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Enhancing grasspea (*Lathyrus sativus* L.) production in problematic soils of South Asia for nutritional security

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Abstract

Grasspea (*Lathyrus sativus* L.) a multi-purpose, climate smart legume crop which can sustain drought, water-logging and salinity, and can be grown under minimal external inputs. It is grown on about one million ha area in South Asia mainly in rice-based cropping system. Global area under its cultivation has decreased because of ban on its trade in many countries due to its association with neurolathyrism, a non-reversible neurological disorder in humans and animals due to consumption of a neurotoxin, β-N-oxalyl-L-α, β-di amino propionic acid (β-ODAP) present in its plant parts. Resource-poor farmers and tribal people are still growing to supplement their diet with traditional varieties. Traditionally, its seed and twigs are used for human consumption and fodder and plant residues as animal feed. It has a great potential for cultivation in areas where other field crops cannot be grown due to soil problems. It provides an excellent opportunity for sustainable agriculture and nutritional security to resource poor farmers and consumers of South-Asian countries. Breeding efforts are underway on reducing ODAP content in its plant parts and yield improvement to provide a remunerative crop for safe consumption. The crop has a specific production niche where it is grown as a relay crop in rice fields, thus no tillage operations are required which reduces its cost of production.

Key words: Grasspea, genetic resources, β-ODAP, neurolathyrism, South Asia

Introduction

At global level, agricultural science technologies have helped in increase in food output (Stewart et al. 2005), while, hunger and malnutrition are still endemic in most of Africa and parts of Asia (Borlaug 2003), where drought, low soil fertility and water-logging pose severe constraints to production, apart from many socio-economic factors. Grasspea (*Lathyrus sativus* L.), commonly known as *Khesari, Teora, Lakhdi* and *Lakh*, a cool season legume crop is considered as drought tolerant. In addition, it can tolerate moderate level of salinity, water-logging and other adverse soil conditions. When other crops fail due to adverse edapho-climate conditions, it can be the only available food source and is sometimes used as a survival food in times of drought-induced famine. Also, it has resistance to several diseases, insects and storage pests (Vaz Patto et al. 2006). Grasspea cultivation is easy and low-cost. It is highly nutritious food and fodder legume crop with 18-34% of protein content in seeds and 17% in mature leaves (Siddique et al. 1996). As a rich source of protein and essential micronutrients, this crop provides nutritional security to many low-income communities. Grasspea plant has a very hardy and penetrating root system, therefore, can be grown on many soil types and conditions including saline and nutrient deficient soils, where other crops can hardly sustain. This hardiness together with its various properties makes this crop suitable for adverse agro-climatic conditions (Campbell et al. 1994). It also helps in fixation of atmospheric nitrogen and fixes approximately 108-125 kg/ha nitrogen to the soil, hence meet its own requirement and nitrogen demand of succeeding crop and plays important role in sustainable farming system (Peoples et al. 2008). Mostly, it is grown as relay crop in rice fields (Das 2000) and is also grown as mixed/intercrop with other winter crops to decrease the risk of complete crop failure.

Many countries of Asia (India, Pakistan, Bangladesh, Nepal and China), Middle East, Middle

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East, Africa (Ethiopia, Ghana, Sudan, Niger, Ivory Coast and Mauritania) and Southern Europe (France and Spain) are cultivating grasspea for both human consumption and livestock feed use. It is grown in North America, South America, Australia and Europe for fodder purpose (Vaz Patto et al. 2006). In India, grasspea is grown in about 521,100 ha, mainly in Chhattisgarh, Bihar, Jharkhand, Maharashtra, Orissa, Assam, West Bengal, and eastern Uttar Pradesh. It is reported that grasspea has good potential as a pulse crop for poor quality soils of South-Australia and low rainfall areas of Canadian prairies (Siddique et al. 1996). There is a great scope for expansion of grasspea cultivation in the dry areas which are becoming more drought prone due to global climate change.

Despite these advantages, relatively little research efforts have been directed to improve grasspea. Its improvement work was initiated at the International Center for Agricultural Research in the Dry Areas (ICARDA) in 1989. The main reason behind the slow progress has been the fear that excessive consumption of grasspea can lead to a neurological disorder in humans and domestic animals (Jackson and Yunus 1984), by the presence of a neurotoxic non-protein amino acid β-N-oxalyl-L-, α-diaminopropionic acid (ODAP) contents (Kumar et al. 2011). To combat neuro-lathyrism, many governments of endemic countries has banned grasspea production and made substitution by the best alternative crops.Under climate change, with serious concerns about sustainability of agricultural production and food security worldwide, interest in the under-utilized crops such as grasspea has been renewed in many countries (Crino et al. 2004; Falco and Pardo 2000; Grela et al. 2010; Hanbury et al. 1999; Mera et al. 2000; Milczak et al. 2001; Polignano et al. 2009; Yang and Zhang 2005). ICARDA holds a collection of 1883 accessions of *Lathyrus* spp. from different parts of the world (Abd El Moneim et al. 2001). Using this precious resource, ICARDA has released about 25 grasspea varieties with earliness, high biomass, resistance to powdery mildew and low seed ODAP content in 13 partner countries namely, Australia, Bangladesh, Bulgaria, Canada, Chile, Ethiopia, India, Jordan, Kazakhstan, Lebanon, Nepal, Poland and Turkey.

Production regions

Worldwide, area under grasspea is assessed at 1.50 m ha with annual production of 1.20 mt, mainly in South Asia and Sub-Saharan Africa. In South Asia alone, it is grown on 0.92 m ha area with 0.63 mt production with productivity of 687 kg ha^{-1} grain yield (Rahman et al. 2008). During 1994-2004, the grasspea area in South Asia has decreased from 1.38 to 0.92 million ha with corresponding decline in production from 0.85 to 0.63 million ton. During the period, however, the productivity has increased from 588 to 691 kg ha^{-1}. In India, grasspea area has declined drastically from 930,000 ha in 1995-1996 to 601,500 ha in 2007-2008 (ICAR, 2009). During this period, the production has declined marginally from 420,000 to 384,800 tons as yield increase from 455 to 640 kg ha^{-1} has compensated the area loss to some extent. Nepal has recorded sharp decline in grasspea production from 17,340 ton in 1995-1996 to 4335 ton in 2008-2009 because of decline in area from 30,780 to 5870 ha (MOAC 2009). The ban on the trade of grasspea seeds in India and Nepal has been the main reason behind the drastic reduction in its cultivation. In Bangladesh, grasspea still occupies the first position among the pulse crops and its production has increased from 181,000 ton in 1995-1996 to 232,500 ton in 2008 (BBS 2009). Similarly, in Ethiopia, area and production of grasspea have increased steadily from 75,950 ha and 80,430 tons in 1996 to 159,731 ha and 202,126 ton in 2009, respectively (CSA 2010). These increases are attributed to the fact that grasspea cultivation has found preference in difficult areas where other crops have generally failed due to prevailing harsh climatic conditions (Lu et al. 1990; Tadesse et al. 1997). In India, it is cultivated primarily in Bihar, Madhya Pradesh, Maharashtra, West Bengal, and Chhattisgarh (Khandare et al. 2014). The majority of the area (~70%) is shared by Chhattisgarh and Vidarbha region of Maharashtra, a rice-growing region where supplemental irrigation is available only for rice (Dixit et al. 2016). Thus, water is not available for subsequent winter crops, hence, grasspea is only alternative for a crop following rice (Asthana and Dixit 1997). Grasspea withstands unfavorable conditions including excessive moisture at sowing, which is often followed by moisture stress at later growth stages. It is favored for cultivation in such areas owing to its hardy nature and low costs of cultivation.

Utilization

The most common use of grasspea is to prepare dal, and nearly 25% of consumers adopted conventional measures to detoxify grasspea grains before consumption. Considerable awareness was found among rural people about the toxic effects of grasspea consumption. It is used in many ways for human and animal consumption (Yadav 1996) which are as follows:

Table 1. Different uses of grasspea

Product	Usage
Leafy vegetable	Young leaves (vegetative parts) are plucked and sold as green leafy vegetable. Also, it is rolled and dried and kept for off-season use as vegetable
Green pods	Green pods are eaten directly as snacks directly, and whole pods are cooked and eaten as vegetable
Dry grains	
Dal	Dried grains are splitted to make *dal* and consumed with rice
Flour	Flour is used to prepare pancake like preparation
Feed	Ground splitted grain or flour are used as feed for lactating animals or for bullock at time of heavy field use
Fodder	It is also used as forage from the young vegetative stage to maturity

Grasspea cultivation maintains the soil fertility by fixing high nitrogen and maintaining poorly drained land better than any other crop therefore, it is also utilized for soil health.

Genetic resources

The genetic diversity of the genus *Lathyrus* is of immense significance, particularly for rain-fed cropping systems of many countries (Campbell et al. 1994) as a resource for the improvement of *L. sativus* L., but also because the genus is largely under-utilized. Several species are cultivated for food, feed, and fodder, as well as for ornamental purposes (Sarker et al. 1997), but there is potential for further exploitation of the *Lathyrus* gene pool. Therefore, collection, conservation, characterization, studies of genetic diversity and utilization of the genus *Lathyrus* is a priority. There is an urgent need actively to conserve the genetic diversity of the genus using both *ex-situ* (gene banks) and *in-situ* (natural habitats) techniques. This will permit a critical assessment of genetic diversity, evolution and genetic erosion of the genus, as well as greatly enhancing further exploitation (Sabanci 1996).

The genus *Lathyrus* includes 160 species, some of which have economic importance as food, fodder and ornamental crops (mainly *L. sativus, L. cicera* and *L. odoratus*, respectively) (Vaz Patto and Rubiales, 2014), chiefly located in Europe, Asia and North America, extending to temperate South America and Tropical East Africa. The primary center of cultivation is in southern Asia, particularly in Bangladesh, China, India, Nepal, Pakistan and also in Ethiopia (Asthana 1996), with more limited production in southern Europe and West Asia. Due to the potential that the genus has (as a food, feed and fodder crop, as well as its extensive cultivation of ornamental species) it is necessary to collect and conserve all available cultivars, landraces as well as the wild species of genus *Lathyrus*. Table 2 provides a list of those species known to be historically or currently cultivated for agriculture or horticulture.

Table 2. Historic or currently cultivated *Lathyrus* species

Species	Use	Status of uses	Location
L. annuus	Pulse, fodder	Rare	Europe, N. America
L. aphaca	Fodder	Rare	India
L. blephari-carpus	Pulse	Historic	Near East
L. cicera	Pulse, fodder	Rare	S. Europe, N. Africa
L. clymenum	Pulse	Rare	Greece
L. gorgoni	Fodder	Historic	Middle East
L. hirsutus	Forage	Common	USA
L. latifolius	Horticulture	Common	Europe
L. ochrus	Pulse, fodder	Rare	Greece, Middle East
L. odoratus	Horticulture	Common	Widespread
L. pratensis	Forage	Rare	S. Europe, N. Africa
L. rotundifolius	Horticulture	Common	Widespread
L. sativus	Pulse, forage	Common	Widespread
L. sylvestris	Forage	Rare	S. Europe, N. Africa
L. tingitanus	Fodder	Rare	N. Africa
L. tuberosus	Tubers	Rare	W. Asia

Source: Adapted from Kearney (1983)

Based on crossability information the gene pool of *L. sativus* is elucidated. The cultivated and wild races of *L. sativus* are included in primary gene pool. Townsend and Guest (1974) suggested that the primary gene pool is poorly differentiated in terms of morphological characters, as there are no clear-cut discontinuities between the cultivated and wild forms. As per Smartt (1984), white flowered and white seeded varieties are highly selected while Jackson and Yunus (1984) advocated that the blue flowered, small speckled seeded forms are primitive. So, we can tentatively place the white flowered, white seeded varieties in GP1A and blue flowered, small speckled seeded in GP1B. Recently, Heywood et al. (2007) extended secondary gene pool to include the other biological species that will cross with some difficulty with the crop species. Therefore, in the GP2, *L. chrysanthus*, *L. gorgoni*, *L. marmoratus* and *L. pseudocicera*, with which *L. sativus* is cross compatible and produce ovules, and possible more remotely *L. amphicarpos*, *L. blepharicarpus*, *L. chloranthus*, *L. cicero*, *L. hierosolymitanus* and *L. hirsutus* are also crossable with *L. sativus* and may form pods. (Table 3). The tertiary gene pool include species that can cross with the original crop species only with use of specialized techniques such as embryo rescue and culture or the use of bridging species and the remaining species of the genus *Lathyrus*, which do not cross compatibility are considered in the tertiary gene pool (GP3).

Table 3. *Lathyrus sativus* gene pools

Primary gene pool	Secondary gene pool	Tertiary gene pool
Wild and cultivated *L. sativus* races	*L. chrysanthus* *L. pseudocicera* *L. hierosolymitanus* *L. amphicarpus* *L. marmoratus* *L. choranthus* *L. cicero* *L. gorgoni* *L. blepharicarpus* *L. hirsutus*	Other *Lathyrus* spp.

Source: Adapted from Heywood et al. (2007)

Genetic improvement

To improve the potential of grasspea a lot of things could be done for enhancing food security in harsh environments, feed for livestock and crop for soil health. Regardless of the availability of low toxin lines, listing of grasspea as a toxic plant and the banning of seed sales in some countries, has limited funding for crop development. Major grasspea improvement programs have been conducted in India (Sharma et al. 2000; Santha and Mehta 2001), Bangladesh (Rahman et al. 2001), Australia (McCutchan 2003), Ethiopia (Tadesse 2003) and at ICARDA in Syria (Abd-El-Moneim et al. 2001; Kumar et al. 2011). Low toxin content of grasspea has been reviewed by Kumar et al. (2011), who advocated for more research to build upon the present evidence that ODAP content can be decreased without affecting yield and yield-stability of the crop. Previous research showed that germplasm from South Asia containing relatively high amounts of ODAP (0.7-2.4 %) whereas, those from North Africa, Syria, Turkey, and Cyprus had significantly lower quantities of ODAP (0.02-1.2 %) although no accessions were found to be free of the toxin (Kumar et al. 2011). A number of Indian accessions with ODAP content below 1 % have been identified (Pandey et al. 2008). Accessions screened at ICARDA, four of 1082, were identified with ODAP content below 0.07 %. Two of these were from Turkey, one from Cyprus and one from Syria (Robertson and Abd-El-Moneim 1997). ICARDA screened 1128 grasspea accessions in 2009 and reported a range of ODAP content from 0.15-0.95 % but only two had low ODAP content; IG 118563 and IG 64888 (Kumar et al. 2011). Breeding programs in India, at ICARDA and elsewhere, have developed lines with low ODAP (Santha and Mehta 2001; Abd-El-Moneim et al. 2001) but this has to be combined with high yield and other agronomic traits to make them suitable for release as commercial varieties.

ODAP content is a polygenic trait and is highly influenced by genotype, environment and their interactions (Hanbury et al. 1999). Germplasm accessions with low ODAP have many undesirable agronomic traits such as late flowering, low yield and susceptibility to biotic and abiotic stresses. In order to combine low ODAP with high yield, appropriate phenology and stress tolerance, breeding programs have been undertaken (Abd-El-Moneim et al. 2000; Addis and Narayan 2000; Crino et al. 2004; Hanbury et al. 2000; Robertson and Abd-El-Moneim 1997; Vaz-Patto et al. 2006). This has resulted in development of high yielding varieties with low ODAP in different countries (Table 4). For example, in India, the extensive evaluation has resulted in development of Pusa 24 with 0.2% ODAP content (Dahiya and Jeswani 1974). Two low ODAP varieties *viz*., Prateek and Mahateora have been developed through hybridization. Prateek (LS8246 x A60) has low ODAP (0.076%), high yield (1.2-1.6 ton ha^{-1}) and tolerance to powdery and downy mildew, while Mahateora (Ratan x JRL11) has 0.074% ODAP and 1.5 ton ha^{-1} yield and is suitable for rice

Table 4. A list of improved grasspea varieties with key traits available globally

Country	Improved varieties	Pedigree	ODAP (%)	Yield (kg ha′)	100-seed wt (g)	Days to maturity	Special features	Reference
Australia	Ceora	K33 x 8604	0.04-0.09	500-1800		Early to medium	White flower, semi-erect	Siddique et al. 2006
	Chalus	Selection from IFLA1279	0.09		6.6	Earlyto medium	26.5% protein	Hanbury and Siddique 2000
Bangla-desh	Bari Khesari 1	P-24 x Local	0.04	1720	6.4	115	Tall (70cm)	Malek et al. 1996
	Bari Khesari 2	P-24 x Local	0.06	1727	6.8	115	Tall (70cm)	Malek et al. 1996
	Bina Khesari 1	Mutation	<0.20	1900	7.9	110	Medium tall, black spotted seed	www.bina.gov.bd
Bulgaria	Strandja	Local selection (VIL)	–	2550	17.0	90	Medium (40-60cm)	IWS, Bulgaria
Canada	LS 8246	Selection from Pusa 24	0.03	2050	9.3	110-130		Campbell and Briggs 1987
Chile	Luanco-INIA	Selection from LS 0027	>0.18	>4000	30-35		White seeded, tall (150)	Mera et al. 2003
Ethiopia	Wasie (ILAT-LS-LS-B2)	SC5 x PGRC46071	0.08	1673	8.6	110	Semi-erect, blue flower, resistant to powdery mildew	ICARDA 2007
Kazakhs-tan	Ali-Bar	Selection from germplasm line (IFLLS 554)	0.01	1200	10.5	156	High biomass, white seeds, drought tolerant	ICARDA 2006
India	Pusa 24	Selection from germplasm	0.2-0.3	1655	8.5	125-130	Blue flower, grey seeds	ICAR 2009
	Prateek	LS82046 x A60	0.08	1560	8.1	110-115	Resistance to powdery mildew	ICAR 2009
	Ratan (BioL 212)	Somaclone of Pusa 24	0.05	2530		108-116	Large seeds, blue flower, resistance to powdery mildew	ICAR 2009
	Mahateora	Ratan x JRL2	0.07	1550		110-115	Pink flower, large seeds	ICAR 2009
Nepal	CLIMA2 pink	Introduction		1550	9.0	132	Pink flowers	www.acribd.com/doc/
	19A	Selection		1075	10.0	131	Blue flowers	www.acribd.com/doc/
	20B	Selection		750	11.0	132	Blue flowers	www.acribd.com/doc/
	Bari Khesari 2	Introduction		1000	10.0	135	Blue flowers	www.acribd.com/doc/
Poland	Derek	Selection from Der		1920	11.5	112	White seeds, semi-erect	Milczak et al. 2001
	Krab	Selection from Kra		2280	19.3	109	White seeds, semi-erect	Milczak et al. 2001
Turkey	Gurbuz 1 line (IFLLS 554)	Selection from germplasm	0.01	1200	10.5	156	High biomass, white seeds, drought tolerant	ICARDA 2007

Source: Adapted from Kumar et al. (2011)

fallows. In Bangladesh, two varieties, BARI Khesari-1 and BARI Khesari-2 with ODAP content of 0.06 and 0.04% and more than 1.7-ton ha^{-1} grain yield have been developed (Malek et al. 1996).

Grasspea lines with <0.1% ODAP concentration have been selected by ICARDA and one of them with high yield (1.67 ton ha^{-1}) and low ODAP (0.08%) has been released in Ethiopia as 'Wasie'. Another cultivar from ICARDA selection, 'Ali-Bar' has been released for cultivation in Kazakhstan after 4 years of evaluation in the Central Asia and Caucasus (CAC) region. It has yield potential of 1.2 ton ha^{-1} in the dry areas with 250-300 mm precipitation. In Canada, a low ODAP (0.03%) line, LS 8246 has been released for fodder and feed purpose (Campbell and Briggs, 1987). Some of the promising lines with low ODAP and high yield are under multi-location evaluation in different countries (Table 4). However, maintenance of genetic purity has been a major concern in grasspea varieties due to out crossing by bees.

Grasspea has the potential to be used more broadly as a cover crop for soil maintenance and animal feed. Campbell (1997) explained one of the advantages of grasspea is that it does not suffer much from pests and diseases. In fact, the *Lathyrus* gene pool offers a source of resistance to important legume diseases such as *Ascochyta* blight (*Mycosphaerella pinodes*), Downy mildew (*Peronospora lathyri-palustris*) and Powdery mildew (*Erisyphe* spp.) (Gurung et al. 2002). Downy mildew is an important disease of grasspea in South Asia and rust diseases (*Uromyces* spp.) are more problematic in parts of Ethiopia (Campbell 1997). Transfer of resistance into cultivars with high yield and agronomic potential is considered to be straight forward by conventional breeding (Vaz Patto et al. 2006).

Cropping system and agronomic practices

In India, understanding its ability to grow under harsh conditions, it is generally grown in three farming systems i.e. sole crop in fallow where irrigation water is not available; relay system in which seeds are broadcasted before harvest of paddy; and mixed cropping with linseed or chickpea. In relay cropping it is very easy to cultivate without much efforts but very difficult to boost up productivity. Under relay condition farmers give more emphasis for its fodder and consider grain yield as bonus (Pandey et al. 1996). In Bangladesh, it is mostly grown as a relay crop in low lying areas in *Aman* rice fields. Broadcast sowing with high moisture in standing rice field, 3-4 weeks before harvest. In some places it is grown as solo crop, and fertilizers and pesticides are not used in its cultivation. (Sarwar et al. 1996). In Nepal, its cultivation is mostly restricted to marginal areas like waterlogged, lowland rice areas where farmers usually can not take other winter crops like wheat, oilseeds or other legumes. Hence, it plays an important role in increasing the cropping intensity (Yadav 1996). Here also no additional chemical fertilizer or insecticide is used in its cultivation.

Production constraints

Plant population: It is mainly grown under relay copping, thus appropriate plant population is major bottleneck for productivity increase.

Suitable varieties: Farmers are using traditional varieties, resulting to low yield. Only few varieties have been developed and further research on development of low toxin varieties and location specific agronomic practices is underway.

Lack of good quality seed: Supply of seed is always less than demand. More efforts are required for quality seed production at formal and informal sources.

Poor yield: In relay cropping, its cultivation faces two different situations viz., excessive moisture at sowing and stress at growth and reproductive stages resulting in low yield

Non-use of fertilizers: Farmers do not use fertilizers, as application of fertilizer in relay system is difficult in standing paddy crop and/or farmers are reluctant to use fertilizers.

Farmers' participatory approach for enhancing grasspea production in India

ICARDA with financial support from National Food Security Mission-Pulses (NFSM-P), Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture (GOI) did a project on enhancing grasspea production for safe human food, animal feed and sustainable rice-based production systems in India. With national partners, from ICAR/SAUs and NGOs, ICARDA implemented the project in state of Assam, Bihar, Chhattisgarh, Uttar Pradesh and West Bengal. Major focus was on replacement of indigenous high toxin grasspea varieties with low toxin and high biomass varieties through farmers' participatory approach and enhancing production of these varieties to support nutritional feed and fodder, where only paddy straw is available as cattle feed. Also, establishing grasspea as a second crop in specific niches like rice-fallows to break mono-cropping and increasing cropping intensity has enhanced farmers' income. The varieties provided were, Nirmal, Ratan, Prateek and Mahateora along with improved agronomic practices. Specific agro-technologies were also provided to farmers as there is no location specific package and practices for this crop. In order to provide seed at right time, 12 seed hubs were developed, which will ensure regular supply of seed. The results of improved technological intervention brought out that the grasspea yield could be increased up to 41%, if proper agronomic practices are followed (Table 5). Crop was also successfully implemented in rice fallows, covering more than 1000 ha of land. With the participation of farmers, a total of 17214 q (Foundation seed-790q, Certified seed-4801q and Truthfully Labelled seed-11623q) quality seeds have been produced. These seeds were further utilized for onwards/nearby dissemination to other farmers' field. (Report ICARDA SACRP, 2016).

Table 5. Grasspea implementation in different states of India during 2013-14 to 2015-16

State	Area (ha)	No. of farmers	No. of villages	% increase in yield over farmers' practice	Rice fallow covered (ha)	Targeted agro-niches
Assam	278	1315	72	41	246	Traditional/seasonal rice fallow with priority to tribal farmers
Bihar	360	603	36	30	-	Mono-cropping and seed production
Chhattisgarh	668	411	78	33	137	Rice-fallow and tribal areas
Uttar Pradesh	94	379	36	34	-	Rice-fallow and degraded land
West Bengal	1115	4527	237	31	658	Rice-fallow and marginal farmers; cyclone affected areas
Total/average	2515	7235	459	34	1041	

Conclusion and future strategies

Grasspea is a food, forage, and fine green manure crop. Its multiple beneficial properties and various uses make it suitable for introduction in problem soil areas. It provides ample opportunities to diversify the existing cereal-based cropping systems to manage the risk of unpredictable weather and increase the profitability and sustainability of agriculture under the climate change scenario. Global attention is needed to embark on its genetic improvement using conventional and bio-technological interventions to make this survival food safe for human consumption.

Several actions that can be made to improve the grasspea cultivation are given as under.

Expansion of growing area: Grasspea area has decreased due to many production constraints. Keeping in mind its importance and easy cultivation, area can be increased in new niches, like rice fallows in eastern India. Strong extension will not only help in new areas but up scaling of existing areas.

Seed production: Seed is considered as a key element in crop production, and it is the material used to establish a new crop each year, and the quality of the seed determines how efficiently that is flourished. Presently, grasspea seed is produced as in informal seed sector, in which the farmers obtain seed by saving a part of the crop directly sowing the following season or buying from neighbors or local traders. The seed quality may not be suitable. An adequate amount of the grasspea seed should be multiplied and disseminated to farmers, while the extension action is put in place.

Investigation achievement: Although several studies on grasspea have produced good results, there is a need to study further on its agronomy and breeding. Its place in crop rotations should be comprehensively investigated, and the seeding rate and fertilization ought to be studied. The breeding efforts should be focused on greater yield and nutritive value. And, after identification of the suitable parental lines, the relevant crosses may be made in order to incorporate the desirable plant characteristics.

At Present, grasspea may be regarded as a marginal feed crop, and its production with low input is realized in a traditional way. However, there appears to be a great potential to expand its cultivation area and improve its production.

Declaration

The authors declare no conflict of interest.

References

Abd-El-Moneim A. M., Van-Dorrestein B., Baum M. and Mulugeta W. 2000. Improving the nutritional quality and yield potential of grasspea (*Lathyrus sativus* L.). Food Nut. Bull., **21**: 493-496.

Abd-El-Moneim A. M., Van Dorrestein B., Baum M., Ryan J. and Bejiga G. 2001. Role of ICARDA in improving the nutritional quality and yield potential of grasspea (*Lathyrus sativus* L.), for subsistence farmers in dry areas, *Lathyrus* Lathyrism Newsl., **2**: 55-58.

Addis G. and Narayan R. K. J. 2000. Inter-specific hybridization of *Lathyrus sativus* (Guaya) with wild *Lathyrus* species and embryo rescue. African Crop Sci. J., **8**(2): 129-136.

Asthana A. N. 1996. Grasspea cultivation in problem areas: present approaches. In: R. K. Arora, P. N. Mathur, K. W. Riley, Y. Adham (Eds.), *Lathyrus* Genetic Resources in Asia: Proc. Regional Workshop, December 27–29, 1995, Indira Gandhi Agricultural University, Raipur, India 1996, pp. 43-48, (IPGRI Office for South Asia, New Delhi, India).

Asthana A. N. and Dixit G. P. 1998. Utilization of genetic resources in *Lathyrus*, In: P. N. Mathur, V. R. Rao, R. K. Arora (Eds.), *Lathyrus* Genetic Resources Network: Proc. IPGRI-ICARDA-ICAR Regional Working Group Meeting, December 8-10, 1997, National Bureau of Plant Genetic Resources, New Delhi, (IPGRI Office for South Asia, New Delhi, India). pp. 64-70.

BBS. 2009. Statistical Yearbook of Bangladesh, 28th edition, Bangladesh Bureau of Statistics (BBS), Planning Division, Ministry of Planning, Dhaka, Bangladesh.

Borlaug, N. E. 2003. Feeding a World of 10 Billion People, In: *The TVA/IFDC Legacy*, Travis, P. (Ed.). Hignett Memorial Lecture, March 14, Muscle Shoals, AL, USA.

Campbell C. G. 1997. Grasspea (*Lathyrus sativus* L.). Promoting the conservation and use of underutilized and neglected crops. International Plant Genetic Resources Institute, Rome, Italy. vol. 18.

Campbell C. G. and Briggs C. J. 1987. Registration of low neurotoxin content *Lathyrus* germplasm LS8246. Crop Sci., **27**: 821.

Campbell C. G., Mehra R. B., Agrawal S. K., Chen Y. Z., Abd-El-Moneim A. M., Khawaja H. I. T., Yadav C. R., Tay J. U. and Araya W. A. 1994. Current status and future strategy in breeding grasspea (*Lathyrus sativus*). Euphytica, **73**: 167-175.

Crino P., Polignano G. B. and Tavoletti S. 2004. Grasspea – a potentially important crop in Mediterranean agriculture. Grain Legumes, **40**: 6-7.

CSA. 2010. Agricultural Sample Survey (2008-2009). Report on Area and Production of Crops, Vol. 1. Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

Das N. R. 2000. *Lathyrus sativus* in rainfed multiple cropping systems in West Bengal, India – a review. *Lathyrus* Lathyrism Newsletter, **1**: 25-27.

Dixit G. P., Parihar A. K., Bohra A. and Singh N. P. 2016. Achievements and prospects of grasspea (*Lathyrus sativus* L.) improvement for sustainable food production, The Crop J., **4**: 407-416.

Falco E. and Pardo A. 2000. Agronomic evaluation of Italian ecotypes of *Lathyrus sativus* L. in hilly area of southern Europe. *Lathyrus* Lathyrism Newsl., **1**: 27.

Grela E. R., Rybinski W., Klebaniuk R. and Mantras J. 2010. Morphological characteristics of some accessions of grasspea (*Lathyrus sativus* L.) grown in Europe and nutritional traits of their seeds. Genetic Resour. Crop Evol., **57**: 693-701.

Gurung A. M., Pang E. C. K. and Taylor P. W. J. 2002. Examination of *Pisum* and *Lathyrus* species as sources of ascochyta blight resistance for field pea (*Pisum sativum*). Aust. J. Plant Pathol., **31**: 41-45.

Hanbury C. D. and Siddique K. H. M. 2000. Registration of 'Chalus' *Lathyrus cicera* L. Crop Sci., **40**: 1199.

Hanbury C. D., Siddique K. H. M., Galwey N. W. and Cocks P. S. 1999. Genotype-environment interaction for seed yield and ODAP concentration of *Lathyrus sativus* L. and *L. cicera* L. in Mediterranean-type environments. Euphytica, **110**: 445-460.

Hanbury C. D., White C. L., Mullan B. P. and Siddique K. H. M. 2000. A review of the use and potential of *Lathyrus sativus* L. and *L. cicera* L. grain for animal feed. Animal Feed Sci. Tech., **87**: 1-27.

Heywood V., Casas A., Ford-Lloyd B., Kell S. and Maxted N. 2007. Conservation and sustainable use of crop wild relatives. Agric. Ecosystems Env., **121**: 245-255.

ICAR. 2009. Project Coordinator's Report of All India Coordinated Research Project on Mungbean, Urdbean, Lentil, *Lathyrus*, Rajmash and Pea. Indian Council of Agricultural Research (ICAR), New Delhi, pp 18.

ICARDA. 2006. ICARDA Annual Report 2005. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria. pp. 54-55.

ICARDA. 2007. ICARDA Annual Report 2006. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria. pp. 57-58.

ICARDA SACRP. 2016. DAC-ICARDA-ICAR Collaborative Project. Compiled Report on Enhancing Grasspea Production in Eastern and North-Eastern States for animal feed, safe human food and for sustainable rice-based production system in India (2013-14 to 2015-16) submitted to NFSM.

Jackson M. T. and Yunus A. G. 1984. Variation in the grasspea (*L. sativus* L.) and wild species. Euphytica, **33**: 549-559.

Kearney J. P. 1993. Wild *Lathyrus* Species as Genetic Resources for Improvement of Grasspea (*L. Sativus*). Ph.D. Thesis, University of Southampton, United Kingdom.

Khandare A. L., Babu J. J., Ankulu M., Aparna N., Shirfule A. and Rao G. S. 2014. Grasspea consumption & present scenario of neurolathyrism in Maharashtra state of India, Indian J. Med. Res., **140**: 96-101.

Kumar S., Bejiga G., Ahmed S., Nakkoul H. and Sarker A. 2011. Genetic improvement of grasspea for low neurotoxin (ODAP) content, Food Chem. Toxicol., **49**: 589-600.

Lu F. H., Bao X. G. and Liu S. Z. 1990. A study of five vein vetchling of *Lathyrus sativus* L. germplasm resources. Crop Genet. Res. (China), **3**: 17-19.

Malek M. A., Sarwar C. D. M., Sarker A. and Hassan M. S. 1996. Status of grasspea research and future strategy in Bangladesh. In: Arora R. K., Mathur P. N., Riley K. W., Adham Y. (Eds.), *Lathyrus* Genetic Resources in Asia. International Plant Genetic Resources Institute, Rome, Italy, pp. 7-12.

McCutchan J. S. 2003. Review: a brief history of grasspea and its use in crop improvement. *Lathyrus* Lathyrism Newsletter, **3**: 18-23.

Mera M., Montenegro A., Espinoza A. and Guete N. 2000. Research backs grasspea exports by small Chilean farmers. *Lathyrus* Lathyrism Newsl., **1**: 31.

Mera M., Tay J., France A., Montenegro A., Espinoza A. and Guete N. 2003. Luanco-INIA, a large seeded cultivar of *Lathyrus sativus* released in Chile. *Lathyrus* Lathyrism Newsl., **3**: 26.

Milczak M., Pedizinski M., Mnichowska H., Szwed-Urba K. and Rybinski W. 2001. Creative breeding of grasspea (*Lathyrus sativus* L.) in Poland. *Lathyrus* Lathyrism Newsl., **2**: 85-88.

MOAC. 2009. Statistical Information on Nepalese Agriculture, 2008/2009. Ministry of Agriculture and Cooperatives (MOAC), Agri-Business Promotion and Statistics Division, Singha Durbar, Kathmandu, Nepal.

Pandey R. L., Chitale M. W., Sharma R. N., Kashyap O. P., Agrawal S. K., Ged A. K. and Chandrakar H. K. 1995. Catalogue on Grasspea (*Lathyrus sativus*) Germplasm. Indira Gandhi Krishi Vishwavidyalaya, Raipur, India. pp 60.

Pandey R. L., Kashyap O. P., Sharma R. N., Nanda H. C., Geda A. K. and Nair S. 2008. Catalogue on Grasspea (*Lathyrus sativus* L.) Germplasm. Indira Gandhi Krishi Vishwavidyalaya, Raipur, India. pp 213.

Peoples M. B., Brockwell J., Herridge D. F., Alves B. J. R., Urquiaga S., Boddey R. M., Dakora F. D., Bhattarai S., Maskey S. L., Sampet C., Rerkasem B., Nielsen H. H. and Jensen E. S. 2008. Biological fixation by food legumes. In: Kharkwal, M.C. (Ed.), Food Legumes for Nutritional Security and Sustainable Agriculture, Vol. 1. Indian Society of Genetics and Plant Breeding, New Delhi, India, pp. 435-453.

Polignano G. B., Bisignano V., Tomaselli V., Uggenti P., Alba V. and Della-Gatta C. 2009. Genotype x environment interaction in grasspea. Inter. J. Agron., doi: 10.1155/2009/898396.

Rahman M. A., Rahman M. M. and Akhtaruzzaman M. 2001. Progress in isolation and purification of *Lathyrus sativus* breeding lines. *Lathyrus* Lathyrism Newsl., 2: 39-40.

Rahman M. M., Mishra S. K., Malik M. R., Haqqani A. M., Neupane R. K., Rahman M. L. and Yadav N. K. 2008. Trends in South Asian production, consumption and trade of food legumes. In: Kharkwal, M.C. (Ed.), Food Legumes for Nutritional Security and Sustainable Agriculture, Vol. 1. Indian Society of Genetics and Plant Breeding, New Delhi, India, pp. 84-100.

Robertson L. D. and Abd-El-Moneim A. M. 1997. Status of *Lathyrus* germplasm held at ICARDA and its use in breeding programs. In: Mathur P. N., Rao V. R., Arora R. K. (Eds.). *Lathyrus* Genetic Resources Network, Proceedings of a IPGRI-ICARDA- ICAR Regional Working Group Meeting, 8-10 December 1997, New Delhi, India, pp. 30-41.

Sabanci C. O. 1996. *Lathyrus* genetic resources in Turkey. *In*: R. K. Arora, P. N. Mathur, K. W. Riley and Y. Adham. (Eds.). *Lathyrus* Genetic Resources in Asia. International Plant Genetic Resources Institute, Rome, Italy, pp. 77-86.

Santha I. M. and Mehta S. L. 2001. Development of low ODAP somaclones of *Lathyrus sativus*. *Lathyrus* Lathyrism Newsl., 2: 42.

Sarker A., Robertson L. D., Abd-El Moneim A. M. and Campbell C. G. 1997. *Lathyrus* species: Conserved germplasm resources, priorities for collection and future prospects. *In*: Proc. International Food Legume Research Conference III, Adelaide, Australia.

Sarwar C. D. M., Malek M. A., Sarker A. and Hassan M. S. 1996. Genetic resources of grasspea (*Lathyrus sativus* L.) in Bangladesh. *In*: R. K. Arora, P. N. Mathur, K. W. Riley and Adham Y. (Eds.), *Lathyrus* Genetic

Resources in Asia. International Plant Genetic Resources Institute, Rome, Italy, pp. 13-18.

Sharma R. N., Chitale M. W., Ganvir G. B., Geda A. K. and Pandey R. L. 2000. Observations on the development of selection criterion for high yield and low neurotoxin in grasspea based on genetic resources. *Lathyrus* Lathyrism Newsl., **1**: 15-16.

Siddique K. H. M., Hanbury C. L. and Sarker A. 2006. Registration of 'Ceora' grasspea. Crop Sci., **46**: 986.

Siddique K. H. M., Loss S. P., Herwig S. P. and Wilson J. M. 1996. Growth, yield and neurotoxin (ODAP) concentration of three *Lathyrus* species in Mediterranean type environments of Western Australia. Aust. J. Exp. Agric., **36**: 209-218.

Smartt J. 1984. Evolution of Grain Legumes. I. Mediterranean Pulses. Exp. Agric., **20**: 275-296.

Stewart W. M., Dibb D. W., Johnston A. E. and Smyth T. J. 2005. The contributions of commercial fertilizer nutrients to food production. Agron. J., **97**: 1-6.

Tadesse W. and Bekele E. 2003. Variation and association of morphological and biochemical characters in grasspea (*Lathyrus sativus* L.). Euphytica, **130**: 315-324.

Tadesse W., Degago Y. and Tilaye A. 1997. Grasspea (*Lathyrus sativus* L.) production and breeding in Ethiopia. In: Tekle-Haimanot R., Lambein F. (Eds.). *Lathyrus* and Lathyrism: A Decade of Progress. University of Ghent, Ghent, Belgium, pp. 87-89.

Townsend C. C. and Guest E. 1974. *Flora of Iraq*. Leguminales Vol. 3. Ministry of Agriculture and Agrarian Reform, Bagdad, Iraq.

Vaz Patto M. C. and Rubiales D. 2014. *Lathyrus* diversity: available resources with relevance to crop improvement – *L. sativus* and *L. cicera* as case studies, Ann. Bot., **113**: 895-908.

Vaz-Patto M. C., Skiba B., Pang E. C. K., Ochatt S. J., Lambein F. and Rubiales D. 2006. *Lathyrus* improvement for resistance against biotic and abiotic stresses: from classical breeding to marker assisted selection. Euphytica, **147**: 133-147.

Yadav C. R. 1996. Genetic Evaluation and varietal improvement Grasspea in Nepal. In: R. K. Arora, P. N. Mathur, K.W. Riley and Y. Adham (Eds.), *Lathyrus* Genetic Resources in Asia. International Plant Genetic Resources Institute, Rome, Italy, pp. 21-27.

Yang H. M. and Zhang X. Y. 2005. Considerations on the reintroduction of grasspea in China. *Lathyrus* Lathyrism Newsl., **4**: 22-26.