa*, but *A. fistulosum* does not develop a bulb. The plants of *A. fistulosum* stop growing, and their leaves start withering out and die-off under short days *i.e.* starts of winter season. *A. fistulosum* and *A. cepa* cross-fertilize readily, yielding interspecific F1 hybrids and hybrid derivatives (Peffley 1992). Nowadays, *A. fistulosum* has been considered as one of the NASA's Advanced Life Support Candidate Crops because of its characteristic flavour, short cropping cycle, suitability in dense planting compared with bulb onion, and ease of hydroponic culturing (Thompson *et al.,* 2004).

2. Biology, ecology and cultivation

Broadly, there are two types of *A. fistulosum* distinguished as cultivar groups (sometimes taxonomically treated as two subspecies) such as Japanese bunching onion group (subsp. *fistulosum*): single-stemmed cultivars grown for in cool climates for their thickened blanched pseudostems, and Welsh onion group (subsp. *caespitosum*): multi-stemmed cultivars grown in warm climates for their green leaves (Kazakova 1978).

Welsh onion is most common in Mizoram (Northeast India), temperate to tropical Asia and African countries. The whole plants; including green leaves, pseudostem as well as roots; are being consumed by Mizo tribes to flavour soups, steamed-boils, salads, vegetables, dals, and other culinary (Singh *et al.,* 2012). *A. fistulosum* is grown throughout the world in the wide range of climates—-temperate to tropical conditions. Globally, it is cultivated in Siberia and Ciscaucasia (Russia), China, Japan, Korea, Taiwan, Thailand, Indonesia, Malaysia, Philippines, Vietnam, Northeast India, Norway, Germany, Sudan, Kenya, Cameroon, Congo, Zaire, Sierra Leone, Zambia and Zimbabwe; moreover China and Japan are leading countries for its commercial cultivation. In India, *A. fistulosum* is grown traditionally in the Northeast states (Mizoram, Manipur, Nagaland, Arunachal Pradesh, Manipur, Assam and Tripura); and sparsely in Odisha, West Bengal, Andaman & Nicobar Islands, and few parts of Tamil Nadu, Kerala and Maharashtra; but unknown to other parts of India. Moreover, In Mizoram, *A. fistulosum* (Mizo-purun) is one of the most important spice crops grown frequently in the home gardens and Jhum lands which is fulfilling the culinary role and spicing the Mizos' cuisines. Under cultivation, the plants thrive best under acidic soil (pH 5.5-6.5), well drained heavy soil, irrigated, humid, long-day conditions; but tends to bolt profusely in short-days of winter months which is ultimately detrimental to leaf growth, quality and aroma. In Mizoram, Welsh onion is cultivated during May-November whose climatic conditions are: mean monthly temperature ranged from 12-29 ^{o}C, monthly relative humidity from 52-91%, monthly rainfall measured from 35-705 mm and number of rainy days from 5-26 days in a month with the altitudes ranged from 900-1100 m MSL. Early nipping (removal of apical buds) promotes vigorous shoot growth and thereby increases yield by 10-20% (Singh *et al.,* 2014). Locally, it is said that planting of Mizo-purun reduces termites' infestation in the home gardens as well as Jhum lands. Welsh onion is a perennial plant, grown generally as an annual, and usually propagated by evergreen clumps and seeds. They are fast growing in nature and very easy to grow. Plant is evergreen glabrous herb, growing in tufts, 50-90 cm tall and ovoid-oblongoid bulbs (Figure 1). Welsh onion forms a poorly developed bulb, normally with a white tunic, with a diameter (1-2 cm) hardly exceeding that of the pseudostem. Leaves are hollow, 5-13 in number, pointed at their tip, glaucous, distichously alternate, with tubular sheath, inflated to entire length, blade D-shaped in cross-section and 30-75 cm long. The hollow stalks topped with little greenish flowers in almost spherical umbels, bloom centrifugal, 2.5-7.5 cm in diameter, without bracts, dense; campanulate perianth; unequal flower pedicel, 0.4–2.0 cm

Figure 1. Plants of Welsh onion (Multi-stemmed *Allium fistulosum*)

long; stamens filaments 0.8–1.2 cm long; and pistils lower than the stamens. Fruits are round, 0.4-0.6 cm in diameter along with minute black seeds. As in other Alliums, the seeds of *A. fistulosum* are also short-lived and their vitality tends to be lost easily during storage. Generally, the floral initiation requires low temperatures and short photoperiod. However, the genotypes markedly differ in the number of leaves developed before reaching the post-juvenile age, the cold and photoperiod requirement for scape elongation and floral induction (Kamenetsky and Rabinowitch 2006). Welsh onion could be propagated by clumps and seeds. Once it has been established, use a trowel to loosen the soil around a clump, take it out, separate the clumps, separate it and transplant in field at the spacing of about 20×10 cm. In Mizoram, the best time to transplant them is the after onset of rains *i.e.* May-June. Additionally, the priming of the seeds with 2% potassium nitrate (KNO_3) increases the activity of antioxidant enzymes (dehydrogenase, superoxide dismutase, catalase) and lipid peroxidation; and thereby seed vigour (Dong *et al.,* 2014). The higher doses of nitrogen (>70 kg/ha) adversely affects the quality of the crop *i.e.* more accumulation of nitrates (Kolota *et al.,* 2013), and also lowers down pungency in the plant tissues. The levels of light and CO_2, basic requirement of photosynthesis, have positive effect on pungency *i.e.* increasing light and CO_2 levels increased the net accumulation of flavour precursors and/or alliinase activity (Levine *et al.,* 2005).

The delay in harvesting results in a substantial yield increment; and simultaneous depletion of vitamin C, carotenoids, chlorophyll-a, chlorophyll-b, sugars, volatile oils, nitrates, total N, K and Ca content (Kolota *et al.,* 2012). Postharvest durability of *A. fistulosum* is very short, mainly due to its high metabolic rate and high water content, coupled with poor techniques of management and transport to the consumer. To manage it, the application of salicylic acid is recommended by Freddo *et al.* (2013) as it decreases the weight loss as well as rottenness of shoots and leaves. As the roots of the *A. fistulosum* are much longer among the *Allium* species (Figure 2), it spreads networking formation inside the soil and changes the entire environment of root zone that is unsuitable for the growth of fungus, *Aspegillus niger* (Das 2010). Also a novel antifungal compound, fistulosin (octadecyl 3-hydroxyindole) has been isolated from the roots of Welsh onion that showed high activity against *Fusarium oxysporum* primarily inhibiting protein synthesis (Phay *et al.,* 1999).

3. Utilization (culinary, nutritional and medicinal)

Welsh onions are used extensively to flavour up the soups, steamed-boils, fries, vegetables, salads, dals and other cookeries especially in northern Hemisphere of world. In East Asia, it is used in diverse dishes including stir-fries and soups; in the West, it is primarily used as a scallion, salad or green onion, and in Mizoram, to relish the soups and steamed-boils (Fritsch and Friesen 2002; Singh *et al.,* 2012). The *Allium* plants, including *A. fistulosum*, are of great importance due to their nutritional composition, antioxidant properties, and uses as flavouring agents, fragrance and therapeutics and medicinal food.

Figure 2. Strong root system of Welsh onion

The nutritional composition of the thickened blanched pseudostems and green leaf blades differs; the green leaf types contain higher levels of β-carotene, vitamin B1 (thiamine), vitamin B2 (riboflavin) and vitamin C (ascorbic acid). However, the contents of each vitamin in the green leaf of Welsh onion are lower than those of other vitamin-rich vegetables. The raw green leaves are reported to contain water 90.5 g, energy 34 kcal, protein 1.9 g, fat 0.4 g, carbohydrate 6.5 g, Ca 18 mg, Mg 23 mg, P 49 mg, Fe 1.2 mg, Zn 0.52 mg, vitamin-A 1160 IU, thiamine 0.05 mg, riboflavin 0.09 mg, niacin (vitamin B 3) 0.40 mg, folic acid (vitamin B 9) 16 µg and ascorbic acid 27 mg in each 100 g edible portions. Carbohydrates are the most abundant class of nutrient in *Allium* species. A large proportion of the storage carbohydrates are sugars and oligosaccharides (Darbyshire and Steer 1990). Besides glucose, fructose and sucrose; they consist of maltose, rhamnose, galactose, arabinose, mannose and xylose. Sugar and protein contents increase in plants grown under low temperatures, and this improves eating quality (Messiaen and Rouamba 2004). Welsh onion leaves contain high levels of quercetin, a flavonol compound, with potential benefit to human health *i.e.* as protective effects in reducing the risk of cardiovascular disease, acts as anti-cancer due to its antiprostanoid and anti-inflammatory responses, and decreases the rate of DNA degradation (Crystal *et al.,* 2003; Feng and Liu 2011). The aroma/smell, a unique feature of edible *Allium* species, is due to the presence of sulphur-containing compounds. The precursors are odourless, stable, non-volatile amino acids of the general name S-alk(en)yl cysteine sulphoxides (Alliin), which are responsible for volatile flavour, pungency, antioxidant activities, nutraceuticals and medicinal properties, and making it as medicinal herb. When cells are damaged, the amino acids break down under the influence of alliinase enzyme and lachrymatory-factor synthase into highly reactive sulphenic acids, ammonia and pyruvate. Then sulphenic acids react with other compounds to form a range of disulphides (Jones *et al.,* 2004; Kamenetsky and Rabinowitch 2006). The aroma of Welsh onion is not very strong as in onion and garlic. Chemically, the leaves of Welsh onion have a fairly intermediate smell of onion and leek. It derives from volatile propyl cysteine sulphoxide (leek aroma) and propenyl cysteine sulphoxide (onion aroma). The antioxidant activity of *Allium* species is due to a variety of sulphur-containing compounds and their precursors, polyphenols, dietary fiber and microelements (Nencini *et al.,* 2007). Stajner and Varga (2003) estimated higher antioxidant activities in the leaves of *A. sativum, A. cepa, A. vineale, A. fistulosum and A. nutans, A. flavum* and *A. ursinum*. Consumption of onion and related *Allium* is associated with a reduction in blood lipids, cholesterol and platelet activity, contributing to decrease risk of cardiovascular disease (August 1990; Block 1992).

The biological activity and human health benefit are thought to be attributable to a suite of organosulphur compounds. The leaf extract of *A. fistulosum* reduces adipocyte size, fat accumulation and serum lipid concentrations by down-regulation of the expression of genes involved in lipogenesis in the adipose tissue of obese mice fed a high-fat diet (Sung *et al.,* 2011). It is also reported to help in recovery from eyesight problems, common colds, headaches, heart problems, wounds and festering sores. Furthermore, the extracts of *A. fistulosum* have antimicrobial activity, more active against *Bacillus sublilis* (Chang *et al.,* 2013).

4. Genetic improvement

Welsh onions have perfect flowers in their umbel, but cannot be self-pollinate because of the protandrous flowers *i.e.* the anthers shed pollen 2-4 days before the stigma is receptive. They cross-pollinate mostly via bees and flies, hence considerable plant to plant variation exists within populations. Being outbreeding species, a strict isolation distance of about 1000-1200 m is required to avoid cross-contaminations. Intraspecific hybridization has been attempted for their genetic improvement, but it takes a long time and has few variations in the group. On the other hand, interspecific hybridization is a useful tool to widen genetic variability, to introgress genes of economic importance or to produce new crops in a short time. Usually, backcrossing and recurrent selection are the most effective breeding approaches in incorporating the traits of economic importance *i.e.* yield, quality and stress tolerance. *A. fistulosum* is hybridized easily with common onion (*A. cepa*). These hybrids have been named as *Allium* × *proliferum* which are generally vigorous, non-blubbing type, smaller leaf-blades and sterile that could prospectively be used as green/spring onion and also noteworthy for their tolerance to hot/dry weather and diseases. In an attempt to increase the carotene level in the leaves of *A. fistulosum*, Umehara *et al.* (2006) produced the interspecific hybrids of *A. fistulosum* and *A. schoenoprasum* through ovary culture that possessed approximately seven times higher carotene content than those of either parent. Besides, the extensive roots of *A. fistulosum* explored higher volume of soil and had higher root density as compare to onion; it *A. fistulosum* was very responsive to indigenous and inoculated Arbuscular Mycorrhizal Fungus (AMF) *i.e.* 50-60% increase in both shoots biomass and roots length (De Melo 2003). This intensive root trait is being incorporated via bridge-cross with *A. roylei* to improve the root system of onion. In a genetic study, segregation analyses for inheritance of isozyme in *A. fistulosum* advocate that 6-phosphogluconate dehydrogenase (6-PGDH) is governed by two loci that have two alleles each, while phosphoglucomutase (PGM) and shikimate dehydrogenase (SKDH) are governed by a single locus each with two alleles (Mangum and Peffley 1994).

Figure 3. Welsh onion (Mizo-purun) in local market of Mizoram

Most of the local genotypes or landraces of *A. fistulosum* are well adapted to wide range of soil moisture and they are more tolerant to excess moisture and high humidity than the other *Allium* species. Besides, it is also a potential donor of resistance to biotic stresses, high soluble solids and folic acid content (Peffley 1986; Kumar and Banerjee 2001). In onion breeding programme; ever since the first attempt to transfer desirable genes from Japanese bunching onion (Emsweller and Jones 1935), several attempts have been made by various researchers to transfer the traits/genes of economic importance. The previous findings also indicated that *A. fistulosum* is resistant/tolerant to various biotic stresses such as pink root disease (*Phoma terrestris*), onion smut (*Urocystis cepulae*), neck rot (*Botrytis aclada* and *Botrytis allii*), leaf blight (*Botrytis squamosa*), anthracnose (*Colletotrichum gloeosporioides*), downy mildew (*Peronospora destructor*), Fusarium basal rot(*Fusarium oxysporum*), thrips (*Thrips tabaci*), onion fly (*Delia antiqua*) and OYDV-onion yellow dwarf virus (Emsweller and Jones 1938; Khrustaleva and Kik 1998; Kik 2002; Khrustaleva and Kik 2000). Therefore, *A. fistulosum* has the potential to incorporate the tolerant genes into onion and to develop varieties/genotypes, especially for Kharif season. Although both the species (*A. fistulosum* and *A. cepa*) are readily crossable, the expression of variable degrees of pollen and ovule sterility in the F1 and subsequent generations has been an obstacle in obtaining desirable recombinants. The existence of chromosomal structural differences between these two species is one of the causes of sterility in the

interspecific crosses (Peffley 1986; Van der Valk *et al.,* 1991; Ulloa *et al.,* 1994; Yamashita *et al.,* 2005). To overcome the sterility, bridge-cross involving *A. roylei* has been proposed as a means to increase the possibility of genetic introgression from *A. fistulosum* into *A. cepa* (Khrustaleva and Kik 1998; Khrustaleva and Kik 2000). In ploidy breeding approach, Yaguchi *et al.* (2008a) developed trisomic genotypes (monosomic additions) of *A. fistulosum* which are more vigorous in plant growth and possesses higher content of vitamin C than the normal euploid plants. Furthermore, the structural genes accountable for sucrose metabolism are located on chromosome-2 and chromosome-8, and that monosomic addition of these chromosomes causes significant increase in sucrose levels and sucrose metabolic enzymes compared with euploid *A. fistulosum* (Yaguchi *et al.,* 2008b).

5. Market potential

The market survey in various parts of Mizoram such as Varingte, Thingdawl, Buckpui, Saihapui, Bhuchang, Kolasib, Sihphir, Aizawl, Lengpuii, Serchip, Seling, Saitul, Khawjawl, Champhai, Darlawn, Lengpui, Mamit, Lawngtlai, Lunglei and Saiha reveals that most of the arrivals are harvested from traditional Jhum lands and few stocks from commercial growers. Usually, the supplies are in deficit to fulfill the demand of consumers.

However, demand is regularly increasing day-by-day. The present retail price is about Rs 25.00/bundle of 6-8 plants depending on the plant growth, clump size and market conditions (Figure 3). A piece of land of size 25×10 m (250 m^2 or 0.025 ha) could fetch minimum of Rs. 20000/- in a cropping season of 6-8 months, showing its economic importance. In conclusion, a series of systematic research for genetic enhancement to develop high yielding cultivars, efficient production technologies for commercial cultivation to harvest the plants in mass, post-harvest management to minimize marketing loss, promotion and widening of its cultivation and marketing, and use as a donor plant in onion breeding programme are needed to harness the potential of Welsh onion.

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