HOSTED BY

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Achievements and prospects of grass pea (*Lathyrus sativus* L.) improvement for sustainable food production

Girish Prasad Dixit[1], *Ashok Kumar Parihar*[*,1], *Abhishek Bohra*[1], *Narendra Pratap Singh*

ICAR-Indian Institute of Pulses Research (IIPR), Kanpur 208024, India

ARTICLE INFO

Article history:
Received 28 May 2016
Received in revised form 29 June 2016
Accepted 11 July 2016
Available online 21 July 2016

Keywords:
Grass pea
Genetic resource
Genetic improvement
Molecular marker
Molecular breeding
Toxin

ABSTRACT

Grass pea offers an attractive choice for sustainable food production, owing to its intrinsic properties including limited water requirement and drought tolerance. However, low productivity and the presence of a neurotoxin (ODAP) have posed major obstacles to its genetic improvement. Also, biotechnological investments remain limited and the genome is complex and not well understood. Strategies that allow identification of genotypes with reduced ODAP content, coupling of low ODAP content with enhanced yield, and effective seed detoxification methods merit immediate attention. Breeder-friendly genomic tools are being increasingly made available to improve the efficiency of breeding protocols. To this end, the application of next-generation sequencing has provided a means of leveraging the repertoire of genomic resources for this somewhat neglected crop. In this review, we describe progress achieved in *Lathyrus* genetic improvement. We also explore potential opportunities in *Lathyrus* research and identify urgent research needs.

1. Introduction

Grass pea (*Lathyrus sativus* L.) is a crop of immense economic significance, especially in developing nations including India, Bangladesh, Pakistan, Nepal, and Ethiopia [1–3]. It is often broadcast-seeded into standing rice crops one or two weeks before the rice harvest. This allows grass pea to effectively exploit the residual moisture left after the rice harvest [4,5]. It is also cultivated in China and in many countries of Europe, the Middle East, and Northern Africa. It serves a variety of purposes including food, feed and fodder, owing in part to its nutritive qualities [4,6–9]. Archeological evidence suggests that the domestication of *Lathyrus* dates to the late Neolithic, and precisely to the Bronze Age [2,9]. Prior to domestication, the crop was presumably present as a weed among other pulse crops. However, evidence based on historical records renders the subject of its origin more contentious [10].

In South Asian countries, grass pea is commonly grown for both grain and fodder purposes. However, the crop has gained more importance for use as animal feed than for use as human food. Animal feed from *Lathyrus* is usually composed of ground or split grain or flour, and is used primarily to feed lactating cattle or other draft animals [11,12]. Human diets include *Lathyrus* as grains that are boiled and then either consumed whole or processed for split dal [13,14].

Grass pea, inherently capable of withstanding temperature extremes, is grown across diverse regions that receive an

* *Corresponding author.*
E-mail address: ashoka.parihar@gmail.com (A.K. Parihar).
Peer review under responsibility of Crop Science Society of China and Institute of Crop Science, CAAS.
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.cj.2016.06.008

average annual precipitation ranging from 300 to 1500 mm [15,16]. In addition to remarkable tolerance to drought [17], *Lathyrus* has tolerance to excess precipitation and flooding [7,18–20]. It has a hardy and penetrating root system suited to a wide range of soil types including very poor soil and heavy clays [20–22]. Its notable robustness along with its intrinsic ability to biologically fix atmospheric nitrogen makes grass pea an attractive crop for adverse agricultural conditions [4,18,23].

Nutrient-dense food crops with reduced water demands such as *Lathyrus* are likely to play a key role in alleviating global malnutrition. However, to date, very limited research efforts have been devoted to improving *Lathyrus*. The major reason underlying this lack of research effort is the presence of a neurotoxin [β-N-oxalyl-L-α,β-diaminopropionic acid (ODAP)], prolonged consumption of which leads to the neurological disorder lathyrism in humans and domestic animals [24–26]. The disease is more pronounced when grass pea forms the dominant component of the diet and accounts for at least 30% of caloric intake for a period of at least three to four months [18,27]. Influences of a variety of factors on ODAP accumulation in *Lathyrus*, including plant growth stage, nutrients, abiotic stresses (drought, salinity, water, and heavy metal) have been comprehensively reviewed by Jiao et al. [28].

2. Implications for human health

As indicated in the previous section, the major health concern associated with grass pea consumption is the neurotoxin ODAP, which is also known as β-N-oxalyl-amino-L-alanine (BOAA) [29,30]. Irreparable loss of motor function may result from prolonged consumption of *Lathyrus* grains [26]. Instances of lathyrism have been reported from various parts of India [15,29,31]. It was observed that lathyrism could affect anyone consuming a diet consisting of more than 25% grass pea for 3–4 months [15,32]. In view of these findings, the sale or storage of *Lathyrus* has been banned in all states in India except for Chhattisgarh, Maharashtra, and West Bengal under rule 44-A of the Prevention of Food Adulteration Act, 1954 [33].

In India, *Lathyrus* cultivation is concentrated mainly in the Chhattisgarh region, where limited cases of human lathyrism are known. In contrast, a higher incidence of human lathyrism has been reported in Rewa division of Madhya Pradesh state, occurring when *Lathyrus* constituted more than 2/3 of the diet for prolonged periods (3–6 months) [34,35]. A survey of the socioeconomic conditions of *Lathyrus*-growing farmers and their culinary practices was conducted in two villages near Raipur. In these villages, the consumption was related to the size of the farm holdings, with non-farm holding families having greater consumption of *Lathyrus* [36].

Grass pea holds tremendous potential as a functional food to improve health conditions associated with cardiovascular disease, hypoxia, and hypertension [37–39]. Importantly, patents have been granted based on ODAP (as a hemostatic agent) in the USA and China, and an increasing number of therapeutic applications derived from *Lathyrus* may be developed in coming years [38]. Further, as highlighted by Singh and Rao [39], ODAP is increasingly being used for therapeutic purposes owing to its role in the stabilization of hypoxia inducible factor-1 (HIF-1). In short, the evolving view of grass pea as a functional food is likely to cause a dramatic shift in the ways pulses and lathyrism are perceived.

3. Economic importance in India

Grass pea is the third most important cool-season pulse crop of India, occupying an area of 0.58 million ha with an annual production of 0.43 million tonnes [14]. It is cultivated primarily in Bihar, Madhya Pradesh, Maharashtra, West Bengal, and Chhattisgarh [37]. The majority of this acreage (~70%) is shared by Chhatisgarh and the Vidarbha region of Maharashtra, which is a rice-growing region where supplemental irrigation is available only for rice. Consequently, water is not available for subsequent winter crops, making grass pea the only alternative for a crop following rice [40–42].

Grass pea effectively withstands unfavorable conditions including excessive moisture at sowing, which is often followed by moisture stress at advanced growth stages. In fact, grass pea is preferred for cultivation in such areas owing to its hardy nature coupled with its marginal costs of cultivation. In early 1990s, the socioeconomic impact of grass pea consumption was assessed in a random sample of 100 farmers from Raipur, Bilapur and Bastar. This study revealed that almost 60% of the rice growers included grass pea in their cropping system. Most of the farmers practiced subsistence agriculture with smaller land holdings (of below 5 ha). However, its consumption among non-farmers did not exceed 3% of total food intake. Among pulses, farmers had a preference for chickpea, which accounted for over 35% of total pulse expenses incurred, followed by other pulse crops including pigeonpea (25.3%), blackgram (17.5%), and grass pea (11.2%). The most common use of grass pea was to prepare dal, and nearly 25% of consumers adopted conventional measures to detoxify grass pea grains before consumption. Considerable awareness was found among rural people about the toxic effects of grass pea consumption. Another study conducted in Gondia district in Maharashtra showed that nearly 60% of the population consumed grass pea as a part of their diet; however, the quantity of grass pea consumed per day was reported to be less than 25 g [37].

4. Trends in area and production in India

Given severe legislative control measures imposed by several state governments, acreage under grass pea has declined considerably over the past decades. Although improved varieties containing low amounts of toxin have been developed by the Indian Council of Agricultural Research (ICAR) and associated agricultural institutes, farmers are increasingly shifting towards higher-value crops. Consequently, a continuous reduction has occurred in the area and production of grass pea across India. The national acreage has gradually fallen from 1.67 million ha to 0.58 million ha over the last four decades. A similar trend has been noted in its production, which has declined substantially from 0.84 million to 0.43 million tons over the same time period (http://agricoop.nic.in/).