Promoting the conservation and use of underutilized and neglected crops. 18.

Grass pea

Lathyrus sativus L.

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Foreword

Humanity relies on a diverse range of cultivated species; at least 6000 such species are used for a variety of purposes. It is often stated that only a few staple crops produce the majority of the food supply. This might be correct but the important contribution of many minor species should not be underestimated. Agricultural research has traditionally focused on these staples, while relatively little attention has been given to minor (or underutilized or neglected) crops, particularly by scientists in developed countries. Such crops have, therefore, generally failed to attract significant research funding. Unlike most staples, many of these neglected species are adapted to various marginal growing conditions such as those of the Andean and Himalayan highlands, arid areas, salt-affected soils, etc. Furthermore, many crops considered neglected at a global level are staples at a national or regional level (e.g. tef, fonio, Andean roots and tubers, etc.), contribute considerably to food supply in certain periods (e.g. indigenous fruit trees) or are important for a nutritionally well-balanced diet (e.g. indigenous vegetables). The limited information available on many important and frequently basic aspects of neglected and underutilized crops hinders their development and their sustainable conservation. One major factor hampering this development is that the information available on germplasm is scattered and not readily accessible, i.e. only found in 'grey literature' or written in little-known languages. Moreover, existing knowledge on the genetic potential of neglected crops is limited. This has resulted, frequently, in uncoordinated research efforts for most neglected crops, as well as in inefficient approaches to the conservation of these genetic resources.

This series of monographs intends to draw attention to a number of species which have been neglected in a varying degree by researchers or have been underutilized economically. It is hoped that the information compiled will contribute to: (1) identifying constraints in and possible solutions to the use of the crops, (2) identifying possible untapped genetic diversity for breeding and crop improvement programmes and (3) detecting existing gaps in available conservation and use approaches. This series intends to contribute to improvement of the potential value of these crops through increased use of the available genetic diversity. In addition, it is hoped that the monographs in the series will form a valuable reference source for all those scientists involved in conservation, research, improvement and promotion of these crops.

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Introduction

The grass pea (*Lathyrus sativus* L., Leguminosae) has over the past decade received increased interest as a plant that is adapted to arid conditions and contains high levels of protein, a component that is increasingly becoming hard to acquire in many developing areas. This monograph attempts to show the large potential this crop has for the areas where it is now grown as well as for other areas where its adaptation or desirable features make it a very attractive crop to produce.

The genus *Lathyrus* is large with 187 species and subspecies being recognized (Allkin *et al*. 1983). Species are found in the Old World and the New World. There are centres of diversity for Old World species in Asia Minor and the Mediterranean region (Zeven and de Wet 1982). However, only one species – *Lathyrus sativus* – is widely cultivated as a food crop (Jackson and Yunus 1984), while other species are cultivated to a lesser extent for both food and forage. Some species are valued as ornamental plants, especially the sweet pea (*L. odoratus*). Cytogenetic and biosysystematic studies that have been conducted on some of the main pulse crops have focused attention on wild species genetic resources and their more efficient utilization in crop improvement. The extent of the morphological variation of *L. sativus* also has received attention, with Jackson and Yunus (1984) finding great variation, especially in vegetative characters within the species.

Grass pea is an important crop of economic significance in India, Bangladesh, Pakistan, Nepal and Ethiopia. It is cultivated and extensively naturalized in Central, South and Eastern Europe (from Germany south to Portugal and Spain and east to the Balkans and S. Russia), in Crete, Rhodes, Cyprus and in West Asia and North Africa (Syria, Lebanon, Palestine, Egypt, Iraq, Afghanistan, Morocco, and Algeria).

The grass pea is endowed with many properties that combine to make it an attractive food crop in drought-stricken, rain-fed areas where soil quality is poor and extreme environmental conditions prevail (Palmer *et al*. 1989). Despite its tolerance to drought it is not affected by excessive rainfall and can be grown on land subject to flooding (Kaul *et al*. 1986; Rathod 1989; Campbell *et al*. 1994). It has a very hardy and penetrating root system and therefore can be grown on a wide range of soil types, including very poor soil and heavy clays. This hardiness, together with its ability to fix atmospheric nitrogen, makes the crop one that seems designed to grow under adverse conditions (Campbell *et al*. 1994). Compared with other legumes, the grass pea is resistant to many pests including storage insects (Palmer *et al*. 1989).

1 Taxonomy and names of the species

1.1 Classification of the genus

Grass pea (*Lathyrus sativus* L.) is a food, feed and fodder crop belonging to the family Leguminosae (= Fabaceae), subfamily Papilionoideae, tribe Vicieae.

Other economically important species include *Lathyrus cicera* and *L. tingitanus* for grain and *L. ochrus*, *L. latifolius* and *L. sylvestris* as forage species. A newly described species, *Lathyrus amphicarpus*, is presently found in the Middle East and has the potential of becoming important as a self-seeding forage species.

1.2 Accepted botanical name and synonyms

The accepted botanical name and synonyms of the species according to Hanelt (1986) are:

Lathyrus sativus L., Sp. Pl. (1753) 730. - *Cicercula alata* Moench, Methodus (1794) 163; *C. sativa* (L.) Alef. in Bonplandia 9 (1861) 147; *Pisum lathyrus* E. H. L. Krause in Sturm, Fl. Deutschld. ed. 2, 9 (1901) 50; *Lathyrus abyssinicus* A. Br. ex Chiov. in Atti Soc. Ital. Progr. Sci. 17 (1929) 548, nom.; *Lathyrus asiaticus* (Zalk.) Kudrj. in Fl. Uzbek. 3 (1955) 781.

1.3 Common names for the species in various countries

Common names of the species according to a large variety of sources are as follows.

Bangladesh	Khesari
Burma	Pé-kyin-baung, pé-sa-li, mutter pea
China	San lee dow
Cyprus	Fovetta, pharetta, dog-toothed pea
Ethiopia	Sabberi, guaya
France	Lentille d'Espagne, pois carré, gesse blanche, gesse chichi, gesse commune, gessette
Germany	Saatplatterbse
India	Kesare, khesari, karas, karil, kasar, khesari dhal, khesra, lang, chural, latri, lakhori, Lakhodi, chattra matur, santal, teora, tiuri, batura, chickling vetch, chickling pea
Italy	Cicerchia coltivata, pisello bretonne, pisello cicerchia
Nepal	Kheshari
Pakistan	Matri, mattra
Sudan	Gilban(eh)
Venezula	Frijol gallinazo, garbanzo

2 Description of the crop

This section gives an overall description of the crop. There is a large range of variation for several of the characters.

Lathyrus sativus is a much-branched (Fig. 1), straggling or climbing, herbaceous annual, with a well-developed taproot system, the rootlets of which are covered with small, cylindrical, branched nodules, usually clustered together in dense groups.

The stems are slender, 25-60 cm long, quadrangular with winged margins. Stipules are prominent, narrowly triangular to ovate with a basal appendage. The pinnate leaves are opposite, consisting of one or two pairs of linear-lanceolate leaflets, 5-7.5 x 1 cm, and a simple or much-branched tendril. Leaflets are entire, sessile, cuneate at the base and acuminate at the top (Figs. 1 and 2).

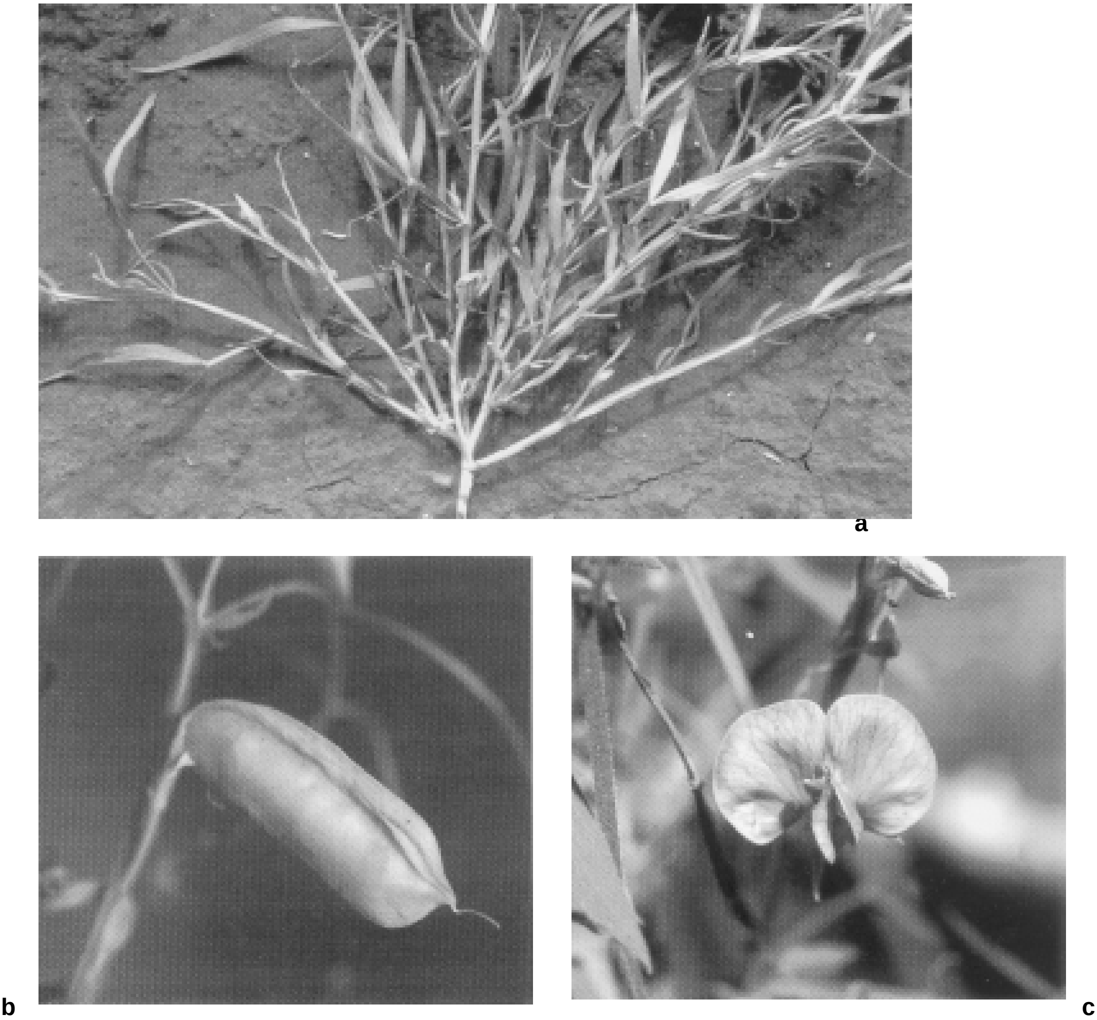

Fig. 1. *Lathyrus sativus*: (a) early branching, (b) flowers and (c) winged pod characteristic.

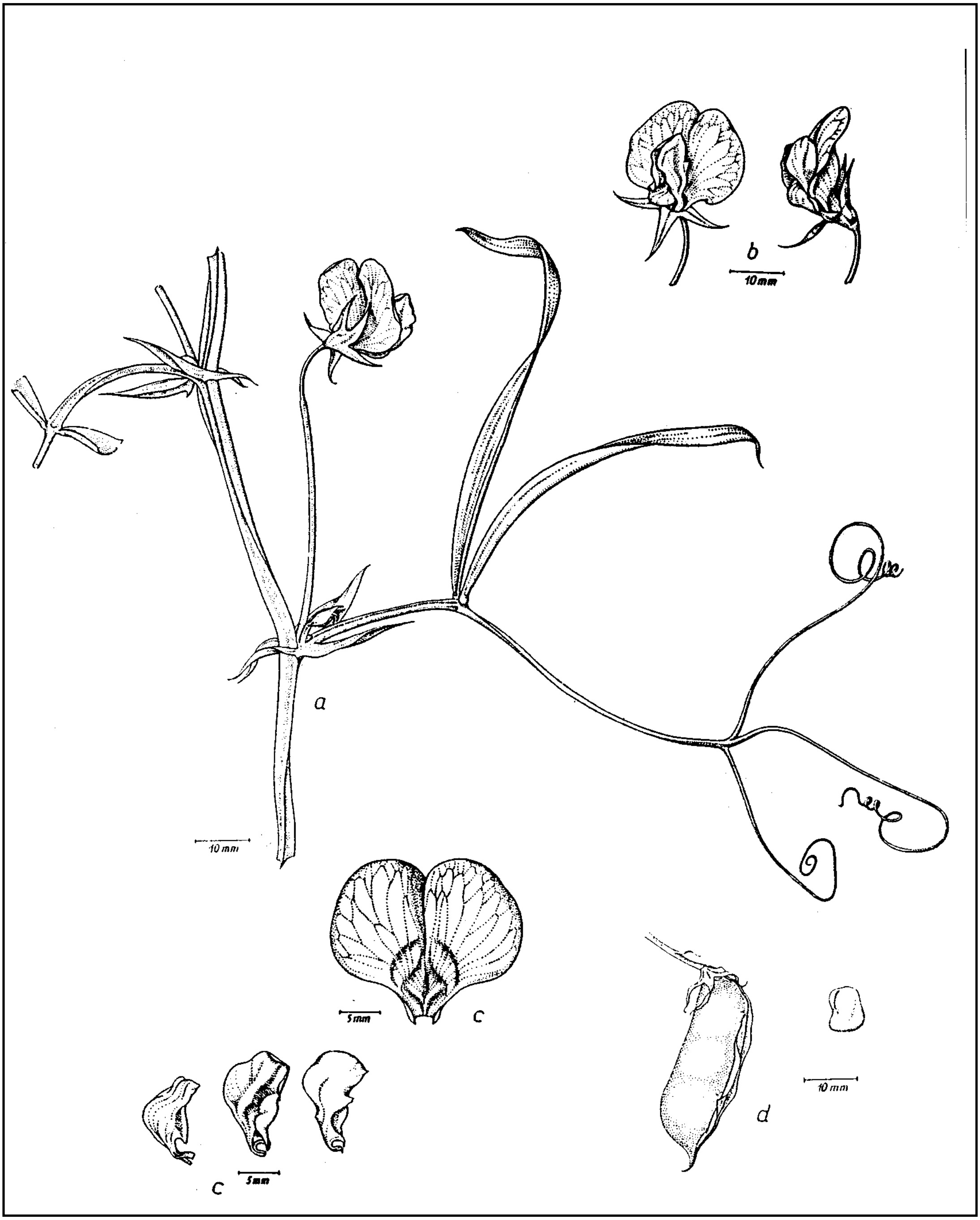

Fig. 2. *Lathyrus sativus* L. (a) part of a flowering branch, (b) flower in front and side view, (c) dorsal petal (bottom), wings and keel (from right), (d) pod with seeds (drawing by R. Kilian in Schultze-Motel 1986, reprinted with permission of the Gustav Fischer Verlag, Berlin).

The flowers are axillary, solitary, about 1.5 cm long, and may be bright blue, reddish purple, red, pink, or white (Fig. 1). The peduncle is 3.0-5.0 cm long with two minute bracts. Flowers have a short and slender pedicel. Calyx teeth are longer and glabrous. Tube is 3 mm long with five lobes, subequal and triangular. Standard petal is erect and spreading, ovate 15 x 18 mm, finely pubescent at upper margin, clawed. Wings are ovate, 14 x 8 mm, clawed and obtuse at top (Fig. 2). Colour is similar to standard. Keel is slightly twisted, boat-shaped, 10 x 7 mm, entirely split dorsally, ventrally split near the base. Colour is a lighter shade than wing and standard.

Stamens are diadelphous (9+1) with vexillary stamens free, 9 mm long, winged at base, apical part filiform, slightly winged. Staminal sheath is 6 mm long, with free filaments of uniform length. Anthers are elliptoid, 0.5 mm long and yellow.

Ovary is sessile, thin, 6 mm long, pubescent with 5-8 ovules. Style is abruptly upturned, 6-7 mm long, widening at tip, and bearded below the stigma. Stigma is terminal, glandular-papillate and spatulate.

Pods are oblong, flat, slightly bulging over the seeds, about 2.5-4.5 cm in length, 0.6-1.0 cm in width and slightly curved (Figs. 1 and 2). The dorsal part of the pod is 2-winged, shortly beaked and contains 3-5 small seeds. Seeds are 4-7 mm in diameter, angled and wedge-shaped (Fig. 2). Colour is white, brownish-grey or yellow, although spotted or mottled forms also exist. Hilum is elliptic and cotyledons are yellow to pinkish yellow.

Germination is hypogeal, the epicotyl purplish-green. The first two leaves are simple. The first leaf is small, scale-like, often fused with two lateral stipulae. The second leaf is sublate, connected at the base with stipulae.

3 Origin of the species and important centres of diversity

3.1 Origin

It has been reported by several authors that the origin of *L. sativus* was unknown as it was thought that the natural distribution had been completely obscured by cultivation, even in southwest and central Asia, its presumed centre of origin (Smartt 1984). However, it is now suggested that the crop originated in the Balkan peninsula. There are reports of wild *L. sativus* in Iraq (Townsend and Guest 1974) but it is not clear if these are indeed wild or escapes from cultivation. As reported by Jackson and Yunus (1984), some of the earliest archaeological evidence comes from Jarmo, in Iraqi Kurdistan, dated at 8000 BC. Remains of *Lathyrus* species have been found at Ali Kosh (9500-7600 BC) and Tepe Sadz (7500-5700 BC) in Iran and are among the most common foods recorded at these sites (Jackson and Yunus 1984). At Azmaska Moghila, in Bulgaria, remains dated at ca. 7000 BC have been tentatively identified as *L. cicera* (Renfrew 1969). Remains of *L. sativus* also have been reported in India dating back to 2000-1500 BC by Saraswat (1980) who indicated the possibility of diffusion of the crop from West Asia.

Vavilov (1951) described two separate centres of origin of the crop. One was the Central Asiatic Centre which includes northwest India, Afghanistan, the Republics of Tajikistan and Uzbekistan and western Tian-Shan. The second was the Abyssinian Centre. In addition, Vavilov noted trends in diversity similar to those found in other pulses, such as lentils and broad beans, in that smaller-seeded forms were found in southern and southwest Asia, whereas around the Mediterranean region, almost all were highly cultivated forms with large white seeds and flowers (Jackson and Yunus 1984).

However, the combination of archaeobotanical and phytogeographical evidence gathered now leads to the conclusion that the origin of *L. sativus* cultivation is located in the Balkan peninsula, in the early Neolithic period, dated to the beginning of the 6th millenium BC (Kislev 1989). Kislev suggests that the practice of agriculture of annuals, including cereals and legumes such as pea and lentil, introduced from the Near East around 6000 BC enabled the domestication of *L. sativus* in this region. This means that *L. sativus* is perhaps the first crop domesticated in Europe as a consequence of expansion of agriculture from the Near East.

There is a large amount of morphological variation, especially in vegetative characters such as leaf length, while floral characters are much less variable (Jackson and Yunus 1984). The development of forms with larger leaves may have resulted from selection for forage types. It appears, therefore, that there is a large base of germplasm present in many countries that can be utilized by plant breeders in the production of locally adapted lines for specific requirements.

3.2 Domestication and evolution

The species *L. sativus* is probably a derivative from the genetically nearest wild species, *L. cicera* (Hopf 1986). This somewhat smaller-seeded vetch grows in the countries from Greece to Iran and Transcaucasia. In this area carbonized *Lathyrus* seeds have been retrieved from a number of prehistoric sites, going as far east as

India. Grass pea could also be traced in Italy and southeast France. One isolated sample is reported from early bronze age Portugal. The most northerly finds are known from Hungary. Hopf (1986) reports that under the scanning microscope the papillae on the seed surface of the two species look somewhat different. In *L. sativus* the papillae were low, wide, with a somewhat blunt top and long, almost radial, protruding ridges; whereas in *L. cicera* the papillae were higher, conic and pointed; and the shorter, shallower ridges did not reach the top and were not connected with those of the neighbouring papillae. He also found that the same differences could be found in a prehistoric sample, and therefore concluded that these two species probably grew together in the same field. It is suggested that expansion of *L. sativus* farming to southern France and Spain may have led to the domestication of the local *L. cicera*. According to archaeobotanical finds it happened not later than the 3rd or 4th millennium BC. Then came the possibility of their being mutually cultivated and the spread of such a mixture throughout the Mediterranean basin. Kislev (1989) believes that seed coat patterns may help in verifying the theory that in the Neolithic period *L. sativus* was cultivated in eastern Mediterranean countries while *L. cicera* was confined to France and Spain, as it is today.

The close morphological affinity of *L. sativus*, *L. cicera* and *L. gorgoni* is interesting and may be a consequence of hybridization or common ancestry (Jackson and Yunus 1984). *Lathyrus sativus* and *L. cicera* resemble each other in certain floral characteristics, although in fruit *L. sativus* is closer to *L. amphicarpus*, *L. blepharicarpos* and *L. marmaoratus* (Davis 1970). The relationship of *L. stenophyllus* to these three species is more problematic on account of the small numbers of specimens examined. From the material studied by Jackson and Yunus (1984) there was a clear distinction between these three species and the other 11 species of section *Lathyrus*, with a few exceptions. In addition, the pollen morphology of *L. sativus*, *L. cicera* and *L. gorgoni* is very similar (Yunus 1982), and preliminary karyotype studies of these species show close similarity. Davies (1958) has indicated a closer link between *L. sativus* and *L. cicera* than to other species. Close association of *L. sativus* with *L. cicera* and *L. gorgoni* also has been shown by Bell (1971), on the basis of the distribution of non-protein amino acids in *Lathyrus* species.

In general interspecific hybrids are difficult to make in *Lathyrus* but the reasons for this interspecific incompatibility are not at all evident. The ability of *L. sativus* and *L. cicera* to hybridize was demonstrated by Lwin (1956) and confirmed by Khawaja (pers. comm.). This suggests a close association between these two species. The hybrid *L. sativus* and *L. amphicarpus* (Khawaja 1988) also suggests a close association between these two species. *Lathyrus sativus*, *L. cicera* and *L. gorgoni* have a sympatric distribution in Turkey and are often found as weeds in other crops. As *L. sativus* has been shown to have varying amounts of outcrossing, ranging as high as 27.8% in Bangladesh (Rahman *et al.* 1995), the possibility of natural outcrossing between these species cannot be discounted. An evaluation of the species genepools is a valuable step in the exploitation of germplasm (Smartt

1981) and this approach appears to be much needed in *Lathyrus* if it is necessary to reach outside the cultivated species genepools for valuable genetic traits.

Subterranean vetch (*L. amphicarpus*) produces underground cleistogamous flowers that are never exposed to light (Abd El Moneim 1989). These flowers are sessile in the axils of minute, lobed leaves on subterranean rhizomes or stems. The flower-bearing rhizomes develop from cotyledonary buds situated at the basal nodes just above the root collar. They are chlorotic, delicate, rarely branched and consist of a few long internodes. The apex is recurved to protect the apical bud as it penetrates the soil. Subterranean and aerial flowers normally appear simultaneously, although occasionally the subterranean flowers develop after those above ground are completely matured. The underground flowers are more fertile than their exposed counterparts. The location of the subterranean flowers probably protects them from environmental factors harmful to pollen formation or fertility and from grazing. This species was discovered during evaluation of new vetch germplasm during 1986/87 at ICARDA (Abd El Moneim 1989). They had been collected from dry areas in the central Anatolian region of Turkey and from barley-growing areas in Syria where the species sometimes grows as a weed.

4 Properties

4.1 Composition

There appear to be few studies on the nutritional aspects of *L. sativus*. Rotter *et al.* (1991) gave the following composition of four samples grown in Manitoba, Canada, as shown in Table 1.

Rahman *et al.* (1974) gave the following values for *L. sativus*: energy 362.3 cal; protein 31.6%; fat 2.7%; nitrogen-free extract 51.8%; crude fibre 1.1% and ash 2.2%. Aletor *et al.* (1994) reported on selected lines of three *Lathyrus* species. They found that crude protein averaged 32.5% (of dry matter) in *L. sativus* compared with *L. cicera* at 29.5%. Ash content was reported to vary from 3.5 to 3.56% for advanced lines and crossing progeny of *L. sativus*.

Table 1. Composition of four samples of grass pea seeds

Component	Range
Water (%)	7.5-8.2
Starch (%)	48.0-52.3
Protein (%)	25.6-28.4
Acid detergent fibre (%)	4.3-7.3
Ash (%)	2.9-4.6
Fat (%)	0.58-0.8
Calcium (mg/kg)	0.07-0.12
Phosphorus (mg/kg)	0.37-0.49
Lysine (mg/kg)	18.4-20.4
Threonine (mg/kg)	10.2-11.5
Methionine (mg/kg)	2.5-2.8
Cysteine (mg/kg)	3.8-4.3

Source: Rotter *et al.* (1991).

4.2 Antinutritional and toxic properties of the species

Data on various antinutritional factors were investigated in 100 germplasm collections of *L. sativus* at Morden Research Station, Canada by Deshpande and Campbell (1992).

A strong epidemiological association is known to exist between the consumption of grass pea and a motor neuron disease called lathyrism (paralysis of lower limbs). A neurotoxin, ß-N-oxalyl-L-a, ß-diaminopropionoc acid (ODAP also known as BOAA) has been identified as the causative principle for lathyrism and is present in all parts of the plant (Campbell *et al.* 1994). ODAP was first identified in *L. sativus* by Bell (1962) when he found ninhydrin-reacting compounds in many *Lathyrus* species. The biosynthesis of b-ODAP from its precursor b-(isoxazolin-5-on-2-yl)-alanine (BIA) was demonstrated in young seedlings by Kuo *et al*. (1994). Prakash *et al*. (1977) reported that ODAP was found in all tissues of *L. sativus* plants, irrespective of age or variety, but maximum content was observed in the leaf at vegetative stage and in the embryo at the reproductive stage. Rotter *et al*. (1991) reported that chicks fed 400 g/kg of low- and medium-ODAP lines or 600 g/kg of low ODAP line suggested that ODAP might play a anti-nutritional role in food digestion. This aspect, however, has not been critically examined.

Condensed tannin levels in *L. sativus* lines ranged from 0 to 4.38 g/kg (Deshpande and Campbell 1992). Out of a total of 100 lines, 29 accessions/genotypes lacked or had barely detectable levels of condensed tannins. Twenty-seven accessions had tannin contents greater than 2 g/kg. Since tannins are strongly astringent (owing to their protein-binding properties), a depression of feed intake, which lowers animal productivity, would be expected. Although astringency seems to be the major cause of lower feed intakes, several other factors may contribute to the lower feed efficiency ratios of tannin-containing diets. These include the formation of tannin/protein complexes that make the protein unavailable, inhibition of the digestive enzymes, increased synthesis of digestive enzymes due to inadequate enzymic digestion, and increased loss of endogenous proteins such as the mucoproteins of the gastrointestinal tract (Price and Butler 1980).

The total phenolics ranged from 39 to 999 and 86 to 891 mg/kg in 100 lines when assayed by Folin-Ciocalteu and Prussian blue assays, respectively (Deshpande and Campbell 1992). The genotypes that were devoid of condensed tannins did contain lower levels of other phenolic compounds. Unlike condensed tannins, low molecular weight phenolic compounds, unless present in very high amounts, do not directly cause any harmful effects to swine and cattle. Their only apparent effect appears to be a contribution to the bitter taste of the ration, thereby lowering the feed intake of animals.

In their study they found that both condensed tannins and total phenolics were highly correlated with the seed coat pigmentation (Deshpande and Campbell 1992). The 29 lines that were almost devoid of tannins were all characterized by a white to creamy yellow seed coat, with very few, if any, speckles. In contrast, with the exception of one accession which had whitish-yellow seeds with brown specks, the moderate to high tannin-containing lines were all characterized by a dark brown to black pigmentation of the seed coats. In these lines, the tannin levels were found to generally vary with the intensity of pigmentation, with the darker seed coats generally giving higher levels of tannins. The flower colour in *L. sativus* is generally highly correlated with the seed colour: the blue, pink or red flowers usually producing speckled, coloured seeds, whereas the white flowers are associated with white to creamy yellow seeds. Breeding and selecting for flower colour should therefore be useful in developing lines with low levels of condensed tannins and phenolics in *L. sativus*.

The trypsin inihibitor activity (TIA) and chymotrypsum inhibitor activity (CIA) varied within narrow ranges in a study on 100 genotypes (Deshpande and Campbell 1992). The mean TIA and CIA values were, respectively, 155 x 103 and 10 x 10^3 units/g of seed. Although TIA was detected in all the genotypes studied, three genotypes were devoid of any CIA. It was interesting that unlike most other food legumes which show an equal if not greater distribution of Bowman-Birk double-headed type inhibitors capable of inhibiting both trypsin and chymotrypsin simultaneously (Deshpande and Damodaran 1990), all the grass pea genotypes studied were characterized by very high levels of TIA. This also suggests the possibility of this legume predominantly containing mostly the Kunitz type single-headed trypsin inhibitor. The only studies in the literature on the purification and characterization of *L. sativus* trypsin inhibitor have shown it to be a protein of apparent molecular mass 22 000 (Roy and Rao 1971; Roy 1972, 1980). It comprised five protein components ('isoinhibitors') of identical isoelectric points and contained 203 to 212 amino acid residues. Their amino acid composition and molecular weights also suggest that they are of the Kunitz class of trypsin inhibitors. Since Kunitz trypsin inhibitors are generally absent from many agriculturally important members of the legumes such as *Phaseolus, Pisum* and *Vigna* (Deshpande and Damodaran 1990), *L. sativus* appears to be an exception to this general rule. The higher TIA, compared with the CIA, of chickling vetch genotypes clearly distinguishes this food legume from the rest, in having a higher content of Bowman-Birk double-headed inhibitors capable of strongly inhibiting both trypsin and chymotrypsin. In evaluation of 36 lines of *L. sativus* (Aletor *et al.* 1994) at 18.16±2.36 g/kg DM was found to be similar to that found in *L. ochrus* and about twice the levels found in *L. cicera.*

The correlation coefficients between different antinutrients were determined. The total phenolics and condensed tannins were positively correlated with the enzyme inhibitory activities of grass pea genotypes. Therefore the selection of white-flowered and white-seeded types could aid in the development of grass pea lines that are low in or devoid of these antinutritional factors.

4.3 Nitrogen fixation

As grass pea is a legume crop and fixes atmospheric nitrogen, it is utilized in many production areas to aid the main economic crop. In many cases grass pea is produced in the farming system before the rice crop or alternately with a rice crop. The growers feel that the nitrogen fixed by the grass pea crop produces higher yields not only for the crop itself but also for the succeeding crop. Therefore the crop fits very well into a long-term sustainable farming system.

5 Uses

The grass pea is an annual legume commonly grown for its grain, but also used for fodder or green manure. The vegetative types are utilized in the production of fodder or forage for animals (Fig. 3).

5.1 Forage and animal feed

The young plants are used as a fodder for cattle or for grazing, as in Bangladesh. Normally, the fields are allowed to be strip-grazed by cattle before the crop is allowed to regrow and then harvested for seed. *Lathyrus* has great potential as a fodder crop. Gowda and Kaul (1982) reported that in studies at BARI, Joydepur, fodder yields of 7-10 t/ha were obtained in intercropping with maize, without affecting the grain yield of the maize.

The growth and seasonal quality of *L. sativus* and some related species have been studied by Abd El Moneim and Khair (1989). Rihawi *et al.* (1984) noted changes in the potential nutrient efficiency of different legumes, including *L. sativus* at different stages of maturity. The stems and chaff remaining after harvest is often the most important factor for producing the crop in South East Asia. The plants are normally pulled while they are still green but after the pods have filled. This allows maximum food value to remain in the biomass and at the same time produces good seed yields.

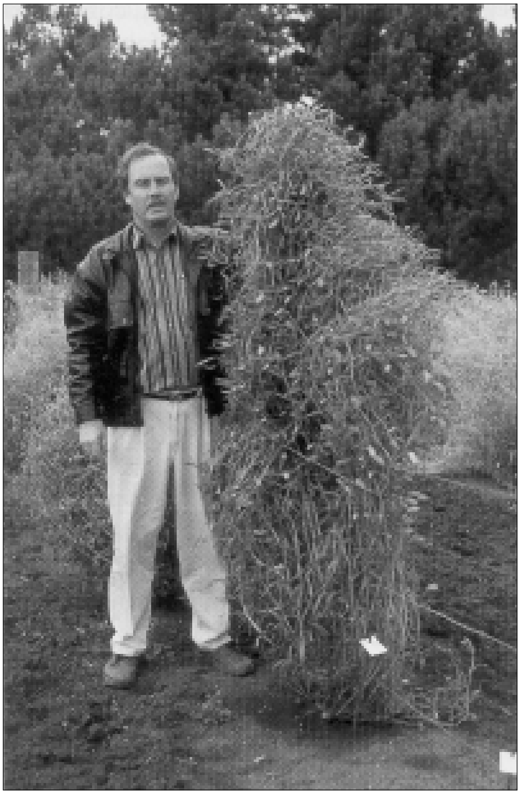

Fig. 3. The author displaying forage type of *Lathyrus sativus*.

In surveys of growers in India it is often found that the animal feed value of the crop is more important than that for human food in determining the production of this crop. This also has been found true in the Sind province of Pakistan where it is estimated that 60% of the crop is used for forage; of the harvested portion, 60% of the seed is used for animal feed and 40% for human consumption or sale (Khawaja, pers. comm.). Often the feed is comprised of ground or split grain or flour and is used as feed for lactating cattle or for bullocks at the time of heavy field use such as during land preparation.

The nutritional value of low lathyrogenic grass pea for growing chicks (Rotter *et al.* 1991) has been reported. As well there has been evaluation of *L. sativus* as an ingredient in pig starter and grower diets (Castell *et al.* 1994).

5.2 Human consumption

Different seed coat colours might be preferred in different regions according to tradition and use of the crop. The seed coat colour can also affect the nutritional value of the seed. Condensed tannin levels were found to be positively correlated with seed coat pigmentation, with coloured genotypes containing greater levels of tannin (Deshpande and Campbell 1992). The genetics of flower and seed coat colour are now starting to be understood in grass pea (Tiwari and Campbell 1996).

In India, the grains are sometimes boiled whole, but are most often processed through a *dal* mill to obtain split *dal*. *Dal*, a soup-like dish, is the most common method of retailing the crop in the Indian subcontinent (Pandey, pers. comm.). The flour, made from grinding either the whole or split seed, is sold as *basan*. In many parts of Bangladesh, *roti* (unleavened bread) made out of grass pea flour is a staple for the landless labourers. More recently the *dal* or *basan* has been used to adulterate pigeonpea *dal* and chickpea *basan* as these crops demand a higher price on the market (Rahman, pers. comm.).

In Nepal the dried grains are split either in a stone grinder on a home scale or milled to make *dal* which is consumed with rice. The grains are also ground and made into flour for use in a pancake-like preparation of *badi* or *pakoda* (Yadov, pers. comm.). Grass pea flour increasingly is being used to adulterate the higher-priced legume flours such as chickpea and mungbean.

In Ethiopia, particularly the northern regions, and in Eritrea tef, wheat, barley, maize and sorghum, either singly or in combination, are used to produce a fermented, sour pancake-like unleavened bread called *enjera*. *Lathyrus* grain is ground into *shiro* and is used in the preparation of *wott*, a sauce that is eaten together with the *enjera*. For snacks, cereals, legumes or their mixture are most often consumed roasted or boiled. Boiled grass pea (*nifro*) is consumed in most areas. *Kitta*, an unleavened bread made from grass pea, is consumed to a more limited extent, mainly at times of acute food shortages (Tekele-Haimanot *et al.* 1993).

During the month of February in South East Asia the tender young vegetative parts are plucked (4-6 cm length) and cooked as a green vegetable. They are also rolled and dried for off-season use as a vegetable (Bharati and Neupane, 1989). The green pods and seeds are eaten directly or the whole pods are cooked and eaten as a vegetable. This augments the supply of fresh vegetables available at this time of year. The remaining plant is then allowed to grow and is harvested for seed.

The young pods are boiled, salted and sold or consumed as a snack. This can be seen in many of the grass pea growing areas of India, Bangladesh and Pakistan where vendors are found on street corners or at public transportation areas during the season. The snacks are said to be very tasty and are prized for this feature.

5.3 Second and low-input crop

The grass pea is utilized in many areas of South East Asia as a 'utera' crop. The seeds are broadcast into a standing rice crop. When the water is drained to allow for harvesting of the rice, the seeds germinate and the crop utilizes the remaining moisture for growth. Normally the smaller-seeded type lines are utilized as the growers believe that they will remain dormant longer under flooded conditions and give better germination when the water is drained.

In many areas of South East Asia and China where grass pea production occurs the crops are either grown under 'utera' conditions and utilize remnant water or are sown on rain-fed areas where they must exist on minimum moisture until harvest. The crops normally are considered to require low or zero inputs and therefore not only utilize remnant water but also must utilize remnant soil nutrients. As many of these soils are deficient in zinc this aspect requires further study to determine the effects on the crop.

6 Genetic resources

6.1 Range of diversity of major characteristics and geographic trends

There have been a number of evaluations of *L. sativus* germplasm to study the variation in it and related or wild species (Jackson and Yunus 1984; Hanbury *et al.* 1995). There also have been evaluations of the nutritional value (Dutta *et al.* 1982; Deshpande and Campbell 1992), of which several have focused on the forage, fodder or feed value (Ghobrial *et al.* 1983; Somaroo 1988; Abd El Moneim *et al.* 1990; Keatinge *et al.* 1991). Several of these compare *L. sativus* collected locally with collections from other areas. It should be noted that in some of the studies only one or two lines have originated from a given country while a large number of lines have been evaluated from another area or country. While these evaluations provide very important data on the geographic variability that exists one must also be aware that a single line may or may not be representative of an area and therefore exercise caution about the conclusions that are drawn. There are, however, many general trends that are evident and that do demonstrate the existing variability.

Days to 50% flowering

There exists a wide range of days to 50% flowering as can been seen in India (Table 2) where it ranged from 47 to 94. The small-seeded lakhori types are usually much earlier flowering than the large-seeded lakh types. Hanbury *et al.* (1995) also reported a wide range from 76 to 123 days of 451 lines collected from a large number of areas. Sarwar *et al.* (1995b) reported a range of 43 to 88 in 1072 accessions collected in Bangladesh. In Canada this trend also has been found with collections from Europe, compared with South East Asian types; the larger-seeded European collections are much later to flower.

Days to maturity

In India days to maturity ranged from 86 to 127 (Table 2). This trend follows that of days to 50% flowering where the smaller-seeded types are usually earlier maturing. Assessment of 732 lines in Canada gave a range of 97 to 121 days (Table 3) which was similar to that found in India. In Australia, Hanbury *et al.* (1995) found a range of 137 to 148 days with maturity being rated as when the pods had all turned a golden brown and the leaves were still on the plant. Many of the lines grown in this study were from Bangladesh and would be expected to mature during a similar time frame as those from India. This indicates the environmental influence on this character and the need to evaluate germplasm under conditions that are very similar to those where the crop is to be produced.

Plant height

Plant height has been found to vary greatly. In India it varied from 15 to 68 cm (Table 2) while in Canada it ranged from 24.5 to 172 cm (Table 3). The small-seeded types were the shortest in plant growth in both studies. This trend also appears to

Table 2. Variation for agronomic characters in grass pea germplasm (n=1187) collected in Madhya Pradesh, India

Descriptors	Mean	Range Min.	Max.	CV (%)
Days to 50% flowering	62.20	47	94	12.108
Days to maturity	107.71	86	127	4.753
Plant height (cm)	33.93	15.4	68.4	23.172
Branches/plant	9.26	1.8	28.4	33.657
Pods/plant	19.38	2.4	59	45.775
Pod length (cm)	2.97	1.88	5.18	11.587
Pod width (cm)	0.88	0.26	1.3	11.013
Seeds/pod	3.27	1.6	4.6	12.756
Seeds/plant	54.70	6.2	200	50.159
Seed index (g)	6.27	2.21	19.5	29.676
Biological yield (g)	8.31	0.4	51	55.933
Yield/plant (g)	3.78	0.62	19.81	59.832
ODAP (%)	0.438	0.128	0.872	38.527

Source: Dr R.L. Pandey, Indira Gandhi Krishi Vishwavidyalaya, Raipur, MP, India.

Table 3. Evaluation of grass pea germplasm (n=732) at Morden, Manitoba, Canada in 1994

Descriptor	Min.	Max.	Mean
Days to maturity	97	121	110.5
Plant height (cm)	24.5	172	108.4
Pod length (cm)	1.7	5.6	3.2
Seeds per pod	1.0	4.3	2.8
1000-seed weight (g)	56	288	145.4
Litre weight (g/L)	612.2	828.6	761.3

be true if small-seeded lines from India, Bangladesh or Pakistan are grown in Canada and compared with accessions from Europe or the Middle East. The larger-seeded lines from Europe and the Mediterranean region usually produce taller plants with larger biomass than lines from South East Asia.

Branches per plant

There is a very large range in the number of branches per plant. Pandey (Table 2) reports that at Raipur they varied from 1.8 to 28.4. It has been found in Canada that this feature can range as high as 40 branches per plant. In direct contrast Mehra *et al.* (1995) reports on evaluation of exotic germplasm. Accessions from France had 5.2 primary branches while those from Bangladesh had 5.7, those from Ethiopia had 5.0, those from Cyprus had 5.5, those from Afghanistan had 5.0, those from Germany had 5.0, and those from the previous USSR had 5.5. These, however, were rated as primary branches and may differ from the above ratings. In most studies there is a high correlation of branches per plant and grain yield. This feature is a very important one. Unfortunately there has not been enough evaluation of this character to demonstrate geographical distribution of the trait.

Pods per plant

This character varies in India from 2.4 to 59 (Table 2). There is a direct association with branches per plant with more branching plants having higher pod numbers. The larger-seeded types also have more pods per plant as they normally have increased pant height. Therefore, there exists a correlation between large seeds, pods per plant and plant height. This is normally also associated with later maturity and increased plant biomass. Further assessment of lines having these characteristics is required, especially for those crop improvement programmes that are concerned with increased herbage production.

In Nepal Yadov (1995) reported that pods per plant varied from 13 to 59 with a mean of 36 when 72 local germplasm accessions were evaluated. Thus this character shows a large range of variation.

General and specific combining abilities have been estimated in grass pea for pods per plant, 100-seed weight, seeds per pod, grain yield per plant and ODAP content (Dahiya and Jeswani 1974). It was generally found that nonadditive gene action was predominant in both the F_1 and the F_2.

Pod length

Pod length in Canada varied from 1.7 to 5.6 cm (Table 3); in India Pandey found a variation from 1.88 to 5.18 cm (Table 2). While this is a very close comparison it should be noted that the European lines in the Canadian study had the same pod length as the smaller-seeded lines in the study in India. Therefore, the smaller-seeded lines from India (having more seeds per pod than the European lines) appear to produce pods with equivalent lengths. This is also indicated in evaluations by Mehra *et al.* (1995) where they report pod lengths of 2.92 to 3.05 cm from 223 accessions that were evaluated. They also report that 48 accessions from Syria had pod lengths ranging from 3.6 to 4.0 cm while 12 accessions from Canada ranged from 3.08 to 4.0 cm in length. It would be very interesting to study this aspect in further depth with increased number of seeds per pod in larger-seeded types. Evaluation of existing germplasm collections might yield lines with increased pod length combined with large seed size which might be desirable for crop improvement programmes desiring to increase yield and seed size at the same time.

Seeds per pod

In Canada seeds per pod varied from 1 to 4.3 (Table 3) while in India they were found to range from 1.6 to 4.6 (Table 2). The small-seeded lines normally had a higher number of seeds per pod than did the large-seeded lines evaluated in Canada. Results reported from Nepal (Yadov 1995) show a range of 2 to 5 seeds. Although the results are similar they were not expected, as the European lines normally have fewer seeds per pod than those from South East Asia. It would appear that this characteristic requires more detailed examination as seeds per pod normally has a high correlation with yield. As increased seed size usually is also highly correlated with higher yield, plant breeders might want to consider increasing seeds per pods in larger-seeded types as an effective means of increasing yield.

Biological yield

In many parts of the world there is a shortage of feed and fodder for livestock. This is especially true for many arid regions were grass pea is grown. In many cases the value of the fodder equals or exceeds that of the grain produced. Pandey reports a range from 0.4 to 51 g (Table 2) which clearly demonstrates a large variation in this character which can be utilized by breeders interested in improving feed or forage production. Somaroo (1988) states that dry matter yield per hectare was found to be 5707 kg in 1980 and 2624 kg in 1981 at ICARDA. This compared with a seed yield of 1802 kg/ha in 1980 and 698 in 1981. Syouf (1995) reports on an evaluation of dry matter yield of eight forage legumes in Jordan in which two lines of *L. sativus* ranged from 425 to 1390 kg/ha. He states that evaluations have shown that *Lathyrus* species were among the most promising ones in the ICARDA programme. The highest-yielding forage species, however, was *L. ochrus*.

Robertson and Abd El Moneim (1995) reported on the evaluation of 272 accessions at Tel Hadya, Syria in 1992-93. The biomass yield ranged from 516 to 5200 kg/ha with a mean of 2167 kg/ha. The straw yield ranged from 440 to 3861 kg/ha with a mean of 1720 kg/ha. This compared with a seed yield of 29-1406 kg/ha with a mean of 445 kg/ha.

1000-seed weight

In Australia, Hanbury *et al.* (1995) reported that a range of 190 to 220 g/1000 seeds was found when 451 lines were evaluated during 1994. The smallest seeded lines originated from Bangladesh with the largest being from Cyprus, Germany, Tunisia, Hungary, Greece and Czechoslovakia. Sarwara *et al.* (1995b) reported that they found a range from 29.5 to 67.6 g/1000 seeds in Bangladesh. Robertson and Abd El Moneim (1995) found a range of 34.5 to 225.9 g for 272 accessions, with a mean weight of 86.8 g. In an assessment in Canada, seed size varied from 56 to 288 g/1000 seeds (Table 3, Fig. 4) with the smallest-seeded lines originating from South East Asia. Although seed size appears to be larger for some of the same lines when grown under Canadian conditions the same trend appears to exist, especially with the ICARDA evaluations. This wide variation in seed size should be of value to the breeder as Hanbury *et al.* (1995) found there was a correlation between seed size and yield. There was also a correlation between seed size and vigour, an aspect that is important in stand development as well as in herbage production.

It has been indicated by many studies that the larger-seeded types of grass pea and those having a larger amount of vegetative material are found around the Mediterranean region. Hammer *et al.* (1989) found material with an exceptionally high 1000-seed weight in south Italy. The small-seeded types have been found in the Indian subcontinent. The small-seeded lines of the Indian subcontinent usually have a tendency for seed shattering caused by the early splitting of the pod down its ventral rib before the pod matures. Many of the lines from Europe do not have this characteristic that is undesirable in most situations. However, if the plants are being used for grazing purposes this feature might be desirable as it does result in the self seeding of the plants.

Seed density

Although seed density has not been evaluated in many studies, in Canada it was found to vary from 612.2 to 828.8 g/L (Table 3). Although this shows fairly large variation it is not of the magnitude of that found in 1000-seed weight. No trends

Fig. 4. Seed variation in *Lathyrus sativus*.

of this characteristic are known to exist, mainly owing to limited evaluation of germplasm.

Flower colour

The flower colour in *L. sativus* can be blue, pink, red, white or various combinations of these colours. As pointed out by Smartt (1984) the white-flowered types are generally found in the Mediterranean region with the blue-flowered types being found as you progress towards South East Asia. In India, Nepal and Pakistan the flower colour is blue with a very few plants having red flowers. In Bangladesh this also holds true except a few plants can also be found with pink flowers. In France many of the plants have white flowers as well as blue. As the flower colour is closely correlated to seed coat colour with white flowers producing white seeds and coloured flowers producing coloured seeds, flower colour is a very useful character that can be used by breeders in selection for this character. As the amount of tannins in the seed is highly correlated with seed coat colour – with white giving low levels (Deshpande and Campbell 1992) – this character becomes very important. Grass pea types with white or cream seeds are often found in European accessions; however these traits are rarely found in accessions from Ethiopia or from the Indian subcontinent.

Insect resistance

There has been little work reported on the resistance of grass pea to various insect pests. Certainly more effort is required in this area in the improvement of this very hardy pulse crop.

In India some 1200 lines have been screened against thrips. Although none has been found resistant against this pest yet, 12 accessions showed a degree of tolerance having a score of 5 against 9 for susceptible genotypes: RLK-264, 117, 539, 557, 617, 6802, 33333, RLS-2, RPL-26, JRL-31, KHB-19, RLK-273-1, RL-273-3 and ST. \ white-14 (Pandey *et al.* 1995; Pandey, pers. comm.).

At ICARDA, resistant genotypes for cyst nematode (*Heterodera ciceri*) and root knot nematode (*Meloidogyne artiella*) have been identified. However, the severity of infection and occurrence of these pests are not presently well documented.

Disease resistance

Lines showing moderate resistance to powdery mildew have been identified in India (Lal *et al.* 1985). At Raipur, the lines RPLK 26 and RL 41 have been found to be tolerant to powdery mildew. In addition 86 lines from local germplasm collected from around Raipur, India have shown resistance to downy mildew (Agrawal, pers. comm.). Efforts are underway in India to transfer the powdery mildew resistance to higher-yielding, more adapted lines. In Syria *L. sativus* lines that were moderately resistant to powdery mildew (*Erysiphe pisi*) have been identified. Lines in India have been identified that were free from infection by downy mildew in a 3-year evaluation under conditions of heavy natural infection (Narsinghani and Kumar 1979).

Germplasm screening is being done to select pure lines or to find donors for resistance against this pathogen. Unfortunately, resistant genes have not been found in the available germplasm. However, it was noted that some landraces appear to have some ability to escape this disease. Promising lines having tolerance/escape were reported as RLS-1, RLS-2, JRS-115, JRL-43, and JRL-16 (Pandey, pers. comm.). It is interesting that he reports resistance of *Lathyrus aphaca* against powdery mildew.

In screening of 96 lines Mishra *et al*. (1986) found 8 lines that were highly resistant or immune to *Cercospora pisi sativae* f. sp. *lathyri* Misha. Six lines were resistant, 40 moderately resistant and the remainder highly susceptible.

Neurotoxin

The ODAP levels in the collection varied from 0.22 to 7.20 g/kg. Among a total of 18 lines that contained less than 1.0 g/kg ODAP, nine had levels of less than 0.5 g/kg. In contrast, 24 lines had ODAP levels over 4 g/kg with the rest having intermediate levels. Thus a large range of variability in ODAP can exist in germplasm collection of grass pea. It should, however, be noted that ODAP levels are influenced by the environment, growing conditions and locality (Leakey 1979). Lines totally lacking in ODAP have not yet been identified in present breeding programmes, but there have been several reports of levels as low as 0.01% from Canada, ICARDA and Ethiopia. The biosynthesis of ODAP in grass pea has only recently been elucidated (Lambein *et al*. 1990). Thus development of safer cultivars of *L. sativus* will likely continue to be dependent in some degree on the development of genotypes that express low levels of ODAP in given environments.

6.2 Evaluations

In the littoral zone of Morocco, Villax (1963) reported that the variety Favetta performed well among varieties introduced from Greece, Libya and Portugal. In Cyprus, Soadou (1959) reported that among 4 local varieties and 23 introductions from Algeria, Australia, Egypt, Greece, Libya, Portugal and Turkey of *L. sativus*, *L. cicera* and *L. ochrus*, a variety of *L. sativus* from Greece outyielded other introductions and was more leafy. In Turkey Hertzsche (1970) recorded that 9 ecotypes of *L. sativus* have been collected from different regions in Turkey during the period 1965-69 and assembled on the west coast of Izmir. The seed yields of 21 *L. sativus* lines were found to differ significantly, ranging between 1201 and 1889 kg/ha in winter and between 1104 and 2167 kg/ha in spring trials at Diyarbakir, Turkey (Düsünceli 1993). In contrast the seed yields of *L. cicera* varied significantly, between 458 and 1354 and 938 and 1438 kg/ha in winter and spring respectively. He found that although there was a significant variation in response of the lines in winter and spring sowing, most of the *L. sativus* lines gave better seed yields when sown in winter than in spring, while most of the *L. cicera* lines gave better yield in spring sowing. Herbage and biomass yields varied from 21 140 to 26 940 kg/ha and 5422 to 8098 kg/ha respectively in *L. sativus*, showing the large potential for forage production by this species.

In Jordan, Hopkinson (1975) recorded that a variety of *L. sativus* from Cyprus performed well, while in Syria Van der Veen (1967) stated that two varieties from Cyrus have proven well adapted. In northern Iraq a local variety of *L. sativus* was cultivated extensively in some areas, while a variety introduced from Turkey proved to be more productive and cold tolerant than the local variety in small adaptability tests at Mosul (Kernick 1976).

In Nepal a collection of 87 local germplasm has been evaluated and compared with 10 exotic lines. The local lines were higher in yield, had more seeds per pod and earlier maturity than the imported lines (Yadov, pers. comm.). Early and final stand counts were also found to be higher in the local material. The exotic lines had a larger seed size – 10.2-11.0 g/100 seeds – compared with 4.7-5.3 g/100 seeds in local material. A summary of the agronomic characteristics examined has shown a wide range of variability, especially in plant height and pods per plant. In 1987 a total of 72 local collections was evaluated at Rapmpur (Yadov 1995). Days to flower varied from 68 to 94 with a mean of 85. Days to maturity ranged from 125 to 139 with a mean of 135. Plant height had a mean of 71 cm and ranged from 46 to 106 cm. The number of pods per plant varied considerably, from 13 to 59 with a mean of 36.

In Bangladesh during 1993-94 the collections that had been made from the Rajshahi Division and the coastal areas were evaluated at BARI (Sarwar *et al.* 1995a). Days to flowering varied from 57 to 91 while days to maturity varied from 117 to 128. Pod length ranged from 2.7 to 3.5 cm and seeds per pod varied from 3.0 to 5.3. Yield was found to vary considerably – from 960 to 2502 kg/ha. ODAP content of the seed ranged from 0.04 to 0.75% with a mean of 0.32%.

An evaluation of 1187 lines collected in India identified variation in maturity, seeds per pod and many other agronomic characteristics (Table 2).

In Chile through a field trial using five dates and three sowing densities of a heterogeneous grass pea population, different parameters related to yield were evaluated. The respective correlations also were calculated and a path coefficient analysis was done on yield and its components. Results indicated that the best sowing dates were at the end of winter and that sowing delays reduced yields significantly. No significant differences were found among seeding rates of 140, 210 and 280 kg of seed per hectare. Yields reached with the three densities were over 3000 kg/ha, and in some cases surpassing 4000 kg/ha. Characterization of the yield parameters indicated that yield per plant, seeds per plant and pods per plant (X) are the most variable. Branches per plant and seeds per pod (Y) have less variability and average seed weight (Z) has the lowest phenotypic and genotypic variation. Correlation analysis indicated the existence of a high degree of association between yield per plant and pods per plant (X), and also between yield and seeds per plant and branches per plant. Seed sowing density, on the other hand, appears negatively correlated with branches per plant and pods per plant (X). The path coefficient analysis between yield per plant and its components (X, Y and Z) indicated that pods per plants (X) had the greatest direct effect over yield and consequently it would be the most important factor in a selection process within the species.

In China among the 16 species that have been found, *L. sativus*, owing to its drought resistance and high protein content in seeds, has been extensively cultivated in the northwest part of China since the 1960s. Until the early 1970s, the production area of *L. sativus* in the Gansu Province reached over 20 000 ha. It was used as a natural fertilizer (green fertilizer) and forage, and in some places also as one of the constituents in human diets, especially when the cereal crop failed. In 1973, the consumption of *L. sativus* was directly attributed to an epidemic outbreak of lathyrism. This has become a matter of public concern and of subsequent action to prohibit cultivation of what would otherwise be a valuable crop. The major result of this work during the past two decades is that four lines of *L. sativus* with relatively low toxin content and good agronomic characteristics have been screened out from 73 varieties with an ODAP seed content ranging from 0.075 to a highly toxic 0.993%. The average protein content of these lines was 23-25%. These low-toxin lines have been stable over several years. Toxicological tests of lines from the Wuwei District of Gansu Province have shown that they were safe when fed to animals. Neither acute nor chronic lathyrism was found when donkeys, pigs and sheep were fed with seeds of these lines constituting 50-80% of the daily intake for 180-250 days (Chen, unpublished).

6.3 Collections

A listing of plant genetic resources collections is given in Table 4. Although this listing gives the main collections of *L. sativus* and the related species *L. cicera*, it is not complete. One of the outcomes of the workshop on *L. sativus* held at Raipur in 1995 was to develop a network that would focus on the development of a database of present collections. This is urgently required and will be instrumental in the development of a long term strategy for germplasm conservation for this species. A brief outline of several collections and their contents are given below.

Bangladesh

In Bangladesh the first systematic collections of grass pea were made in 1979 in collaboration with ICRISAT. During 1980 and 1981 additional collections were made financed by FAO. Unfortunately the major part of these collections was either damaged or lost because of lack of proper storage facilities (Sarwar *et al*. 1995a).

In 1992 and 1994 the Pulses Centre, in collaboration with the Department of Agricultural Extension, collected 2078 accessions from 55 districts of Bangladesh. Of these, 1072 accessions were evaluated at the Central Experimental Station Farm, Gazipur in 1993 with an additional 788 accessions being evaluated in 1994. The germplasm that was collected is being safety-duplicated at ICARDA and CLIMA. To date, 1153 and 200 accessions have been sent to ICARDA and CLIMA, respectively. The evaluation included days to first flowering, days to 50% flowering, days to maturity, pod length, seeds per pod, ODAP content and yield

Table 4. Institutions with collections of *Lathyrus sativus* (>10 accessions) and *Lathyrus cicera*

Country/Institution†		*L. sativus*	*L. cicera*
Australia		583	141
Bangladesh		584	
Canada	Plant Genetic Resources of Canada, Ottawa	113	30
	Crop Diversification Centre, Morden	776	34
Chile		74	
China		43	13
Cyprus		19	
Ethiopia	Biodiversity Institute	206	
	ILRI	12	4
France		1807	509
Germany		170	63
Greece		15	13
India	Raipur	2659	
	NBPGR	1119	
Italy		129‡	
Nepal		99	
Pakistan		666	
Poland		74	0
Russia		723§	
Spain	Centro de Recursos Fitogeneticos	59	114
	Banco del Germoplasma de Leguminosas - Grano	27	24
Syria	ICARDA	1560	185
	Scientific Agriculture and Research Directorate	85	
Turkey		2¶	37
UK		142	102
USA	North Central Regional Plant Introduction Station	181	
	Western Regional Plant Introduction Station	206	38

Source: FAO - World Information and Early Warning System on PGR, Frison and Serwinski (1995) and information collected by the author. † For full addresses see Appendix I. ‡ Wild/weedy species from Italy. § Various *Lathyrus* spp. ¶ Wild/weedy species from Turkey.

(Sarwar *et al*. 1995a). It is interesting to note that seeds collected in the drought-prone areas away from the coast were larger in size than seeds collected from the coastal areas. This was thought to be due to the environment of these two areas (Sarwar *et al*. 1993). In 1993 all 1072 accessions were found to be blue flowered; however, a lot of flower mutants were identified in the collection. These included white, pink, deep pink, red, light violet, reddish blue, pinkish blue and light blue. It was thought probable that these arose from the blue flower colour and were alleles, suggesting that flower colour might be governed by multiple alleles.

Canada

The Agriculture and Agri-food, Research Centre, Morden, Manitoba has 776 accessions of *L. sativus* and 34 of *L. cicera* in storage at 3°C and 20% RH. These have been evaluated for all the descriptors as set out by the 'International Network for the Improvement of *L. sativus* and the Eradication of Lathyrism' (INILSEL) (Fig. 5). The accessions include a back-up set of 82 accessions from Nepal. The Plant Genetic Resources of Canada, Ottawa also has 113 accessions of *L. sativus* and 30 accessions of *L. cicera* in long-term storage. All accessions have been evaluated using the list of descriptors developed by INILSEL.

Chile

The Instituto de Investigaciones Agropecuarias, Castilla, Chile has 74 accessions. Although a former collection had previously been made of which 56 accessions were in storage, there was another collection made in 1992. These 74 accessions were collected in inland and coastal dryland areas between Llicao and San Nicholas at an altitude of 50 to 230 m asl. These samples were collected in the main area where *L. sativus* is grown. However, future collections should take in all the coastal dryland areas of Chile. The purpose of the collection is to obtain the greatest

Fig. 5. Field evaluation of *Lathyrus sativus* at Morden, Manitoba, Canada.

possible genetic diversity in main characteristics. Accessions are stored in plastic containers at –4°C and 45% RH. The 74 accessions have been evaluated for time of flowering, flower colour, plant height, number of pods per plant, number of seeds per pod, 1000-seed weight, yield, protein content and ODAP concentration. They are available subject to a previous agreement regarding their use.

China

In China 16 species of *Lathyrus* have been found: *L. caudatus, L. davidii, L. dielsianus, L. gmlinii, L. humilis, L. japonicus, L. komarovii, L. krylovii, L. odoratus, L. palustris, L. isiformis, L. pratensis, L. quinquenervius, L. sativus, L. tuberosus* and *L. vaniotii.* Forty-three samples of *L. sativus* are conserved at the Institute of Crop Germplasm Resources.

Ethiopia

In Ethiopia the total holding of *Lathyrus* is 282 accessions out of a total pulse crop collection of 4912 accessions on 12 species (Tadesse 1994). *Lathyrus* ranks fifth among the pulses in this collection in importance after faba bean, field peas, chickpea and lentil. These collections are preserved under conditions of –10 and 4°C. The largest collections of *Lathyrus* have been derived from the traditional field crop of the country. In some cases the samples do not correspond with the growing area index (GIA) percentage calculated for the various administrative regions. As an example, a relatively large number of samples was collected from the Wello area were the GIA% is low. On the other hand, few samples were collected from Gondar, which has a higher GIA%. The samples were obtained from a wide altitudinal range: as low as 1685 m to as high as 2795 m (Tadesse 1994). These accessions have been evaluated for a large range of agromorphological characteristics. On the basis of flower colour, which is highly heritable, it is considered that the northern regions of Ethiopia possess large genetic variation.

There are 206 lines officially in storage at the present time at the Biodiversity Institute, Addis Abeba. However, unfortunately the documentation of most of these, which were originally on computer, is now only available manually from the original documents.

It is quite apparent that there are wide gaps in the collection as it now exists. To fill this gap, it is suggested that a targeted collecting expedition be undertaken in collaboration with relevant crop specialists. This operation should focus on both random sampling and specific traits of interest.

France

The collection at the University of Pau, France has 1807 accessions of *L. sativus* originating from: Belgium (3), Bulgaria (13), Czechoslovakia (18), Cyprus (44), Germany (261), Spain (31), France (487), Greece (158), Hungary (5), Italy (41), Poland (10), Portugal (104), Romania (2), former USSR (30), and Ukraine (4). In addition the following other species are conserved: *L. cicera* (509 accessions), *L.*

heterophyllus (80), *L. latifolius* (311), *L. sylvestris* (666) and *L. tuberosus*. Storage conditions are at –40°C and 80% RH in unsealed plastic containers. The storage volume of the room is 5 m3, but Dr Combes reports that there is no room remaining for additional accessions. The *L. sativus* accessions have been evaluated for flower and seed coat colour.

India

The first effort to systematically collect the grass pea germplasm in India was in 1967 (Mehra *et al*. 1995). Approximately 600 accessions were collected and analyzed for ODAP content. In 1969 subsequent collections were made from Bihar, Eastern U.P., West Bengal, Gujarat and Haryana. In 1975 IARI scientists collected from the tribal areas of Bihar. In 1976 some indigenous accessions were sent to the Lathyrus Improvement Program at Raipur M.P. from Jawahar Lal Nehru Krishi Vishwa Vidyalaya, Jabalpur. Later on the Directorate of Pulses Research, Kanpur also supplied some indigenous materials to this programme. Exotic accessions belonging to Italy, Canada, Germany, Bangladesh, France and Iowa were also received from NBPGR (National Bureau of Plant Genetic Resources), New Delhi. During 1989-90 and 1990-91, 1187 landraces of grass pea were collected from the growing regions of Madhya Pradesh. At the present time 2659 accessions are being maintained at Raipur. A set of landraces has been stored in the National Genebank at NBPGR, New Delhi. These have been coded as IC 142554 to IC 143565. Short-term storage facilities have been developed at the Indira Gandhi Agricultural University, Raipur.

The NBPGR was started in 1976 and presently maintains 1119 accessions, including exotics. Of these, 1061 samples have been conserved as base collections in the genebank (Singh and Chandel 1995). Approximately 1154 exotic accessions have been introduced into India during the past decade.

In 1994-95, 283 accessions of *L. sativus* and five other *Lathyrus* species (*L. pseudocicera, L. inconspicuus, L. aphaca, L. cicera* and *L. chrysanthus*) were evaluated at IARI, New Delhi. Evaluations were made on plant height, number of primary branches, pod length, number of pods per plant, seeds per pod and 1000-seed weight (Mehra *et al*. 1995).

Jordan

Collecting missions in 1981, 1989, 1990 and 1993 reported 36 accessions of eight species of *Lathyrus* (Syouf 1995), although only one *L. sativus* accession was reported. Syouf also reports that 20 Jordanian *Lathyrus* accessions were evaluated for 12 descriptors at Tel Hadya, Syria in 1992. These included days to 50% flowering, days to 90% podding, days to 90% maturity, pods per inflorescence, pod length, pod width, seeds per pod and 100-seed weight.

Pakistan

The Cytogenetics Laboratory of NARC has 666 accessions in storage. These include 103 accessions from the Sind province. Recently collections have been obtained from Afghanistan as well to augment the *Lathryus* Improvement Program.

Evaluation of 880 accessions for ODAP content and 590 accessions at seven different agroclimatic regions in Pakistan has been completed. The Plant Genetic Resource Institute at the National Agricultural Research Institute, Islamabad has 97 accessions of grass pea from the Sind province of Pakistan. In addition they have 46 accessions comprised of nine related species as well as 35 exotic lines (Haqqani and Arshad 1995).

Russia

The N.I. Vavilov Institute of Plant Industry in Saint Petersburg has a total collection of 723 accessions of *Lathyrus* species. It is not known, however, how many of these are of *L. sativus* or of *L. cicera*.

Syria

ICARDA holds 'in-trust' *Lathyrus* germplasm for more than 45 countries under the auspices of the FAO (Robertson and El Moneim 1995). The emphasis of the collection is on the species *L. sativus*, *L. cicera* and *L. ochrus*; however, over 40 other species are also in storage. The majority of the accessions are from the WANA region. A total of 1560, 185 and 138 accessions are being conserved for *L. sativus*, *L. cicera* and *L. ochrus* respectively. There are an additional 1056 accessions of the other species. Germplasm has been evaluated for stress resistance and tolerance to cold, and ODAP content. In 1992-93, 1082 accessions belonging to 30 species were evaluated using 21 descriptors. The complete results are reported in Robertson and El Moneim (1995).

Turkey

In 1987, 1988 and 1995 a total of 449 *Lathyrus* seed samples were collected in Turkey (Sabanci 1995). Seventeen accessions were of *L. sativus* while the remainder were from 31 other species. A complete list of accessions that are available for distribution is given in Sabanci (1995). He notes, however, that the number of species found in the more recent collections was about half of that found in 1970, showing the serious erosion that has taken place in this genera. However, only 185 accessions are stored at the Plant Genetic Resources Department (Frison and Serwinski 1995).

United Kingdom

The collection at Southampton University also contains a very large number of accessions of other species of *Lathyrus*. An effort is being made at the present time to organize the collections, databases and descriptors for *L. sativus* as well as for the other two important species – *Lathyrus ochrus* and *L. cicera*. These aspects need to be addressed as the potential of this crop and related species becomes more recognized.

6.4 Databases

During the fifth meeting of the working group on forages of the European Cooperative Programme for Crop Genetic Resources (ECP / GR) it was recommended that a European Vicieae database be established and managed jointly by the University of Southampton, IBEAS, Pau and CNR, Bari. This recommendation is implemented within the framework of ECP/GR. The responsibility for updating the database on *Lathyrus* lies with Daniel Combes, IBEAS, Pau (Gass *et al.* 1995). The database was established in 1985 after a colloquium on *Lathyrus* held in Pau. It includes two annual species (*L. sativus* and *L. cicera*) and four wild or semi-wild perennial species (*L. heterophyllus*, *L. latifolius*, *L. sylvestris* and *L. tuberosus*). The total number of accessions is 4000, out of which 1810 are *L. sativus*. Countries of origin are mostly European, but also from North Africa, the Middle East, Ethiopia and India. The database can be provided to everyone on floppy disk or on paper (see Appendix II for address). It is also freely accessible through the Internet on the Pau University web site (http://www.univ-pau.fr) by clicking on 'La recherche' and then on 'Biologie' (Daniel Combes and Monique Delbos, pers. comm.). It is also accessible through Dirk Enneking's CLIMA web site (http://www.general.uwa.edu.au/u/enneking/home.html) which contains other useful information on *Lathyrus*.

A database of other *Lathyrus* species is managed by F. Bisby, University of Southampton (for address see Appendix II). This database contains 1491 entries, covering approximately 70 species.

6.5 Descriptors

Until now most descriptors that have been used for collections have been passport descriptors. Those that have been used for the collection at Pau, France have been recommended by the forages working group of ECP/GR. Unfortunately, many passport data are missing for most of the accessions, as collecting of accessions was done generally before any IBPGR/IPGRI recommendations had been established.

Although there are a number of institutions with fairly sizeable collections of grass pea and related species, nothing really consistent has been done on the standardization of these descriptors. Ray Clark from NPGS in Washington has established a quite important list of evaluation descriptors for *L. odoratus* (sweet pea). This could constitute a possible base of discussion for the establishment of such a descriptor list for *L. sativus*. It contains morphological descriptors as well as descriptors for resistance/sensitivity to parasites (particularly fungi). It might be of interest to add a list of enzymatic descriptors, as new data in this area are beginning to accumulate (Godt and Hamrick 1991; Yunus *et al.* 1991; Al Kadi 1993). In a near future one can also imagine descriptors for DNA markers (RFLP, RAPD) that could be added, as they begin to be studied.

The Germplasm Resources, Crop Improvement and Agronomy Committee of INILSEL agreed in 1988 to use the following descriptors as the basis for their collections:

- Days from seeding to 50% flowering of plants
- Anthocyanin present in stem
- Flower colour
- Leaf width (narrow = 0.5 cm, medium = 1 cm, wide = 1.5 cm)
- Seed coat colour

- Days to maturity (from seeding to 90% pods turned brown)
- Plant height (cm)
- Downy mildew severity (0 = none, 10 = severe)
- Pod shattering at maturity (0 = none, 9 = 90-100%)
- Plant type (Indeterminate or determinate)
- Plant habit (1 = erect, 5 = prostrate)
- 1000-seed weight (g)
- Seed density (kg/hl)
- Seeds per pod
- Insect resistance
- ODAP content of seed.

At the IPGRI-ICAR/IGKV regional workshop on *Lathyrus* genetic resources, held 27-30 December 1995 at Indira Gandhi Krishi Vishavidyalaya, Raipur, India it was agreed that a list of minimum descriptors be developed and made available to cooperators (Arora *et al*. 1996). A booklet on the list of descriptors for the *Lathyrus* genepool, including wild species, will be prepared and published by IPGRI. They identified the following as Minimal Descriptors for working and long-term *Lathyrus* collections:

- Days from seeding to 50% plants with flowers
- Anthocyanin present in stems
- Flower colour
- Leaf width (narrow = 0.5 cm; medium = 1 cm; wide = 1.5 cm)
- Seed coat colour
- Maturity (days from seeding to 90% pods turned brown)
- Plant height (cm)
- Downy mildew severity (0 = none: 9 = severe)
- Pod shattering at maturity
- Plant type (indeterminate or determinate)
- Plant habit (1 = erect; 5 = prostrate)
- 1000-seed weight (gram)
- Seed density (kg/hl)
- Seeds/pod
- Insect resistance
- ODAP content of seed.

A completed list of descriptors will be developed in the near future for this crop. This is badly needed as the crop's agronomic and economic importance becomes more evident and a more organized collecting, evaluation and storage programme is developed. At the recent workshop at Raipur there was strong interest in the development of a Lathyrus Resources Network, especially for the West Asia and North Africa (WANA) and South Asia regions (Arora *et al*. 1996). The network will focus on genetic resources, securing present collections and identifying what diversity remains uncollected. Dr Arora, IPGRI, India was named the coordinator. It was agreed that the network would complement the work being done by INILSEL which has been recently reorganized as ILLRA (International *Lathyrus* and Lathyrism Research Association).

6.6 Conservation methods and techniques used

Ex situ

As *L. sativus* has orthodox seeds the general method of *ex situ* storage has been drying to approximately 5% moisture content and storage under refrigeration or frozed conditions. The methods of storage in the existing collections have, however, ranged from paper bags to plastic containers to sealed laminated pouches. Clearly this is an area which deserves more attention and correct practices have to be implemented by the various storage facilities.

In situ

Although no *in situ* conservation of germplasm in the farmers' fields has been reported, this aspect received support from the Regional Workshop on *Lathyrus* Genetic Resources in Asia held at Raipur, December 27-29 1995. They recommended that some pilot studies be carried out for *in situ* conservation (Arora *et al.* 1996).

6.7 Major gaps in the conservation of the species

Comprehensive collections of *L. sativus* germplasm have been made in Bangladesh and in the province of Madhya Pradesh in India. While many other collections have taken place in other countries, many have not been comprehensive, or did not include other closely related species or in some cases have been lost after collecting. There is an urgent need to determine accurately the status of the present collections and areas which have been adequately sampled. The need for this was expressed in the recent workshop held at Raipur, India. An internationally coordinated effort will be required to determine the present status of collection as well as to coordinate further efforts that are deemed required.

In vast areas of Rissa, Bihar, West Bengal, Eastern Utter Pradesh and the Himalayan region of India, surveying and collecting of *Lathyrus* species still has not been done. The subspecies *aphaca* and *ochrus* are found at the present time as weeds in the areas that have been collected for *L. sativus*; however, they were not included in the collections. Possibilities do exist that other species of *Lathyrus* may exist in India, especially in the mountainous regions of the country. Davis (1970) reported on the existence of about 60 species of *Lathyrus* in Turkey alone, while Maha (1995) reported nine species of *Lathyrus* collected from mountainous regions of Jordan. In India many unexplored areas should be surveyed for the presence of wild relatives of *L. sativus* as well as for the major species.

In Spain there are reports of decreased production of both *L. sativus* and *L. cicera*. These species were grown in the more mountainous areas. However, at the present time they are often found only at the edges of fields or in gardens for personal use. It appears that there is a very real threat of this germplasm being lost if a comprehensive collection is not made at the earliest possible time. The status of local landraces and collections needs to be established for other areas of southern Europe, including southern France, Greece, Italy and Turkey, as the same threat may be present for their germplasm.

Only 103 accessions have been collected from the Sind area of Pakistan because of difficulties involving the security of the collectors. As the Sind province produces approximately 65% of the *Lathyrus* grown in Pakistan, this area requires adequate collecting. Other production areas of Pakistan have not been sampled at the present time, nor have other related species been determined or collected to any extent. There appears to be and urgent need to determine the status of the present collections and to undertake further systematic sampling of the existing germplasm.

In Nepal only one accession of *L. sativus* germplasm has been collected. The Nepalese government banned commercial trade in this crop in 1993. The production of the crop is expected to decline, thereby putting severe erosion pressure on existing germplasm. As grass pea is number two in area of production of pulse crops in Nepal the existing germplasm should be adequately protected through collecting, evaluation and storage before the expected erosion has had serious effects on the collectors' ability to representatively sample the existing germplasm.

In Ethiopia in 1995, a group of scientists from Ethiopia, CLIMA and ICARDA collected more accessions from several regions in the country in a joint expedition but official figures of the accessions have not been released yet. About 300 accessions of grass pea cultivars were collected by breeders at the Adet Research Center in the dense growing areas of Gojam and Gondar in the 1987 and 1994 cropping seasons. These are not included in collections registered at the Biodiversity Institute in Addis Abeba. Therefore the exact state of collection, evaluation and storage for Ethiopia is not clear. This needs to be determined before long-range plans can be developed for this country.

It is known that production of *L. sativus* occurs in the provinces of Gansu and Shaanxi of China where production is increasing. The representation of these areas in the collection of the Institute of Crop Germplasm Resources must be determined.

ICARDA has the most extensive collection of germplasm for the Mediterranean region as well as for North Africa (Table 4). This has taken place under their mandate on forage crops. Although they have been involved in recent collecting of germplasm from these areas, there still exists a need to adequately sample this large area.

7 Breeding

As expressed by Smartt (1984) it is rather puzzling that a crop which has been used as a pulse for at least 8000 years and is still so used, should have made so little evolutionary progress as a grain crop during this time. He considers it probable that the lack of progress as a pulse crop might have been due to its other and possibly more important use as a forage crop. The selection pressures imposed on forage crops are in many ways the opposite of those on grain crops. The large seed, an advantage in grain crops, is not necessary in a forage crop, while the luxuriant vegetative growth, desirable in a forage, is much less important in a grain crop, especially if it is at the expense of seed production. These countervailing selection pressures may have cancelled each other out and maintained the status quo over this long time period. He points out that this suggests that there may be unrealized potential for the development of grass pea as a pulse crop. He considers that the development of a more compact growth habit, combined with some increase in seed size and elimination of the neurotoxin, could transform this into one of great value in the semi-arid areas of developing countries.

7.1 Cytogenetics

Chromosomal and cytogenetic studies have shown the genus *Lathyrus* to be predominantly diploid with $2n$=28 chromosomes. The chromosome numbers of more than 60 species have been reported with only three species having been shown to have more than 14 somatic chromosomes. Two species (*L. pratensis* and *L. venosus*) are tetraploid with $2n$=28 chromosomes and one species (*L. palustris*) is hexaploid with $2n$=42 chromosomes. These species have been studied cytologically and have been shown to be autopolyploids. The occurrence of an autohexaploid is among the very few examples in the plant kingdom (Khawaja, unpublished). These autopolyploids are, in reality, cytotypes as diploid forms also occur in nature.

Interest in experimental interspecific hybridization in the genus was shown in sweet pea (*L. odoratus*) as early as 1916. Burpee (1916) and others were interested in trying to introduce genes for yellow flower colour into the cultivated species from wild relatives in the same genus. Successful interspecific hybridization in the genus has been shown to be exceedingly rare, as has been found in other genera of the Leguminosae.

Interspecific hybridization between other species in the genus *Lathyrus* has been attempted by many researchers since the report of the successful crossing of *L. hirsutus* x *L. odoratus* by Barker (1916). Most attempts have been failures and even though many thousand cross-combinations are theoretically possible, only 16 have been reported as successful. Interspecific hybridization involving *L. sativus* has only been reported as successful in two instances. In 1956 Lwin succeeded in crossing *L. cicera* with *L. sativus*; however, this cross has been unsuccessful in subsequent attempts (Davies 1958; Khawaja 1988). Khawaja (1988) reported that *L. sativus* crosses readily with *L. amphicarpus* when the latter is used as the female. It also has been noted that in certain cross-combinations fertilization is successful but the embryo aborts during development. The stage of development at which abortion takes place differs with the cross-combination. Cytological studies of the F_1 hybrids between *L. amphicarpus* x *L. sativus*, *L. amphicarpus* x *L. cicera* and *L. odoratus* x *L. chloranthus* were carried out by Khawaja (1988) which showed 50-70% chromosome homology and pollen fertility in conformity with the meiotic pairing.

From the information available on crossing, fertility and chromosome behaviour of the hybrids it may be concluded that breeding strategies involving alien genetic transfer for the improvement of grass pea are possible through the readily crossable species *L. amphicarpus*. There also appears to be a high probability of success in obtaining interspecific crosses between some species that do not cross because of embryo abortion after fertilization through the utilization of embryo rescue techniques.

Plant regeneration techniques developed by Dr P.K. Roy and Dr Mehta (Mehta *et al.* 1991) have been successful in regenerating plants from explants derived from stem, leaf and root tissue. The resulting plants showed a high amount of somaclonal variation in plant habit. This technique may be successfully exploited in the production of agronomically desirable types in low ODAP lines and thus provide a faster means of improvement than that allowed by conventional crossing and backcrossing methods.

7.2 Breeding method

The floral biology of *L. sativus* is such that it favours self-pollination. However, there have been indications that some outcrossing occurs in the species, which is dependent on environmental or genetical factors. The extent of natural outcrossing that can occur in *L. sativus* has been a concern of several plant breeders over the past 10 years. Rahman *et al.* (1995), in a study using four flower colours for which the genetics were known, found outcrossing from 9.8 to 27.8%. This was determined by planting red, white and pink (all recessive to blue) flowered lines and then surrounding them with a blue-flowered line, the blue flower being dominant. Evaluation of the flower colour of individual plants was used to compute the outcrossing that occurred between lines based on natural pollinating mechanisms. It did not attempt to determine the amount of pollination that occurred within the genotypes.

It is not known if wind or insects are the major vector in the transfer of pollen, which can rapidly increase the heterogeneity in different populations. In most breeding programmes the crosses are done under controlled conditions in the greenhouse or under gauze coverings. The flowers are emasculated by removing the anthers in the late bud stage. The following morning the styles are fertilized with pollen from a preselected parental plant as soon as possible following dehiscence of the anthers. The pollen at this time is orange and rapidly becomes clear as it loses its viability. Although this is a time-consuming process it can rapidly result in a large number of successful pollinations as several seeds normally develop from each pollination.

Male sterility has been reported in many plant species but has only been reported to a limited amount in *L. sativus*. The first report of male sterility was by Srivastiva and Somayajulu (1981), in which they found that some plants had reduced stamens and the anthers did not produce pollen. No seed set was observed on selfing these plants although open-pollination gave good seed set. Quader (1987), in a study involving 40 sterile plants and 40 pollinator lines, found that 26 pollinator lines produced sterile plants. The F_1 showed complete fertility in four cross combinations and complete sterility in another three cross combinations. The presence of both cytoplasmic and genetic factors controlling male sterility was indicated. The rest of the crosses segregated for sterile and fertile plants. He concluded that there were both single and double restorer genes.

Crop improvement by mutation breeding

Mutation breeding can be a valuable supplement to conventional plant breeding methods. It can be used to create additional genetic variability that may be utilized by the plant breeder in the development of cultivars for specific purposes or with specific adaptabilities. Mutation studies on *L. sativus* have shown that the chemical mutagens EMS (ethyl methanesulphonate) and NMU (N-nitroso-N-methyl urea) are more efficient than radiation in the production of chlorophyll mutations (Nerkar 1976). However, varieties have been found to respond differently to exposure to gamma irradiation (Prassad and Das 1980a). A wide spectrum of morphological mutations has been found to affect plant habit, maturity, branching, stem shape, leaf size, stipule shape, flower colour and structure, pod size, and seed size and colour (Nerkar 1976). Plant habit mutants such as dwarf and erect, as well as giant forms, also have been induced (Prassad and Das 1980b). There thus appears to be a large selection of both naturally occurring and induced morphological characteristics that are available to the plant breeder.

Studies by Singh and Chaturvedi (1986) have shown that at biologically comparable doses the mutagenic effectiveness was in the order of N-nitroso-N-methyl urea (NMU), ethyl methane sulphonate (EMS) and gamma-rays and efficiency in the order of Gamma-rays, EMS and NMU.

An indication that ODAP content might exhibit a simple Mendelian inheritance has been reported from variation induced in grass pea through both physical and chemical mutagens (Nerkar 1972). In the segregating M_2 generation in all treatments the distribution curves showed three distinct peaks which are characteristic of monogenic F_2 segregation.

While these studies report on the formation or development of many mutations it is not known if they were stored for future utilization. This aspect needs to be addressed as they are a potential source of additional variation in the species.

7.3 Breeding objectives

Inheritance of ODAP

Genetic detoxification of the toxin ODAP is the most feasible method of producing a safe crop compared with other physicochemical processing methods that have been developed (Gowda and Kaul 1982; Smartt *et al.* 1994). Flower and seed coat colour could be useful genetic markers for identifying lines with low neurotoxin content (Dahiya 1976; Kaul *et al.* 1986; Quader *et al.* 1986). Flower colour in grass pea varies from blue to pink, red and white. Grass pea types with blue flowers and speckled (coloured) seed coat are common in the Indian subcontinent whereas white flowers with white seed coat are common in the Mediterranean region (Jackson and Yunus 1984) and in many European lines. Dahiya (1976) reported that genotypes with light cream colour seed contained low neurotoxin content. But Quader *et al.* (1986) reported that white-flowered plants had increased toxin compared with blue-flowered plants. However, Kaul *et al.* (1986), in a survey of 127 accessions of grass pea germplasm, did not find any association between flower or seed coat colour with the neurotoxin content. Although no association exists, flower colour could be introduced into low or zero neurotoxin lines as a means of identifying these lines from high neurotoxin lines. It is probable that the introduction of seed size, seed shape or seed colour could have an effect on consumer preference for this pulse and would therefore be less desirable.

The ODAP content of *Lathyrus* has been shown to differ widely both between accessions and between environments (Ramanujam *et al.* 1980; Dahiya and Jeswani 1975). Although many attempts have been made to find a correlation between ODAP content and seed coat or flower colour, the results have either been conflicting (Dahiya 1985; Quader *et al.* 1985) or have not been successful (Roy and Rao 1978). Although a high correlation to a readily identifiable plant characteristic would allow the characteristic to be used as a rapid selection technique for low ODAP content, it is not essential. Any rapid and inexpensive method capable of handling large numbers of progenies in a breeding programme can be utilized for the identification of low-ODAP segregates.

Germplasm has been collected and evaluated at a large number of sites and there are numerous reports concerning the evaluation of local germplasm and lines that were introduced from other areas. In many of these cases they have been evaluated for both seed and forage purposes and to determine their adaptability. In most cases the amount of ODAP also was determined.

An indication that ODAP content might exhibit a simple Mendelian inheritance has been reported from variation induced in *Lathyrus* through both physical and chemical mutagens (Nerkar 1972). In the segregating M_2 generation in all treatments the distribution curves showed three distinct peaks which are characteristic of monogenic F2 segregation.

In a study done at Morden, Manitoba (Tiwari and Campbell 1996) four low-ODAP lines were intercrossed (crosses and reciprocals) to evaluate the genetic basis of low seed ODAP concentration in grass pea. Mean ODAP concentration of the low lines ranged from 0.338 to 0.677 mg/g of seed. The F_1 progenies of the crosses LS90235 x L900436, LS82046 x LS90235 and the reciprocals exhibited heterosis, producing higher seed ODAP concentration than the high parent. However, high ODAP concentration of the progenies of line LS82046, when this line was used as the female parent, was associated with a cytoplasmic influence. The high ODAP values in the F_1 also could be explained by the interaction of different modifiers or background genes. In general, progenies of the low-ODAP lines did not segregate for high ODAP concentration, which suggested common genes among the low lines in grass pea. The F_2 progenies exhibited a wider variability than the parental or F_1 generation which suggests the presence of different modifier genes between the lines. A cytoplasmic influence was detected in two of the low lines. Line L720060 had progenies that segregated for lower ODAP concentration when it was used as the female parent compared with using it as the male parent. Line LS82046, in contrast, produced progeny that segregated for higher ODAP content when it was utilized as the female parent. Similar to the present observation, Quader *et al.* (1987) have postulated ODAP content to be influenced by cytoplasmic factors.

The four low-ODAP lines were crossed to the high-ODAP line, L880283, to observe resulting segregation patterns. Mean ODAP concentration of all the low-ODAP lines was below 0.7 mg/g of seed compared with 2.540 mg/g for the high-ODAP line. Mean ODAP concentration of the F_1 and F_2 progenies of the low-ODAP x high-ODAP lines was found to be in the intermediate range. The segregation of F_2 progenies covered the entire parental range and exhibited higher variability than both parental and F_1 progenies. Classification of the F_2 data for discrete classes of low and high ODAP concentration was not possible. In monogenic inheritance, two distinct groups of low and high ODAP concentration would be expected in a segregating F_2 population. The continuous variation of ODAP concentration in the segregating F_2 progenies of all the crosses, together with very close to normal distribution, indicated that ODAP content was inherited quantitatively. A significantly higher seed ODAP concentration was detected when the high-ODAP line L880283 was used as the female parent in some of the crosses, indicating the presence of a cytoplasmic factor.

Nerkar (1972) reported that ODAP content might exhibit a simple Mendelian inheritance in a study of variation induced in *Lathyrus* in segregating M_2 generations. However, variation was continuous in his experiment, although three peaks were present. The choice of phenotypic class intervals was somewhat arbitrary in this case. As reported by Quader *et al.* (1985), variation of the F_2 progenies was continuous although they postulated a simple monogenic inheritance on the basis of two peaks. Biosynthetic pathways studies by Malathi *et al.* (1967) and Lambein *et al.* (1990) revealed that at least two enzymes were involved in the synthesis of the neurotoxin. This also suggested that more than one gene controls ODAP synthesis. Quader *et al.* (1987) reported the possibility of more than one gene controlling ODAP content. However, results could easily be confounded with additive genetic effects influencing a monogenic trait. This could occur if differences between the parents were small and there was difficulty in distinguishing a segregating pattern from the normally distributed population of a quantitative trait. In this investigation, however, contrary to a few reports suggesting monogenic inheritance of ODAP seed content, it was found to be quantitatively inherited.

ODAP concentration of grass pea seed was also found to be affected by the stage of seed development in the pod. Relatively higher amounts of ODAP were detected from immature shrivelled seeds than from plump seeds from the same plant. An intermediate level of ODAP was found in average-sized seed. This observation indicated that ODAP may be synthesized during the early stages of pod development and the concentration may be diluted as the cotyledon is filled with starch. Hence, it is important that analysis of ODAP content be conducted on well-matured pods.

Grain yield

While the problem of ODAP content has been focused on by most plant breeders there has been increased activity in the past decade on the grain yield of the crop. Increased yield has been a selection criteria for most crop improvement programmes. However, some of the yield components that affect yield, such as double podding or increased seeds per pod (see Fig. 6), have seen few efforts in

a

b

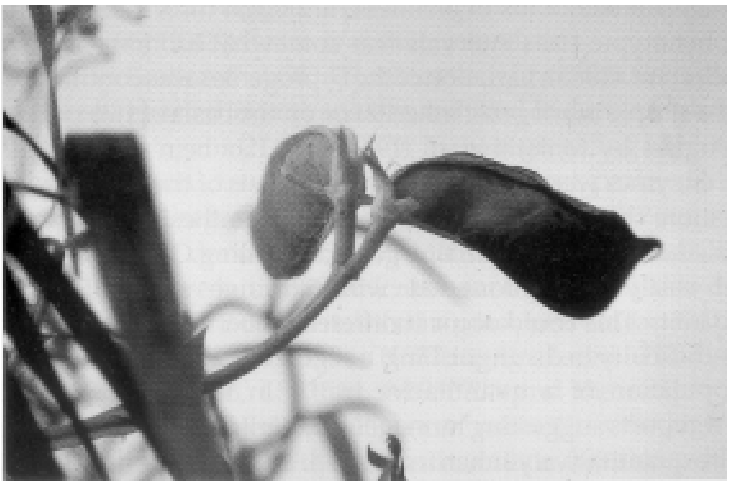

Fig. 6. Two flowers per node (a) give two pods per node (b).

most breeding programmes. This area requires more input to allow the potential of this very hardy pulse to be more fully exploited.

Herbage yield

The biomass yield of *L. sativus* has started to receive attention in breeding programmes only during the past few years, although evaluation of this character has taken place over the past 30 years. There is active improvement in this aspect in the ICARDA *Lathyrus* improvement programme as well as in Canada at Morden, Manitoba. The aspects of improvement of forage, fodder and straw are presently hampered by lack of information on nutritional values of these components in livestock feeding. This area requires more emphasis as *Lathyrus* has been shown to have a large potential for forage in the WANA area as well as forage and straw in the South Asian region.

7.4 Breeding programmes

Most of the reported work on grass pea improvement has been on the reduction of ODAP content in the seed. Although low lines were identified almost 20 years ago no concentrated effort was placed on this problem until after 1985. The Lathyrus Collogue held that year at Pau, France has served as a catalyst in many ways to focus research on many of the different aspects of grass pea improvement.

The ODAP content of grass pea has been shown to differ widely, both between accessions and between environments (Dahiya and Jeswani 1975; Ramanujam *et al.* 1980). The distribution of ODAP content in landraces in several countries is quite similar (Table 2). Although many attempts have been made to find a correlation between ODAP content and seed coat colour or flower colour the results have either been conflicting (Dahiya 1985; Quader *et al.* 1985) or have not been successful (Roy and Rao 1978). Although a high correlation to a readily identifiable plant characteristic would allow the characteristic to be used as a rapid selection technique for low ODAP content, it is not essential. A rapid and fairly inexpensive method capable of analysing over 100 samples per day has been developed for a breeding programme for the identification of low-ODAP segregates (Hussain *et al.* 1994). This method is based on the method of Briggs *et al.* (1983).

Genetic improvement work on *L. sativus* commenced in 1966 at the Jawaharlal Nehru Agricultural University, Jabalpur with the collecting, maintenance and evaluation of 503 germplasm accessions (Lal *et al.* 1985). In 1970, over 1500 samples of *Lathyrus* maintained at the IARI at Delhi were screened for ODAP content, with a few lines having a low content of 0.15-0.3% (Jeswani *et al.* 1970). It was reported that in 1971, 1000 samples were screened for ODAP content in a research programme at IARI. They were found to vary from 0.2 to 2.0% (Leakey 1979). The distribution of ODAP in different plant tissues also was determined (Mehta *et al.* 1991). A breeding and selection programme using recurrent mutagenic treatment was started to produce high-yielding, low-toxin lines of *Lathyrus* (Swaminathan *et al.* 1971).

The *Lathyrus* improvement programme in India was transferred to the Indira Gandhi Agricultural University at Raipur where work is continuing on screening lines for low ODAP content as well as developing lines with specific morphological characters. Through an active hybridization programme they are transferring low ODAP content from Canadian lines into adapted, high-yielding material. Recently the *L. sativus* breeding programme at IARI has been reactivated with emphasis being placed on lowering the ODAP content through the use of both hybridization and somaclonal variation. Kumari and Mehra (1989) have evaluated the genetic basis of some traits in grass pea. Roy *et al.* (1993) have reported the findings of reduced ODAP content in somaclones derived from internode explants of *L. sativus.*

In Bangladesh, a screening programme was initiated in 1979 to explore the possibility of isolating toxin-free lines from germplasm systematically collected from 10 districts (Kaul *et al.* 1986). The screening of the germplasm continued for over 5 years. Lines having ODAP contents of as low as 4.5 mg/g of sample to a high of 14 mg were found, indicating a large variation in ODAP content. Line 3968 was selected as being significantly low in ODAP, as well as earliest in maturity and the highest yielder (Anonymous 1980). An ongoing *Lathyrus* improvement programme at the Bangladesh Agricultural Research Institute at Joydepur has recently produced a number of lines having very low ODAP content, ranging as low as 0.03% (Quader, pers. comm.). These lines, however, are not as high yielding as some of the local accessions. More recently a total of 2078 accessions was collected(Sarwar *et al.* 1995a). These accessions are available at the Pulses Research Centre, Ishurdi and the Genetic Resources Centre of the Bangladesh Agricultural Institute, Joydepur. In addition, during 1995, in collaboration with ICARDA and CLIMA a further collecting trip was made that resulted in an additional 62 accessions.

Canadian evaluation of *Lathyrus* germplasm began in 1967 at the Agriculture Canada Research Station, Morden. A breeding and improvement programme was established in 1982 and has resulted in the release of the germplasm LS 8246 (LS82046) having a ODAP content of 0.03% in the seed (Campbell 1987). An additional two lines containing a factor for low ODAP content have been developed. These lines – L900239 and L920278 – have been shown to produce low ODAP content in the seeds when used as parents in crosses. They also appear to differ in the content of ODAP in the cotyledons and in the seedlings. It is possible that the amount of ODAP found in the seed of grass pea is dependent not only on the amount produced in the plant but also on the amount transferred into the developing seed. Studies are underway to determine the inheritance and mode of action of the three sources for low ODAP content in the seed. As well the present objectives of the programme are to transfer these low-ODAP characters into high-yielding, adapted lines having good agronomic potential. Some of these lines have been selected for increased seeds per pod and for double pods per node. This involves hybridization of selected lines with screening and evaluation of the resulting progenies.

Grass pea improvement in Nepal commenced with the collecting of 17 lines in 1986 and an additional 89 lines in 1987. These are presently being evaluated for agronomic characteristics under the Grain Legumes Improvement Program and are being screened for ODAP content at the Morden Research Station, Canada. High-yielding accessions have been selected as parental material for a hybridization programme to develop high-yielding, adapted types with very low or zero ODAP content in the seed.

Collecting and evaluation of grass pea also has taken place in Ethiopia, with 252 lines of locally collected material being maintained at the Plant Genetic Resource Centre in Addis Abeba. At least 127 of these line have been evaluated for agronomic characteristics at the Adet Research Station.

7.5 Improved lines

Attempts to provide growers with varieties with low ODAP content led to the selection and release in 1973-74 of the variety Pusa-24 by IARI in India (Lal *et al*. 1985). This variety had been shown to yield as well as some local collections in most years. Pusa-24 was a very important breakthrough as it clearly demonstrated that the level of ODAP could be selected against and that lines low in or lacking ODAP were indeed possible.

In Chile the variety Quila-blanco was developed in 1983 (Tay *et al*. pers. comm.). It was selected from the locally grown heterogeneous population and based on a bulk of six plants. The principal characteristics of this variety are uniform maturity, large white seeds (1000-seed weight of 287 g) and a protein content of 24.3%.

Line 8612 was released recently in Bangladesh as a low-neurotoxin variety. It is the first line that was developed specifically for this feature that has been released although a number of crop improvement programmes have lines in final evaluation or field trials.

8 Major and minor production areas

Statistics on production of grass pea are not available for all countries where it is produced (Table 5).

Table 5. Production of grass pea in various countries

Country†	Area (1000 ha)	Production (1000 t)	Yield (kg/ha)
India	1500	800	533
Bangladesh	239	174	728
Pakistan	130	45	346
China	20	–	–

† India: Pandey, pers. comm.; Bangladesh: Malek *et al.* (1995); Pakistan: Khawaja *et al.* (1995); China: Chen, pers. comm.

The major grass pea growing states in India are Madhya Pradesh, Maharashtra, Bihar, Rissa, West Bengal and Eastern Uttar Pradesh. It is grown on an area of approximately 1.5 million hectares with the annual production of 0.8 million tonnes. Owing to a ban on its cultivation and trade, exact statistics are not available for this crop. However, nearly two-thirds of national acreage under grass pea is in southeastern Madhya Pradesh and in the Vidarbha region of Maharashtra (Pandey, pers. comm.). However, the official statistical report for India lists an area of 783 800 ha, a production of 482 300 t, and a yield of 615 kg per ha in 1992-93 (Ministry of Agriculture 1993).

Pulses play an important role in the rain-fed cropping systems of Bangladesh. Among the pulses, khesari (*L. sativus*) ranks first in area and production and contributes approximately 35% of the total pulse production for the country. The productivity is low at 728 kg/ha (Malek *et al.* 1995).

Grass pea in Pakistan was classed under field pea production for many years and therefore statistics are incomplete or lacking. The area of production in 1991-92 was reported at 129 800 ha with a production of 45 400 tonnes with an average yield of 459 kg/ha (Khawaja *et al.* 1995)

Approximately 20 000 ha of grass pea were grown in North Gansu province of China in recent years (Chen, pers. comm.) with a stable yield 20% higher than field peas (*Pisum sativum*). This production has increased in spite of human lathyrism being a serious problem in the province of Gansu in the 1970s. The farmers like the crop for its usefulness as an animal feed, as a supplement in food processing and for its nitrogen-fixing capabilities. Although the Ministry of Agriculture of China once restricted the cultivation of the species, this restriction has now been removed. Jing-Zhong (1995) reported that 20 000 ha of land was under production in the north of Shaanxi province.

Grass pea occupies approximately 8.7% of the total area and 7.6% of the total production of food legumes in Ethiopia. It is grown in areas with severe natural production disasters. Grass pea production is mainly concentrated in the northwest zone (58.04%), the central zone (16.3%) and the northeast (12.8%) and northern parts of the country (Dibabe *et al*. 1994). The seed is used for human consumption and the straw for animal feed

The surface cropped in Italy with *L. sativus* fell from 9674 ha in 1950 to 160 ha in 1972; more recent data are not available because the crop was not assessed because of its economic irrelevance. The regions in which the crop was most cultivated were Abruzzo, Toscana and Puglia in their less-favoured environments where it was used for grazing and grain for both human and animal consumption.

There is limited production of grass pea in many other countries in Central, South and Eastern Europe (from Germany south to Portugal and Spain and east to the Balkans and S. Russia), and in Crete, Rhodes, Cyprus, Syria, Lebanon, Palestine, Egypt, Iraq Afghanistan, and Iran. It is also produced in North Africa, Morocco and Algeria.

9 Ecology and agronomy

In general grass pea is a crop that grows well under the high temperatures of the subtropics as a winter crop. It is therefore best adapted to areas with arid or semi-arid conditions. The crop, under these conditions, is generally sown in October/November and harvested in March (Sarwar *et al.* 1995b). Haqqani and Arshad (1995) state that *Lathyrus* is a winter season crop adapted to the subtropics or temperate climates. Usually, when it is grown in more northerly regions it is produced as a summer crop and thus must mature during the generally cooler autumn weather. In many cases this produces excessive biomass growth as the plant continues vegetative growth, usually until freezing terminates growth.

Grass pea is usually grown after a crop of rice in South Asia and is broadcast into the standing rice crop approximately 2 weeks before harvest. The grass pea then germinates and grows on the residual moisture. It was also noted in Ethiopia by Negere and Mariam (1994) that the crop can withstand heavy rains in its early stage and prolonged drought at maturity and during grain-filling. This demonstrates a very hardy root system that allows the crop to grow under harsher conditions than do many other pulse crops.

9.1 Seeding

The production of grass pea in South East Asia has often been observed in marginal areas that are often waterlogged, lowland, or rice-growing areas and plays an important role in increasing the cropping intensity. In such areas, farmers cannot produce a good winter crop of wheat, oilseeds or other winter legumes. It is mostly sown into almost mature rice fields during November when field moisture is at a totally saturated condition. Usually the seeds are soaked overnight and mixed with the fresh cow dung before sowing (broadcasting). Growers appear to be under the impression that mixing cow dung with the seeds protects the seeds from birds and insects and also enhances germination.

Grass pea in India, Bangladesh, Nepal and Pakistan is generally sown at a rate of 40 kg/ha under ‘utera’ conditions. There is no land preparation as the seeds are broadcast by hand into standing water in rice fields before the rice is harvested. When it is sown on rain-fed land the soil is usually prepared by two ploughings by oxen. The seeds are broadcast and planked about 2 weeks after the first ploughing. In Ethiopia and Syria the seeding rate can vary from 40 to 60 kg / ha although most of the preplanting cultivation remains almost the same.

In the Mediterranean region *L. sativus*, *L. cicera* and *L. ochrus* are normally seeded after the first autumn rains. In Pakistan the crop is normally sown in November and thus grows through the winter months. It is reported to be relatively tolerant to frost and so can withstand some freezing temperatures. The plants often form a rosette during this period but rapidly elongate with the occurrence of warmer weather.

Grass pea in South East Asia is often sown mixed with other crops as an insurance against adverse weather conditions that might affect growth or yield of the various crops utilized in the mixture.

9.2 Weeding

Normally in most growing areas of South East Asia weeds are controlled by hand weeding. This may or may not be practised as the crop often is considered a low-input crop with lower returns and therefore weeding may not take place. In Canada it was shown that *L. sativus* yields decreased with increasing density of volunteer wheat or barley (Wall and Campbell 1993). *Lathyrus* was not competitive with weeds, especially when moisture was a limiting factor to plant growth. Herbicides which might safely control annual weed in *Lathyrus* have been identified (Wall *et al.* 1988; Wall and Friesen 1991), but none are currently registered for use in Canada.

9.3 Pests and diseases

Aphids (e.g. *Aphis craccivora*) are reported to be a major pest in India, Bangladesh and Ethiopia. Powdery mildew (*Erysiphe polygoni* DC) and downy mildew (*Peronospora lathyri-palustris* Gaumann) are the two major diseases that infect grass pea. Losses due to these organisms as well as varietal reaction have not been critically studied. Powdery mildew (*Erysiphe pisi*) is an important disease of grass pea in India, causing economic losses of grain yield. This region has very congenial climatic conditions for endemic outbreak of this pathogen. Downy mildew is reported as a serious disease in South East Asia. However, documentation of the occurrence or severity is scant and therefore more studies are required on this disease. Also, resistance or tolerance of collections have not been evaluated and should be addressed.

Survey work in 1988 and 1990 in Ethiopia revealed that powdery mildew (*E. polygoni*) and rust (*Euromyces fabae*) were low in incidence (less than 5% of the plants infected) and light in severity (under 5 in a 1 to 9 scale) on local landraces while heavy powdery mildew infection with ratings of 8 and 9 was recorded on cultivars introduced from other countries. In 1989 both powdery mildew and rust infection were heavier in Woreta district and Meshenti around Bahr Dar. The severity and incidence of root rot and wilt diseases (*Fusarium* spp.) ranged between 5-9 and 5-25%, respectively. It can be concluded from the survey results that powdery mildew and rust are important diseases of the crop in the northwestern part of Ethiopia. However, severity varies from season to season.

9.4 Yield

Although the small-seeded types are desired for ‘utera’ production it can be seen that they are not necessarily higher yielding under these conditions (Table 6). The amount of seed that is used per area of production does become important as the small-seeded types need significantly less than do large-seeded types to produce the same stand. There appears to be a need for further evaluation of lines that produce higher amounts of biomass under these conditions. Greater biomass serves two different purposes. It allows for better ground cover, a factor that is very important in South East Asia as the crop matures into the heat of the spring season, which aids in protecting the soil from drying out. It also helps maintain lower soil temperatures, which aids in crop growth. Greater biomass also produces a higher yield of fodder, which is highly desirable for the growers. Perhaps selection for higher biomass production while retaining small seed size would be desirable for improvement of the crop under these conditions. Although generally larger-seeded types have higher biomass production it has been found under Manitoba conditions that seeds of 1000-seed weight from 200 to over 300 g produced equivalent biomass (unpublished data) and therefore the trait can be selected for. Unfortunately, there has been little evaluation of this character in *L. sativus*.

Table 6. Performance of promising pure lines under 'utera' conditions at Raipur, India

Genotype	Yield (kg/ha) 1988-89	1991-92	1992-93	Mean
Lakh (Bold-seeded)				
Pusa-24	451	728	845	674
LSD-3	627	539	862	676
JRL-115	429	596	881	635
RLS-1	539	889	921	783
Lakhadi (Small-seeded)				
JRL-43	627	380	928	645
JRL-41	605	747	763	705
JRL-16	638	988	638	754
Rewa-2	602	498	870	657
Local	506	456	565	509

Source: Dr R.L. Pandey, Indira Gandhi Krishi Vishwavidyalaya, Raipur, India.

Table 7. Yield performance of promising pure lines under upland situation with one irrigation at Raipur, India

Lines	Yield (kg/ha) 1990-91	1991-92	1992-93	Mean	ODAP (%)
JRL-115	1657	1744	1985	1795	0.36
JRLS-1	1534	1778	1913	1742	0.21
JRL-6	1594	1539	1642	1592	0.35
JRL-43	1510	1592	1538	1547	0.38
Pusa-24	1565	1582	1818	1655	0.24
Local check	1255	1225	1475	1318	0.45

Source: Dr R.L. Pandey, Indira Gandhi Krishi Vishwavidyalaya, Raipur, MP, India.

It can be seen that in India there has been significant progress in the development of lines higher yielding than the check variety Pusa 24 (Table 7). This germplasm can provide a good basis for the further development of adapted lines that have very low or zero amounts of the neurotoxin ODAP. The development of such lines has already been demonstrated in Canada, Bangladesh and Ethiopia.

9.5 Harvest

The leaves turn yellow and the pods turn grey when mature. Pod splitting, which leads to premature shattering of seeds, is common in small types found on the Indian subcontinent (Fig. 7). There the plants are pulled out by hand or cut with a sickle near the base. The plants are then stacked and allowed to dry in the field or on the threshing floor for 7-8 days. The plants are spread out on the threshing floor and beaten with sticks. The seeds are more resistant to damage during harvesting operations than are field peas. It is a common practice to use cattle to help thresh the pods by trampling. The seed is then winnowed and cleaned. The seeds may be dried for several days before being stored. The straw and chaff are used for cattle feed, generally mixed with rice straw. The growers value the straw as a feed stuff as it is an important source of protein. In many cases the value of the straw can be as great as that of the grain and thus is a major consideration for the farmer in the production of this pulse.

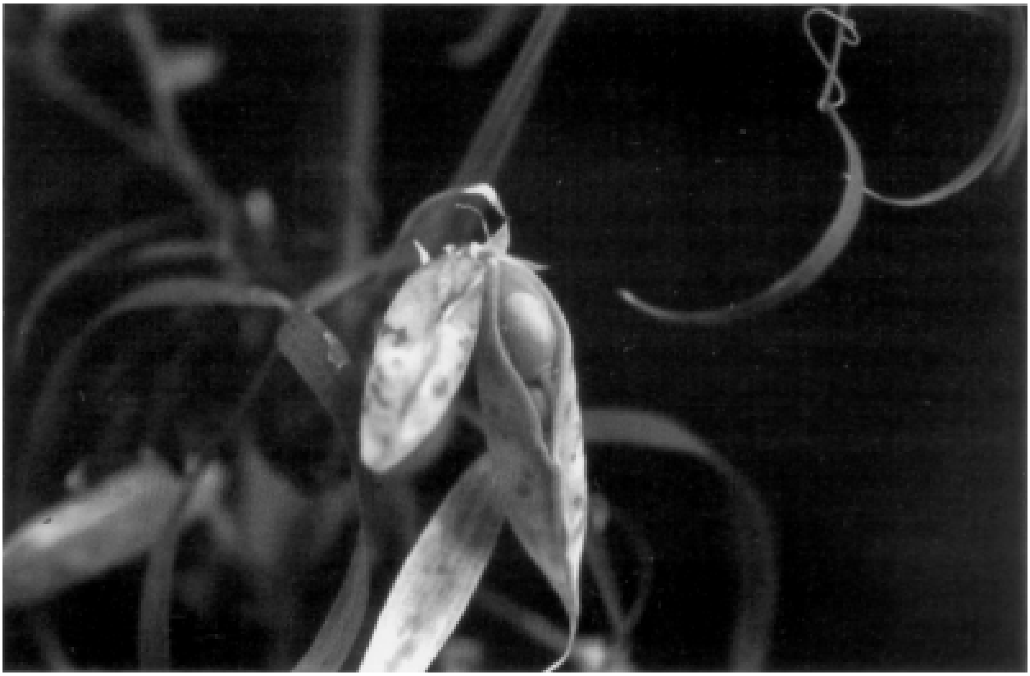

Fig. 7. Pod splitting which leads to premature shattering of seeds.

10 Limitations of the crop

The main limitation of grass pea is the neurotoxin ODAP. If the seeds are consumed as a major part of the diet for an extended period, irreversible crippling can occur. This will remain a major limiting factor in the production of this valuable crop until such time as low- or zero-toxin lines are released. However, as there are now several sources with ODAP levels at 0.01% it would appear that this is no longer a limitation for most breeding programmes. However, owing to the severity of this problem most research over the last 25 years has concentrated on this aspect. Unfortunately this has resulted in many other areas of evaluation and crop improvement being neglected. *Lathyrus sativus* at present is banned for commercial sale in several of the states in India and in Nepal. While this has had little impact on the production of the crop it has had very serious repercussions on the research on this crop. Politically it is very difficult to fund germplasm collections, evaluations and development of new varieties on a banned crop. Therefore the major effect of the ban on commercial trade has appeared to be a reduction of the much-needed research on this crop. This research effort is required as grass pea is ranked as the second pulse in area of production in Nepal and the fourth in India in spite of the bans.

The small-seeded lines, known as *lakhori* in India, often have a very severe shattering problem. This occurs with the splitting of the ventral vein of the pod as the seeds enlarge and before they are mature. This necessitates early harvest if seed shattering and loss are to be avoided. Fortunately most large-seeded types do not shatter and therefore the trait should be readily improved in breeding programmes.

There appear to be fairly high levels of trypsin inhibitor in grass pea (Deshpande and Campbell 1992) compared with many of the food legumes, the notable exception being soya beans. In the few studies to date on this trait there appears to be little variation that could be exploited in breeding programmes. The reduction of this trait would make the crop much more desirable as animal food. As heating during food preparation almost eliminates this problem it does not appear to be a major concern for most human consumption. There are reported uses in Bangladesh, however, where the seeds are ground, mixed with water and eaten as paste balls. In cases such as these the amount of trypsin inhibitor would affect the nutritional value of the crop.

Thrips can be a serious pest of grass pea, resulting in crop damage. In evaluations of germplasm in India there appears to be little known resistance to this insect problem.

11 Prospects

Lathyrus sativus has a number of unique features that make it attractive to the grower and to the consumer. These are:

- Adapted to growing under harsh environmental conditions such as drought stress. This is a very favourable trait throughout the arid regions of china, South Asia, the Middle East and North Africa.
- Adapted to growing under waterlogged conditions. This has been exploited in south east asia where the seeds are broadcast into the water of a standing rice crop. It also has been reported from Ethiopia where flooding from monsoon rains can severely damage other crops.
- A high level of protein which normally ranges from 26 to 28% but can be as high as 32%.
- Agreeable taste which can be utilized in snack foods as well as a component of the regular diet.
- A high biological nitrogen fixation rate which allows the crop to be an important component in sustainable farming systems.
- Can be used as forage or fodder for animals, both as a primary crop and as the residue remaining after harvesting the grain.
- The grains are used as human food or as animal feed.
- Requires few inputs and therefore is adaptable to ecological sustainabilty.

12 Further research needs

Several courses of action have been indicated to date, including:

- Collecting, conservation and evaluation of germplasm from areas that have not had adequate sampling yet.
- Investigation of interspecific hybrids that might allow the transfer of desirable traits into *L. sativus*.
- Initiate breeding programmes for forage and fodder production in South Asia utilizing the vast amount of germplasm and expertise available from ICARDA.
- Physiological studies are required to determine the drought tolerance mechanism in *L. sativus* and closely related species.
- Physiological studies of the nitrogen-fixing ability of *L. sativus* and closely related species, including evaluation of *Rhizobium* development under flooded conditions of rice-growing areas.
- Breeding of lines with higher-yielding ability through the incorporation of yield components such as double pods per node and increased seeds per pod.
- Breeding of lines with increased forage production both for present production areas and also to allow increased production in arid regions as forage.
- Physiological studies to determine the role of zinc in ODAP concentration, especially in the zinc-depleted rice-growing areas where *L. sativus* is presently being grown.
- Physiological studies to determine the need, if any, of ODAP content in plant parts other than the seed.
- Assessment of resistance or tolerance to *Orobanche* species and the development of control measures.
- Assessment and identification of resistance to insects such as thrips.
- Assessment of present germplasm collections for disease resistance or tolerance, especially to powdery mildew and downy mildew.
- Assessment of germplasm for increased herbage production, for increased seed yield and harvest index.
- Assessment of germplasm for yield components, including double podding and seeds per pod.
- Assessment of genotypes for hardiness traits such as cold tolerance.
- Assessment of germplasm for nutritional components such as protein.
- Assessment of germplasm for anti nutritional factors such as tannins, phenolics and trypsin inhibitors. At present it appears that variability exists in all such factors except trypsin inhibitors.
- Identification and elimination of the enzyme responsible for ODAP production.
- Safe levels, if they exist, of the neurotoxin ODAP need to be identified.
- Development of new export markets which will require very low or zero ODAP levels in new varieties.
- Identification of areas for *in situ* conservation.
- Development of varieties for specific end needs including herbage production, self-seeding mechanisms, seed size and plant vigour.

13 Lathyrus Genetic Resources Network

A workshop on *Lathyrus* genetic resources in Asia was held at Raipur, India, 27-29 December 1995. The following recommendations were developed from the discussions and deliberations of the workshop sessions (Arora *et al.* 1996):

- It was felt desirable to estabish a network on *Lathyrus* genetic resources.
- The proposed network will include countries from South Asia and WANA region including Ethiopia. CLIMA and other research organizations interested in *Lathyrus* may also be associated as research interest groups.
- The network activities will be coordinated by IPGRI Coordinator for South Asia located at NBPGR, Pusa Campus, New Delhi 110 012, India.
- There will be a representative from each country to act as a country coordinator in the network.

The activities suggested for the Network are as follows:

- Emphasis on two other species of economic importance – *L. cicera* and *L. ochrus* – besides *L. sativus*. The wild species genepool also may be given adequate attention.
- Current status of germplasm collections needs to be assessed by each country. Documentation of existing genetic resources held by different national programmes needs priority. ICARDA may take up creation of database for germplasm from WANA region and Ethiopia while IPGRI can take up preparation of database for South Asia.
- A list of minimum descriptors as discussed may be made available by IPGRI to cooperators. A booklet on the list of descriptors for the *Lathyrus* genepool (including wild species) may be prepared and published by IPGRI involving WANA and South Asia region.
- Once the databases are prepared, these will be supplied to member countries for sharing information.
- IPGRI Coordinator at South Asia office, New Delhi may develop a Directory of *Lathyrus* genetic resources and expertise from network countries.

Priorities for networking

- The major objective of the networking would be germplasm exchange, collecting, evaluation, characterization, conservation and utilization.
- It was agreed to assess the status of existing germplasm available within different member countries.
- Depending on the outcome of critical evaluation of the above information, the gaps for further collecting can be identified.

Collaborative studies

Adaptive studies

- Adaptive studies need to be carried out by countries in the South Asia and WANA regions with emphasis on both grain and forage purposes. Mechanisms for coordination/country contacts need to be identified.

Breeding

- It was agreed to have a collaborative breeding approach to quicken the process of developing lines with low ODAP, high yield (biomass/seed yield), and resistance to diseases and pests/abiotic stresses.

Basic studies

- Basic studies on genetic control of different traits such as flower colour, ODAP content, etc.; outcrossing mechanisms; preparation of linkage maps and studies on reproductive biology in different *Lathyrus* species; inter-relationships between different *Lathyrus* species using genetic and cytogenetic techniques, molecular markers and other biotechnology approaches, and interspecific hybridization needs to be undertaken. It was suggested that such work may be carried out in India through collaboration.
- The network should have a close link with other groups concerned with establishment of safe ODAP threshold limit; survey of Lathyrism, public awareness, microbiological studies on nodulation/nitrogen fixation, and preparation of agronomic packages.
- Development of low-ODAP lines should be coupled with development of appropriate strategies for maintenance of genetic purity through proper isolation mechanisms.
- Some pilot studies may be carried out for *in situ* (on-farm) conservation of germplasm in farmerss fields.
- It may be desirable for Network functioning to approach the national systems to identify/nominate country coordinators and the expert scientists/ institutes.

Core collection

- The importance and need for a core collection was stressed. It was suggested that it should be possible to define the core collection with available data.

Safety-duplicate collection

- It was suggested to duplicate the germplasm accessions at two places in India: base collection at NBPGR, New Delhi and active germpalsm collection may be maintained at IGAU, Raipur and IIPR, Kanpur.
- It was suggested that other participating countries may, if they desire, deposit their germplasm with either NBPGR, New Delhi or ICARDA.

Genetic diversity

- Collecting of genetic diversity in hot spots and its study may be given due emphasis.
- The active and working collections are being maintained in a number of countries. Such procedures need to be followed by each country. Complementary conservation strategies need to be developed based on experience from pilot studies.

Funding for the proposed Network

- IPGRI may explore the possibilities of obtaining funds. Need-based proposals are to be developed by Network participating countries for support. The potential donaors such as ACIAR, Asian Development Bank, BMZ Germany, FAO, UNDP and EU, etc. may be approached.

Other follow-up action

- It was felt that expertise within the region may be fully utilized for various PGR-related activities.
- To promote concern on conservation and use of *Lathyrus*, information on work being carried out in the region may be published in the IPGRI-APO Newsletter.
- Proceedings of the workshop may be brought out by IPGRI, New Delhi office.
- The Network Coordinator will have the country coordinator nominated by the nodal agencies in the participating countries.
- It was agreed that the Network coordinator will indicate steps to have a Steering Committee constituted in consultation with the country coordinators.

References

Abd El Moneim, A.M. 1989. Preliminary evaluation of the subterranean vetch (*Vicia sativa* ssp. *amphicarpa*). ICARDA Annual Report 1989. ICARDA, Aleppo, Syria.

Abd El Moneim, A.M. and M.A. Khair. 1989. Growth and seasonal quality of some vetch and chickling species (Preschedule F23). ICARDA Annual Report 1989. ICARDA, Aleppo, Syria.

Abd El Moneim, A.M., M.A. Khair and P.S. Cox. 1990. Growth analysis, herbage and seed yield of certain forage legume species under rainfed conditions. J. Agron. Crop Sci. 164:34-41.

Al Kadi, I. 1993. Etude du polymorphisme biochimique de quelques espèces du genre *Lathyrus* (Fabacées). Thèse de l'Université de Pau.

Aletor, V.A., A.M. Abd El Moneim and A.V. Goodchild. 1994. Evaluation of the seeds of selected lines of three *Lathyrus* species for b-*N*-Oxalylyamino-L-Alanine (BOAA), tannins, trypsin inhibitor activity and certain *in-vitro* characteristics. J. Sci. Food Agric. 65:143-151.

Allkin, R., T.D. Macfarlance, R.J. White, F.A. Bisby and M.E. Adey. 1983. Names and synonyms of species and subspecies in the *Vicieae*. Issue 2, Vicieae Database Project Publication No. 2, Southampton.

Anonymous. 1980. Annual report. Pulses Improvement Project, Bangladesh Agricultural Research Institute. Joydebpur, Dhaka, Bangladesh.

Arora, R.K., P.N. Mathur, K.W. Riley and Y. Adham, editors. 1996. *Lathyrus* Genetic Resources in Asia: Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India. IPGRI Office for South Asia, New Delhi, India.

Barker, B.T.P. 1916. Sweet pea hybrids. Gard. Chron. Ser. 3.60:156-157.

Bell, E.A. 1962. Associations of ninhydrin-reacting compounds in the seeds of 49 species of *Lathyrus*. Biochem. J. 83:225-229.

Bell, E.A. 1971. Comparative biochemistry of the non-protein amino acids. Pp. 186-194 *in* Chemotaxonomy of the Leguminosae (J.B. Harborne, D. Boulter and B.L. Turner, eds.). Academic Press, London and New York.

Bharati, M.P. and R.K. Neupane. 1989. *Lathyrus sativus* cultivation and screening of germplasm in Nepal. Pp. 159-167 *in* The Grass Pea: Threat and Promise. Proc. of the International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism (P. Spencer, ed.). Third World Medical Research Foundation, New York.

Briggs, C.J., N. Parreno and C.G. Campbell. 1983. Phytochemical assessment of *Lathyrus* species for the neurotoxic agent, B-N-oxalyl-L-a-B-diaminopropionic acid. J. Medicinal Plant Res. 47:188-190.

Burpee, D. 1916. The yellow sweet pea. Gard. Chron. Ser. 3.60:148.

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

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

Castell, A.G., R.L. Cliplef, C.G. Briggs, C.G. Campbell and J.E. Bruni. 1994. Evaluation of Lathyrus (*Lathyrus sativus*) as an ingredient in pig starter and grower diets. Can. J. Anim. Sci. 74:529-539.

Dahiya, B.S. 1976. Seed morhphology as indicator of low neurotoxin in *Lathyrus sativus*. Qual. Plant Eds. Human Nutrition 25:391-94.

Dahiya, B.S. 1985. Genetics and stability analysis in grass-pea (*L. sativus* L.). Its implications in future breeding programs. Pp. 161-168 *in Lathyrus* and Lathyrism (A.K. Kaul and D. Combes, eds.). Third World Medical Research Foundation, New York.

Dahiya, B.S. and L.M. Jeswani. 1974. Estimation of genetic variances by full-sib and half-sib analysis in grass-pea. Ind. J. Agric. Sci. 44(1):829-832.

Dahiya, B.S. and L.M. Jeswani. 1975. Genotype & environment interactions for neurotoxic principle (BOAA) in grass-pea. Ind. J. Agric. Sci. 45(9):437-439.

Davies, A.J.S. 1958. A cytogenetic study in the genus *Lathyrus*. PhD Thesis, University of Manchester.

Davis, P.H. 1970. *Pisum* L. Flora of Turkey 3:370-372. Edinburgh, University Press.

Deshpande, S.S. and C.G. Campbell. 1992. Genotype variation in BOAA, condensed tannins, phenolics and enzyme inhibitors in grass pea (*Lathyrus sativus)*. Can. J. Plant Sci. 72:1037-1047.

Deshpande, S.S. and S. Damodaran. 1990. Food legumes: Chemistry and technology. Adv. Cereal Sci. Technol. 10:147.

Didabe, A., W.A. Wolde, B. Hundie, R. Ensemu, W. Haile, Y. Ashagrie, A. Yalew and W. Seyuom. 1994. The status of grass pea (*Lathyrus sativus*) research and production in Ethiopia. Pp. 44-60 *in* Nutrition, Neurotoxins and Lathyrism: The ODAP Challenge (B. Begaz, R.T. Haimanot, V.S. Palmer and P.S. Spencer, eds.). Third World Medical Research Foundation, New York.

Düsünceli, F. 1993. Prospects for production of *Lathyrus sativus* and *L. cicera* in southwest Anatolia in Turkey. Pp. 131-137 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus/ Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Dutta, P.C., C.S. Saha, B.P. Lahiri, S. Begum, M.A.Q. Shaikh. 1982. Variation in the content of neurotoxin b-(N)-ovalyl-amino-L-alanine (BOAA) and protein in some local and exotic cultivars of grasspea (*Lathyrus sativus*). Pp. 219-225 *in* Proceedings of the National Workshop on Pulses, 18-19 August 1981. Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

Frison, E. and J. Serwinski, editors. 1995. Directory of European Institutions Holding Plant Genetic Resources, fourth edition. Vols. 1 and 2. International Plant Genetic Resources Institute, Rome, Italy.

Gass, T., R. Sackville Hamilton, K. Kolshus and E. Frison (editors). 1995. Report of a working group on forages. Fifth meeting, 31 March-2 April 1995, Hissar, Bulgaria. European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR). IPGRI, Rome, Italy.

Ghobrial, K.M., A.H.A. Younis and A.Z. Halim. 1983. A comparative study on some winter leguminous forage crops. Agric. Res. Rev. 61:36-41

Godt, M.J.W. and J.L. Hamrick. 1991. Genetic variation in *Lathyrus latifolius* (Leguminosae). Am. J. Bot. 78:1163-1171

Gowda, C.L.L. and A.K. Kaul. 1982. Pulses in Bangladesh. Bangladesh Agricultural Research Institute and Food and Agriculture Organization of the United Nations.

Hammer, K., G. Laghetti and P. Perrino. 1989. Collection of plant genetic resources in South Italy, 1988. Kulturpflanze 37:401-414.

Hanbury, C.D., A. Sarker, K.H.M. Siddique and M.W. Perry. 1995. Evaluation of *Lathyrus* germplasm in a mediterranean type environment in south-western Australia. Occasional Paper No. 8. Co-operative Research Centre for Legumes in Mediterranean Agriculture, 1995.

Hanelt, P. 1986. Papilionoideae. Pp. 579-699 *in* Rudolf Mansfelds Verzeichnis landwirtschaftlicher und gärtnerischer Kulturpflanzen (ohne Zierpflanzen) (J. Schultze-Motel, ed.). Akademie Verlag, Berlin.

Haqqani, A.M. and M. Arshad. 1995. Crop status and genetic diversity of grasspea in Pakistan.Pp. 59-65 *in Lathyrus* Genetic Resources in Asia. Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India (R.K. Arora, P.N. Mathur, K.W. Riley and Y. Adham, eds.). IPGRI Office for South Asia, New Delhi, India.

Hertzsche, W. 1970. Fodder crops. P. 71 *in* Technical report, Agricultural Research and Introduction Centre, Izmir AGP:SF / TUR 8, FAO, Rome.

Hopf, M. 1986. Archaeological evidence of the spread and use of some members of the Leguminosae family. Pp. 35-60 *in* The Origin and Domestication of Cultivated Plants (C. Barigozzi, ed.). Elsevier, Oxford, New York and Tokyo.

Hopkinson, D. 1975. Technical report on the development of crop husbandry in the dry farming areas around Karak. Jordan 169 / 518, FAO, Rome.

Hussain, M., B. Chowdhurry, R. Haque, G. Wouters and C.G. Campbell. 1994. A comparative study of the *0*-phthalaldehyde method for the neurotoxin 3-*N*-oxalyl-L-2,3-diaminopropanoic acid as modified by various laboratories. Phytochem. Analy. 5:247-250

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

Jeswani, L.M., B.M. Lal and Shiv. Prakesh. 1970. Studies on the development of low neurotoxin (N-N- oxalyl amino alanine) lines in *Lathyrus sativus* (Khesari). Curr. Sci. 22:518.

Jing-Zhong Y. 1995. Cultivation of grass pea and selection of lower toxin varieties and species of *Lathyrus* in China. Pp 145-151 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.). Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Kaul, A.K., M.Q. Islam, and A. Hamid. 1986. Screening of *Lathyrus* germplasm of Bangladesh for BOAA content and some agronomic characters. Pp. 130-141 *in Lathyrus* and Lathyrism (A.K. Kaul and D. Combes, eds.). Third World Medical Research Foundation, New York.

Keatinge, J.D.H.B., A. Asghar, B.R. Khan, A.M. Abd El Moneim and S. Ahmad. 1991. Germplasm evaluation of annual sown forage legumes under environmental conditions marginal for highlands of west Africa. J. Agron. Crop Sci. 166:48-57.

Kernick, M.D. 1976. Rainfed forage crops in northern Iraq 1: Agronomy and performance of promising rainfed forage crops at field crop and livestock stations and farmer's co-operatives. Tech. Rep. IRQ 71 / 542. Mimeo.

Khawaja, H.I.T. 1988. A new interspecific *Lathyrus* hybrid to introduce the yellow character into sweet pea. Euphytica 37:69-75.

Khawaja, I., H.I.T. Khawaja, I. Ullah, N.U. Raja and Ali M. Khushk. 1995. Lathyrism in Pakistan: a preliminary survey. Pp. 55-62 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Kislev, M.E. 1989. Origins of the cultivation of *Lathyrus sativus* and *L. cicera* (Fabaceae). Econ. Bot. 43:262-270.

Kumari, V. and R.B. Mehra 1989. Nature and limitation to genetic base for quantitative traits in Kaesari *in* National Symposium on Recent Advances in Genetics and Plant Breeding. Nov. 15-16. 1989. BHU, Varanasi.

Kuo, Y., J.K. Khan and F. Lambein. 1994. Biosynthesis of the neurotoxin b-ODAP in developing pods of *Lathyrus sativus*. Phytochem. 35:911-913.

Lal, M.S., I. Agrawal and M.W. Chitale. 1985. Genetic improvement of chickling vetch in Madhya Pradesh, India. Pp. 146-160 *in Lathyrus* and Lathyrism. Proceedings at Collogue Lathyrus (A.K. Kaul and D. Combes, eds.). Third World Medical Research Foundation, New York.

Lambein, F., G. Ongena and Y. Kuo. 1990. Beta-isoxazolinone-alanine is involved in the biosynthesis of the neurotoxin beta-N-oxalyl-L-alpha, beta-diaminopropionic acid. Phytochemistry 12:3793.

Leakey, C. 1979. Khesari Dhal - The poisonous pea. Appropriate Technology 6:15-16.

Lwin, S. 1956. Studies in genus *Lathyrus*. MSc Thesis, Manchester University.

Maha, Q.S. 1995. Natural distribution of *Lathyrus* in Jordan. Pp. 67-76 *in Lathyrus* genetic resources in Asia. Proceedings of a regional workshop, Raipur, India, 27-29 December 1995. (R.K. Arora, P.N. Mather, K.W. Riley and Y. Adham, eds.). IPGRI, New Delhi, India.

Malathi, K., G. Padmanaban, S.L.N. Rao and P.S. Saram. 1967. Studies on the biosynthesis of beta-N-oxalyl-L-alpha, beta-diaminopropionic acid, the *L. sativus* neurotoxin. Biochem. Biophys. Acta. 141:71-78.

Malek, M.A., C.D.M. Sarwar, A. Sarker and M.S. Hassan. 1995. Pp. 7-12 *in Lathyrus* Genetic Resources in Asia. Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India (R.K. Arora, P.N. Mathur, K.W. Riley and Y. Adham, eds.). IPGRI Office for South Asia, New Delhi, India.

Mehra, R.B., D.B. Raju and K. Himabindu. 1995. Evaluation and utilization of *Lathyrus sativus* collection in India. Pp. 37-43 *in Lathyrus* Genetic Resources in Asia. Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India (R.K. Arora, P.N. Mathur, K.W. Riley and Y. Adham, eds.). IPGRI Office for South Asia, New Delhi, India.

Mehta, S.L., I.M. Santha, V.K. Yadav, P.K. Roy and G.K. Barat. 1991. Plant biotechnological approaches for elimination of oxalyl diaminopropionic acid neurotoxin from *Lathyrus sativus*. Pp. 325-332 *in* Proceedings Golden Jubilee Celebrations symposium on grain legumes. (B. Sharma, ed.). Indian Society of Genetics and Plant Breeding. New Delhi.

Ministry of Agriculture. 1993. Area and production of principal crops in India 1990-93. Directorate of Economics and Statistics (Department of Agriculture and Co-operation), Ministry of Agriculture.

Mishra, R.P., S.R. Kotasthane, M.N. Kare, O. Gupta, and S.P.Tiwari. 1986. Screening of germplasm collections of *Lathyrus* spp. against *Cercospora pisi sativae* f. sp. *lathyri sativae*. Mishra. Ind. J. Mycol. and Plant Pathol. 16:302.

Narsinghani, V.G. and S.M. Kumar. 1979. The field reaction to powdery and downy mildew in *Lathyrus* genetic stock. Ind. J. Mycol. and Plant Pathol. 9(2):252-253.

Negere, A. and S.W. Mariam. 1994. An overview of grass pea (*Lathyrus sativus*) production in Ethiopia. Pp. 67-72 *in* Nutrition, Neurotoxins and Lathyrism: The ODAP Challenge (B.M. Abegaz, R.T. Haimanot, V.S. Palmer and P.S. Spencer, eds.). Third World Medical Research Foundation, New York.

Nerkar, Y.S. 1972. Induced variation and response to selection for low neurotoxin content in *Lathyrus sativus*. Ind. J. Genet. and Plant Breed. 32(2):175-180.

Nerkar, Y.S. 1976. Mutation studies in *Lathyrus sativus*. Ind. J. Genet. and Plant Breed. 36:223-229.

Palmer, V.S., A.K. Kaul and P.S. Spencer. 1989. International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism (INILSEL): A TWMRF initiative. Pp. 219-223 *in* The Grass Pea: Threat and Promise. Proc. of the International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism (P. Spencer, ed.). Third World Medical Research Foundation, New York.

Pandey, R.L., S.K. Agrawal, M.W. Chitale, R.N. Sharma, O.P. Kashyap, A.K. Geda, H.K. Chandrakar and K.K. Agrawal. 1995. Catalogue on grasspea (*L. sativus* L.) germplasm. Indira Gandhi Agricultural University, Raipur.

Prakesh, S., B.K. Misra, R.N. Adsule and G.K. Barart. 1977. Distribution of b-N-oxalyl-L.a-b diaminopropionic acid in different tissues of aging *Lathyrus sativus* plant. Biochem. Physiol. Pflanzen. 171:369-374.

Prassad, A.B. and A.K. Das. 1980a. Relative sensitivity of some varieties of *Lathyrus sativus* to gamma irradiation. Ind. J. Cytol. and Genet. 15(1):156-165.

Prassad, A.B. and A.K. Das. 1980b. Morphological variants in Khesari. Ind. J. Genet. and Plant Breed. 40(1):172-175.

Price, M.L. and L.G. Butler. 1980. Tannins and nutrition. Purdue Univ. Agric. Exp. Stn. Bull. No. 272. W. Lafayette, IN.

Quader, M. 1987. Male sterility in *Lathyrus sativus* L. Bangladesh. J. Bot. 16(1):9-13.

Quader, M., S. Ramanujam and G.K. Barat. 1986. Genetics of flower colour, BOAA, content and their relationship in *Lathyrus sativus* L. Pp. 93-97 *in* Lathyrus and Lathyrism (A.K. Kaul and D. Combs, eds.). Third World Medical Research Foundation, New York, NY.

Quader, M., S. Ramanujam and G.K. Barat. 1985.Genetics of flower colour, BOAA content and their relationship in *Lathyrus sativus* L. Pp 93-97 *in Lathyrus* and Lathyrism. Proceedings of Collogue *Lathyrus*. (A.K. Kaul and D. Combes, eds.). Third World Medical Research Foundation, New York.

Quader, M., S.P. Singh and G.K. Barat. 1987. Genetic analysis of BOAA content in *Lathyrus sativus* L. Ind. J. Genet. 47:275-279.

Rahman, Q.N., N. Akhtar and A.M. Chowdhury. 1974. Proximate composition of food-stuffs in Bangladesh. Part 1. Cereals and Pulses. J. Sci. & Ind. Res. 9:129-133.

Rahman, M.M., J. Kumar, M.A. Rahaman and M. Ali Afzal. 1995. Natural outcrossing in *Lathyrus sativus* L. Ind. J. Genet. 55:204-207.

Ramanujam, K.L., K.L. Sethi and S.L.N. Rao. 1980. Stability of neurotoxin content in Khesari. Ind. J. Genetics and Plant Breed. 40(1):300-304.

Rathod, K.L. 1989. Status of *Lathyrus sativus* L. in India with special reference to Madhya Pradesh. Pp. 168-174 *in* Grass pea: Threat and Promise. Proceedings of the International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism (P.S. Spencer, ed.). Third World Medical Research Foundation, New York.

Renfrew, J.M. 1969. The archaeological evidence for the domestication of plants: methods and problems. Pp. 149-172 *in* The Domestication and Exploitation of Plants and Animals (P.J. Ucko and G.W. Dimbleby, eds.). Duckworth, London.

Rihawi, S., P.C. Williams and B.H. Somaroo. 1984. A note of changes in potential nutrition efficiency of different legumes at different stages of maturity. Pp. 92-96 *in* ICARDA Annual Report 1989. ICARDA, Aleppo, Syria.

Robertson, L.D. and Ali M. Abd El Moneim. 1995. *Lathyrus* germplasm collection, conservation and utilization for crop improvement at ICARDA. Pp. 97-111 *in Lathyrus* Genetic Resources in Asia. Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India (R.K. Arora, P.N. Mathur, K.W. Riley and Y. Adham, eds.). IPGRI Office for South Asia, New Delhi, India.

Rotter, R.G., R.R. Marquardt and C.G. Campbell. 1991. The nutritional value of low lathyrogenic *Lathyrus* (*Lathyrus sativus*) for growing chicks. Brit. Poultry Sci. 32:1055-1067.

Roy, D.N. 1972. Further purification, fractionation and properties of trypsin inhibitor isolated from *Lathyrus sativus*. J. Agric. Food Chem. 20:778-780.

Roy, D.N. 1980. Trypsin inhibitor from *Lathyrus sativus* seeds: Final purification, separation of protein components, properties and characterization. J. Agric. Food Chem. 28:48-54.

Roy, D.N. and K.V. Rao. 1978. Physicochemical values in different varieties of *Lathyrus sativus* and their interrelationships. J. Agric. Food Chem. 26(3):687-689.

Roy, D.N. and S.P. Rao. 1971. Evidence, isolation, purification and some properties of a trypsin inhibitor in *Lathyrus sativus*. J. Agric. Food Chem. 19:257-259.

Roy, P.K., K. All, Arju Gupta, G.K. Barat and S.L. Mehta. 1993. b-N-oxalyl-L-a, b-diaminopropionic acid in somaclones derived from internode explants of *Lathyrus sativus*. J. Plant Biochem. and Biotechnol. 2:9-13.

Sabanci, C.O. 1995. Lathyrus genetic resources in Turkey. Pp. 77-86 *in Lathyrus* genetic resources in Asia. Proceedings of a regional workshop, Raipur, India, 27-29 December 1995. (R.K. Arora, P.N. Mather, K.W. Riley and Y. Adham, eds.). IPGRI, New Delhi, India.

Saraswat, K.S. 1980. The ancient remains of the crop plants at Atranjikera. J. Ind. Bot. Soc. 59:306-319.

Sarwar, C.D.M., A. Sarkar, A.N.M.M. Murshed and M.A. Malik. 1993. Variation in natural populations in Khesari. Pp. 23 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Sarwar, C.D.M., M.A. Malek, A. Sarker and M.S. Hassan. 1995a. Genetic resources of grass pea (*Lathyrus sativus* L.) in Bangladesh. Pp. 13-19 *in Lathyrus* Genetic Resources in Asia. Proceedings of a Regional Workshop, 27-29 December, 1995, Indira Gandhi Agricultural University, Raipur, India (R.K. Arora, P.N. Mathur, K.W. Riley and Y. Adham, eds.). IPGRI Office for South Asia, New Delhi, India.

Sarwar, C.D.M., A. Sarkar, A.N.M.M. Murshed and M.A. Malik. 1995b. Variation in natural population of grass pea. Pp. 161-164 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Singh, I.P. and K.P.S. Chandel. 1995. *Lathyrus* germplasm resources at NBPGR, India. Pp. 53-57 *in Lathyrus* Genetic Resources in Asia. Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India (R.K. Arora, P.N. Mathur, K.W. Riley and Y. Adham, eds.). IPGRI Office for South Asia, New Delhi, India.

Singh, M. and S.N. Chaturvedi. 1986. Effectiveness and efficiency of mutagens alone or in combination with dimethyl sulphoxide in *Lathyrus sativus* Linn. Ind. J. Agric. Sci. 57(7):503-507.

Smartt, J. 1981. Evolving gene pools in crop plants. Euphytica 30:415-418.

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

Smartt, J., A.K. Kaul, W.A. Araya, M.M. Rahman and J. Kearney. 1994. Grass pea (*Lathyrus sativus* L.) as a potential safe legume food crop. Pp. 144-155 *in* Expanding the production and use of cool season food legumes (F.J. Muehlbauer and W.J. Kaiser, eds.). Kluwer Academic Publishers, Netherlands.

Soadou, A.C. 1959. Comprehensive report on pasture and fodder crop species tested during 1956-1959 period. Dep. Agric. Cyprus.

Somaroo, B.H. 1988. Relationship between dry matter yield, seed yield, and flowering time in annual forage legumes under dry conditions. J. Appl. Seed Prod. 6:31-35.

Srivastava, Y.C. and P.L.N. Somayajulu. 1981. Male sterility in *Lathyrus*. Ind. J. Genet. and Plant Breed. 41(1):1964-1966.

Swaminathan, M.S., M.S. Naik, A.K. Kaul and A. Austin. 1971. Choice of strategy for the upgrading of protein properties in cereals, millets and pulses. Ind. J. Agric. Sci. 41(5):394-406.

Syouf, M.Q.A. 1995. Natural distribution and utilization of *Lathyrus* in Jordan. Pp. 67-76 *in Lathyrus* Genetic Resources in Asia. Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India (R.K. Arora, P.N. Mathur, K.W. Riley and Y. Adham, eds.). IPGRI Office for South Asia, New Delhi, India.

Tadesse, D. 1994. Grass pea (*Lathyrus sativus*): genetic resources, conservation and utilization in Ethiopia. Pp. 61-66 *in* The Grass Pea and Lathyrism. Proceedings of the Second International Lathyrus / Lathyrism Conference in Ethiopia (B.M. Abegaz, R. Tekle Haimanot, V.S. Palmer and P.S. Spencer, eds.). Third World Medical Research Foundation, New York.

Tekele-Haimanot, R., B. Abegaz, E. Wuhib, A. Kassina, Y. Kidane, N. Kebe, T. Alemu and P.S. Spencer. 1993. Nutritional and neuro-toxicological surveys of *Lathyrus sativus* consumption in northern Ethiopia. Pp. 41-45 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Tiwari, K.R. and C.G. Campbell. 1996. Inheritance of neurotoxin (ODAP) content, flower and seed coat colour in grass pea (*Lathyrus sativus*). Euphytica 91:195-203.

Townsend, C.C. and E. Guest. 1974. The flora of Iraq. Volume 3, Leguminales. Ministry of Agriculture and Agrarian Reform, Bhagdad, Iraq.

Van der Veen, J.P.H. 1967. Report to the Government of Syria on range management and fodder development. FAO / TA No. 2351.

Vavilov, N.I. 1951. The origin, variation, immunity and breeding of cultivated plants. Chronica Bot. 13:13-47.

Villax, E.J. 1963. La culture des plantes fourragères dans la région Mediterranéene occidentale. Cah. Rech. Agron. No. 17, INRA, Rabat.

Wall, D.A. and C.G. Campbell. 1993. Competitiveness of *Lathyrus* grown in monoculture and intercropping systems with cereals. J. Prod. Agric. 6:399-403.

Wall, D.A. and G.H. Friesen. 1991. Effectiveness of selective herbicides for the control of annual weed species in *Lathyrus* (*Lathyrus sativus* L.). Crop Prot. 10:494-500.

Wall, D.A., G.H. Friesen and D. Dryden. 1988. Effect of herbicides and annual weeds in the yield and seed quality of *Lathyrus* (*Lathyrus sativus* L). Crop Prot. 7:372-377.

Yadov, C.R. 1995. Genetic evaluation and varietal improvement of grasspea in Nepal. Pp. 21-27 *in Lathyrus* Genetic Resources in Asia. Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India (R.K. Arora, P.N. Mathur, K.W. Riley and Y. Adham, eds.). IPGRI Office for South Asia, New Delhi, India.

Yunus, A.G., M.T. Jackson and J.P. Catty. 1991. Phenotypic polymorphism of six enzymes in the grass pea (*Lathyrus sativus* L). Euphytica 55:33-42.

Yunus, A.G. 1982. A taxonomic study of the grass pea, *Lathyrus sativus* L. MSc. Thesis, University of Birmingham.

Zeven, A.C. and J.M.J. de Wet. 1982. Dictionary of cultivated plants and their regions of diversity. Pudoc, Wageningen.

Further reading

Aall, C. 1977. Report II on lathyrism in Bangladesh with suggestion for action plan. FAO / UNDP, Dhaka. (Limited circulation).

Adhikary, B.R., M.P. Bharti, R.P. Sah and R.K. Neupane. 1987. Collection of *Lathyrus sativus* germplasm in Nepal. Agricultural Association Kathmandu, Nepal

Adiga, P.R., S.L.N. Rao and P.S. Sharma. 1963. Some structural features and neurotoxic action of compound from *L. sativus* seeds. Curr. Sci. 32:153-155.

Ahmed, H.U. 1991. Progress and prospects of disease management research on pulses. Pp. 113-117 *in* Advances in Pulse Research in Bangladesh. Proc. 2nd Nat. Workshop on Pulses, 6-8 June 1989, BARI, Joydebpur. BARI, Joydebpur, Bangladesh and ICRISAT, India.

Ahmed, N. 1985. *Lathyrus*: Guide book of pulses in Bangladesh. FAO / UNDP Dhaka.

Angelini F. 1965. Coltivazioni erbacee. SOGRARO, Rome.

Bailey, E.T. 1952. Agronomic studies of vetches and other large-seeded legumes in southern western Australia. CSIRO Division of Plant Industries. Technical Paper No. 1.

Begum, K., M.Q. Islam, M.A. Wahhab and S.K. Shaha. 1981. Status of research on Khesari at BARI under BARAC programme. Pp. 71-82 *in* Proceed. Nat Workshop on Pulses, 18-19 Aug. 1981, BARI, Joydebpur (A.K. Kaul, ed.). Dhaka

Ben Brahim, N. 1989. Biologie florale et variabilité morphologique et enzymatique chez trois espèces de *Lathyrus*: *L. cicera* L., *L. articulatus* L. et *L. ochrus* D.C. Thèse de l'Université de Tunis.

Berhanu Abegaz and Naod Kebede. 1988. B-N-oxalyl amino L. Alanine estimation in *Lathyrus* germplasm accessions from Adet. Chemistry Department, Addis Abeba University.

Bharati, M.P. 1986. Status of *Lathyrus sativus* among grain legumes in Nepal. Pp. 142-145 *in Lathyrus* and Lathyrism (A.K. Kaul and D. Combes, eds.). Third World Medical Research Foundation, New York.

Bharati, M.P. and R.K. Neupane 1988. Situation of *Lathyrus sativus* cultivation and screening of germplasm in Nepal. Pp. 159-167 *in* The Grass Pea: Threat and Promise. Proc. of the International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism (P. Spencer, ed.). Third World Medical Research Foundation, New York.

Bhniyan, M.A. and P.C. Sarker. 1980. Socio-economic conditions of lathyrism affected families of Rajshahi and Kushtia districts. Shaw Unnayan, Rjshahi, Bangladesh. (Limited circulation).

Bisby, F.A., R. Allkin, B.A. Otto and M.T. Almeida. 1987. Genetic resources of medically important Vicieae (vetches and peas). Pp. 51-56 *in* International symposium on conservation of genetic resources of aromatic and medicinal plants, May 1984, Oeiras, Portugal (M.Mota and J. Baeta, eds.). Oeiras, Portugal.

Bonciarelli, F. 1995. Coltivazioni erbacee da pieno campo. Edagricole Bologna.

Central Statistics Office. 1989. Agricultural sample survey 1987/88. Results on area, production, and yield of major crops by sector and season. Statistical Bulletin No. 74. ONCCP, Addis Abeba.

Central Statistics Office. 1990. Agricultural sample survey 1988/89-1991/92. Results on area, production and yield of major crops by sector and season. Statistical Bulletin No. 79. ONCCP, Addis Abeba.

Central Statistics Office. 1996. Agricultural sample survey 1994/95 Vol. I. Results on area, production and yield of major crops by sector and season. Statistical Bulletin No. 132. ONCCP, Addis Abeba.

Cooriols, V. 1965. Essai d'adaptation de plantes fourragères en Tunisie. Vol. 38.

Crescini, F. 1951. Piante erbacee di grande coltura. REDA, Rome.

Davies, A.J.S. 1957. Successful crossing in the genus *Lathyrus* through stylar amputation. Nature 180:612.

Davies, C.L., K.H.M. Siddique and M.W. Perry. 1993. A bibliography of grasspea (*Lathyrus* species) and vetches (*Vicia* species). Occasional Publication No. 2. Co-operative Research Centre for Legumes in Mediterranean Agriculture.

Davies, C.L., K.H.M. Siddique and M.W. Perry. 1993. Preliminary evaluation of *Lathyrus* and *Vicia* species in Western Australia. Technical report 58. W.A. Department of Agriculture. Division of Plant Industries.

De Falco, E., F. Basso and P. Iannelli. 1991. Morphological and productive features of ecotypes of chickling vetch (*Lathyrus sativus* L.). Agricoltura Mediterranea 121:99-109.

Debre Zeit Experiment Station. 1983. Annual research report, 1982/83. Debre Zeit, Ethiopia.Institute of Agricultural Research. 1968. Holetta Research Station progress report for the period Feb. 1966 to March 1968. IAR, Addis Abeba.

Dixit, G.P., R.L. Pandey, S. Chandra, P.S. Pandey and A.N. Asthana. 1995. Stability of neurotoxin (ODAP) in grasspea. P. 92. *in* Int. Conf. on Lathyrus and Lathyrism, Addis-Abeba, 27-29 Nov. 1995 (Haimanont, ed.). Addis Abeba.

Ehrman, T. and N. Maxted. 1989. Ecogeographic survey and collection of Syrian Vicieae and Cicereae (Leguminosae). Plant Genet. Resour. Newsl. 77:1-8.

Ellena, D.F. 1993. Efecto del distanciamiento entre hileras y diferentes formulas de fertilization sobre los rendimientos y su componentes en chicharos. (*Lathyrus sativus* L). [Effect of row spacing and different fertilization levels on yield and yield components of grasspeas]. Ingeniero Agronomo Thesis, Universidad Austral de Chile.

Foti, S. 1981. Cicerchia (*Lathyrus sativus*). Coltivazioni erbacee. Bologna Patron 353-354.

Foury, A. 1954. Les légumineuses fourragères au Maroc. Cah. Res. Agron, Rabat, Maroc 5:284-657.

France, I.A, C.M. Paredes, J. Tay and A.M.Y Cortes. 1989. Principales enfermedades de las leguminosas de grano [Principal diseases of pulse crops]. Investigacion y Progreso Agropecuario (Quilamapu) 40:14-19.

Francis, C.M. 1993. Observations on the distribution and ecology of Vicieae and *Lathyrus* species in Northern Morocco. A report based on the joint ICARDA, INRA and CLIMA collection tour, June 1993. Occasional Publication 3. Co-operative Research Center for Legumes in Mediterranean Agriculture (CLIMA).

Furman, B.J. and M.P. Bharati. 1989. Collection and characterization of legume germplasm in Nepal. Ministry of Agric., National Agric. Res. Center, National Grain Legumes Improvement Program.

Ganapathy, K.T. and M.P. Dwivedi 1961. Studies on clinical epidemiology of lathyrism. Lathyrism enquiry unit. Indian Council of Medical Res. Gandhi Memorial Hospital, Rewa.

Garlinge, J.R. and M.W. Perry. 1993. Potential for *Vicia* and *Lathyrus* species as new grain and fodder legumes for southern Australia. Proceedings of the *Vicia* / *Lathyrus* Workshop, Perth, Western Australia, 22-23 September 1992. Occasional Publication No. 1. Co-operative Research Centre for Legumes in Mediterranean Agriculture.

Geda, A.K., R.L. Pandey and K.K. Agrawal 1993. Environmental influence on ODAP content in *Lathyrus*. Pp. 33 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Haimanot, R.T. 1989. Lathyrism in Ethiopia. Pp. 36-40 *in* The Grass Pea: Threat and Promise. Proc. of the International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism (P. Spencer, ed.). Third World Medical Research Foundation, New York.

Hamid, M.A. 1993. A database on minor crops, cash crops livestock and fisheries in Bangladesh. BARAC / Winrock International Publication, Dhaka (Limited circulation).

Hammer, K., H. Knüpffer, H. Laghetti and P. Perrino. 1992. Seeds from the past. A catalogue of crop germplasm in South Italy and Sicily. Istituto del Germoplasma del Consiglio Nazionale delle Ricerche, Bari.

Haque, A. and M.A. Mannan. 1988. The problem of lathyrism in Bangladesh. Pp. 27-35 *in Lathyrus sativus* and the Eradication of Lathyrism (P.S. Spencer, ed.). Third World Medical Research Foundation, New York.

Haque, R., N. Kebede, Y.H. Kue, M. Hussain and F. Lambein. 1993. Effect of nutrient elements and environmental factors on ODAP and other amino acids content in *Lathyrus sativus*. Pp. 32 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Hussain, M., B. Chowdhury and G. Wouters. 1993. Agro-ecological factors effecting the concentration of ODAP in *Lathyrus sativus* seeds. Pp. 25 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Hussain, M., G. Wouters, L. Lambein and A. Hague. 1993. Epidemiological and follow-up study of lathyrism in Rajshahi and Natore districts of Northwestern Bangladesh. Pp. 6 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Iannelli, P. and A. Bozzini. 1991. Leguminose da granella. Fonti proteiche da riscoprire. REDA, Rome.

Infantino, S., G. Laghetti, A. Filippetti and P. Perrino. 1994. Genetic variation in a collection of *Lathyrus sativus* L. Agricoltura Mediterranea 124:70-78.

Institute of Agricultural Research. 1977. Nazret Research Station progress report for the period April to March 1975. IAR, Addis Abeba.

Institute of Agricultural Research. 1982. Holetta Research Station progress report for the period April 1980 to March 1981. IAR, Addis Abeba.

Islam, M.S., C.S. Saha, M.A.Q. Shaikh and B.P. Lahiri. 1986. Spectrum of variability in seed size and BOAA in grasspea (*Lathyrus sativus*) germplasm. Bangladesh J. Nucl. Agric. 2:6-9.

Jing-Zhong Yu. 1993, Cultivation of grass pea and selection of lower toxin varieties and species of *Lathyrus* in China. Pp. 145-151 *in Lathyrus sativus* and Human Lathyrism: Progress and Prospects (H.K.M. Yusuf and F. Lambein, eds.) Proc. 2nd Int. Colloq. Lathyrus / Lathyrism, Dhaka, 10-12 December 1993. University of Dhaka.

Jubete, F.F. 1991. Los titarros. El cultivo de *Lathyrus* en Castilla y Leon. Coleccion de Estudios Agrarios. Junta de Castilla y Leon.

Kashyap, O.P., M.W. Chitale and K.K. Agrawal. 1991. Use of developmental traits in selection of high yielding low toxic varieties of *Lathyrus sativus*. *in* Golden Jubilee Symposium on Genetic Research and Education; Current Trend and Next Fifty Years. Vol. II (B. Sharma, ed.). Indian Society of Genetics and Plant Breeding, New Delhi.

Kaul, A.K. and Q. Islam. 1981. Khesari cultivation in Bangladesh and Lathyrism. Pp. 208-218 *in* Proceed. Nat. Workshop on Pulses, 18-19 August 1981 (A.K. Kaul, ed.). BARI, Joydebpur.

Kaul, A.K. M.A. Hamid and R.U. Akand. 1988. An agro-economic survey of two lathyrism-prone areas in Bangladesh. Pp. 41-53 *in Lathyrus sativus* and the Eradication of Lathyrism (P.S. Spencer, ed.). Third World Medical Research Foundation, New York.

Kaul, A.K., M.Q. Islam and K. Begam. 1982. Variability for various agronomic characters and neurotoxin content in some cultivars of khesari in Bangladesh. Bangladesh J. Bot. 11:158-67.

Kernick, M.D. 1978. Indigenous arid and semi-arid forage plants of north-Africa and MiddleEast. Pp. 519-689 *in* Ecological Management of Arid and Semi-arid Range lands in Africa and the Near and Middle East (EMASAR) Vol. 14. Food and Agriculture Organization of the United Nations, Rome.

Khawaja, H.I.T. 1985. Cytogenetic studies in the genus *Lathyrus*, PhD Thesis, University of London, UK.

Kolotilov, V.V. and A.S. Kolotilova. 1989. Variation in growth period duration in a collection of *Lathyrus sativus*. Nauchno Tekhnicheskii Byulleten' Vsesoyuznogo Ordena Lenina i Ordena Druzhby Narodov Nauchno Issledovatel'skogo Instituta Rastenievodstva Imeni N.I. Vavilova 193:63-66.

Krapup, H.A. 1983. Caracterizacion de una poblacion heterogenea de chicharos (*Lathyrus sativus* L.) y analisis de cause y efecto entre rendimiento y sus componentes, bajoefecto de distintas epocas y densidades de siembra [Characterization of a heterogeneous chickling vetch (*Lathyrus sativus* L.) population and cause and effect analysis among yield, and its components, under the effects of different planting dates and densities of sowing]. Agro Sur 11(1):30-37.

Kumari, V., R.B. Mehra, D.B. Baju and J. Himabindu. 1993. Genetic basis of flower colour production in grasspea. Lathyrus and Lathyrism Newsl. 5(1):10.

Kyr'Ian, N.A. 1973. The collection of *Lathyrus sativus* of the All Union Institute of Plant Industry as planting stock for breeding for resistance to rust. Zakhyst Rosl. 18:86-88.

Lapushkin, V. 1975. Crops resistant to drought. Zemledelie 11:29-33.

Lu, F.H. X.G. Bao and S.Z. Liu. 1990. Study of genetic resources in five species of vetch. (*Lathyrus* L.). Crop Genet. Resour. 3:17-19.

Nagarajan,V. and C. Gopalan. 1968. Variation in the neurotoxin content in *Lathyrus sativus* samples from Madhya Pradesh. Ind. J. Med. Res. 56(1):95-99.

Paredes, C.M., U.J. Tay, I.A. France and S.A.Y. Valenzuela. 1989. Produccion de chicharos en la VII y VIII regiones. Investigacion y Progreso Agropecuario (Quilamapu) 38:26-29.

Poma, I. and F. Noto. 1990. La cicerchia, una leguminosa da recuperare. L'Informatore Agrario 24:41-48.

PRC (Pulses Research Centre). 1993. Reports on Pulses Breeding for the year 1992-93. Regional Agric. Research Station, Ishurdi, Pabna, Bangladesh.

Quader, M. 1985. Genetics of flower colour, BOAA content and their relationship in *Lathyrus sativus*. Pp. 93-97 *in Lathyrus* and Lathyrism (A.K. Kaul and D. Combes, eds.). Third World Medical Research Foundation, New York.

Quader, M., M.A. Ahadmiah, M.D. Wahidizzaman and S. Rahman. 1989. Present status of *L. sativus* research in Bangladesh. Pp. 152-158 *in* The Grass Pea: Threat and Promise. Proc. of the International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism (P. Spencer, ed.). Third World Medical Research Foundation, New York.

Rachie, K.D. and M.P. Bharti. 1985. A consultancy report on Pulses Improvement in Nepal. Integrated Cereal Project, Department of Agriculture, Nepal

Rahman, G.M.M., G.A. Fkir and M.B. Miah. 1987. Reaction of grass pea lines to *Fusarium oxysporum* and *Sclerotium rolfsii*. Bangladesh J. Plant Pathol. 3:17-23.

Rahman, M.M., M. Quader and J. Jumar. 1991. Status of khesari breeding and future strategy. Pp. 25-28 *in* Advances in Pulses Research in Bangladesh. Proceed. 2nd Nat. Workshop on Pulses, 6-8 June 1989 at BARI, Joydebpur. BARI, Joydebpur and ICRISAT.

Reshnovetskii, S.B. 1986. Results of a study of *Lathyrus sativus* varieties in Kokchetav province. Trudy, tselinogradskii Sel'skokhozyaistvennyi Institut 72:67-71.

Rutter, J. and S. Percy. 1984.The pulse that maims. New Scientist 23.

Sahu, S.L. 1991. Genetic variability, correlation and path studies and their implication in selection of high yielding, low BOAA content genotypes of grasspea (*L. sativus* L.). MSc Thesis submitted to IGAU, Raipur, India.

Sarma, B.K., B.D. Sharma and G.N. Hazarika. 1991. Crop genetic resources of North East India: II. Pulses and oilseed, a review. Agric. Rev. 12:213-224.

Seme Debela. 1988. Brief remarks on grass pea production in Ethiopia. Pp. 147-151 *in* The Grass Pea: Threat and Promise. Proc. of the International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism (P. Spencer, ed.). Third World Medical Research Foundation, New York.

Senatore, F. and F. Basso. 1994. Fatty acid and sterol composition from seeds of some *Lathyrus* ecotypes. La rivista italiana delle sostanze grasse 71:567-569.

Sepulveda, R.P. 1988. Identificacion de *Botrytis cinerea* Pers. causando atizonamiento en chicharo (*Lathyrus sativus* L.) [Identification of *Botrytis cinerea* Pers. causing blight on chickling vetch in Chile]. Agriculture Tecnica (Chile) 48(4):345-346.

Shaikh, M.A.Q., M.A. Majid and B.P. Lahiri. 1993. Mutant derivative low neuro-toxin lines of grasspea (*Lathyrus sativus*). P. 24 *in* 2nd Inter. Colloq. On Lathyrism in Bangladesh, held at Dhaka, 10-12 Dec., 1993.(H.K.M. Yusuf and F. Lambein, eds.). University of Dhaka.

Sharma, Hemant. 1994. Karyomorhpological, biochemical and intro regeneration studies in *Lathyrus sativus*. MSc Thesis submitted to IGAU, Raipur, India.

Shrivastava, Praveen. 1996. Studies on genetic variability and diversity in grasspea (*Lathyrus sativus*). MSc Thesis submitted to IGAU, Raipur, India.

Singh, B.P., R.V. Singh and M.N. Koppar. 1991. Germplasm resources in pulse crops - Introduction, collection, evaluation and their conservation. Pp. 199-203 *in* Golden Jubilee Celebrations: Symposium on Grain Legumes. (B. Sharma, R.B. Mehra, R.P.Puri, D.B. Raju, Hayat Ram, K.Kant and D.S.Mather, eds.). Indian Society of Genetics and Plant Breeding. Indian Agricultural Research Institute, New Delhi.

Sinha, S.K. 1977. Food Legumes: distribution, adaptability and biology of yield. Food and Agriculture Organization of the United Nations, Rome.

Soteriadou, A.C. 1959. Comprehensive report on pasture and fodder crop species tested during 1956-59 period. Dep. Agr. Cyprus.

Spencer, S. P. and H.H. Schaumburg. 1983. Lathyrism: A neurotoxic disease. Neurobehav. Toxicol. Teratol. 5(6):625-629.

Spencer, S. P., A. Ludolph, M.P. Dwivedi, D.N. Roy, J. Hugon and H.H. Schaumburg. 1986. Lathyrism: Evidence for role of the neuroexcitatory amino acid BOAA. Lancet ii:1066-1067.

Tapia, F.F. and B.G.Y. Bascur. 1987. Chicharo, otra leguminosa de grano [Grass pea, other grain legume]. Investigacion y Progreso Agropecuario (La Platina) 41:21-25.

Tomar, S.L. 1994. Study of genetic variability and stability for yield, its components and neurotoxin content in Khesari. MSc thesis submitted to IGAU, Raipur, India.

Urga, K., A. Fite and B. Kebede. 1995. Nutritional and antinutritional factors of grasspea (*Lathyrus sativus*) germplasms. Bull. Chem. Soc. Ethiopia 9:9-16.

Van der Veen, J.P.H. 1967. Report to the government of Syria on range management and fodder development. FAO / TA No. 2351.

Westphal, E. 1974. *Lathyrus sativus* L. Pp. 104-108 *in* Pulses in Ethiopia, their Taxonomy and Agricultural Significance. Cant. Agric. Publ. Agric. Res. Rep. 815. PUDOC, Wageningen.

Wolde-Amlak Araya and Alellign Kefyalew. 1990. Status of grass pea (*L. sativus*) production in Ethiopia. IAR Newsl. Agric. Res. (Ethiopia) 5(1):4.

Wuletaw Tadesse, Wollelie Melesse and Yohannes Degago. 1995. Identification of alternative crops for grass pea production in the Fogera plains of Gondar region. Pp. 75 *in* International Conference on *Lathyrus* and Lathyrism: A decade of progress, 27-29 November 1995, Addis Abeba (Redda Tekle Haimanot, ed.).

Yamamoto, K., T. Fujiware and I.D. Blumenreich. 1986. Isozymic variation and interspecific crossability in annual species of the genus *Lathyrus*. Pp. 118-129 *in Lathyrus* and Lathyrism (A.K. Kaul and D. Combes, eds.). Third World Medical Research Foundation, New York.

Yurchenko, I.T., L.R. Azarkh, L.P. Tkachuk and A.Z. Glukhov. 1990. Results of work at the Donetsk Botanic Garden of the Ukrainian Academy of Sciences on the introduction of crop plants (fodder crops, grain legumes). Introduktsiya i Akklimatizatsiya rastenii 14:26-30. Botanicheskii Sad. Donetsk, Ukrainian SSR.

Appendix I. Centres maintaining collections of grass pea

Australia
Australian Temperate Field Crops Collection
Private Bag 260
Horsham VIC 3401

Bangladesh
Plant Genetic Resources Centre
Bangladesh Agricultural Research Institute
GPO Box 2235
Joydebpur, Gazipur 1701

Canada
Plant Genetic Resources of Canada
Central Experimental Farm
Agriculture Canada, Wm. Saunders Bldg.
Ottawa, ON K1A 0C6

Crop Diversification Centre
Unit 100-100 Route 100
Morden, MB R6M 1Y5

China
Institute of Crop Germplasm Resources (CAAS)
30 Bai Shi Qiao Road
Beijing 100 081

Cyprus
Plant Genetic Resources and Herbarium
Agricultural Research Institute
PO Box 2016
Nicosia
Fax: +357-2-316770
Email: ari@zeus.cc.ucy.ac.cy

Ethiopia
Biodiversity Institute
PO Box 30726
Addis Abeba
Fax: +251-1-613722/654976

International Livestock Research Institute (ILRI)
PO Box 5689
Addis Abeba
Fax: +251-1-611892
Email: ILRI-Ethiopia@cgnet.com

France

Laboratoire d'Ecologie Moléculaire
Faculté des Sciences et Techniques
Université de Pau
Avenue de l'Université
64000 Pau
Fax: +33-59841696

Germany

Institute for Plant Genetics and Crop Plant
Research (IPK) - Genebank
Corrensstr. 3
06466 Gatersleben
Fax: +49-39482-5155

Greece

Greek Genebank
Agricultural Research Centre of Macedonia and Thrace
National Agricultural Research Foundation
PO Box 312
570 01 Theri - Thessaloniki
Fax: +30-31-471209

India

National Board of Plant Genetic Resources
Pusa Campus
New Delhi 110012

Indira Gandhi Agricultural University
Kishak Nagar
492 012 Raipur, Madhya Pradesh

Italy

Germplasm Institute
CNR, National Research Council
Via G. Amendola 165/A
70126 Bari

Fax: +39-80-5587566
Email: ricerca@vm.csata.it

Nepal

Nepal Agricultural Research Council
Khumaltar, Lalitpur

Pakistan

Cytogenetics Laboratory
Pakistan Agricultural Research Council
PO Box 1031
Islamabad 44000

Poland

Plant Breeding and Acclimatization Institute
05-870 Blonie,
Radzikow near Warsaw
Fax: +48-2-7254714

Russia

N.I. Vavilov All-Russian Research Institute of Plant Industry
Bolshaya Morskaja Street 42-44
190 000 St. Petersburg
Fax: +7-812-3118762
Email: vir@glas.apc.org

Spain

Centro de Recursos Fitogenéticos
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria
Aut. Aragón A-2, km 36 - Apdo 1045
28800 Alcalá de Henares, Madrid
Fax: +34-1-8819287

Banco de Germoplasma de Leguminosas-Grano
Centro de Investigación de Albaladejito
Ctra. Toledo - Cuenca km 174
16194 Cuenca
Fax: +34-69-232151

Syria
International Centre for Agricultural Research in the Dry Areas (ICARDA)
PO Box 5466
Aleppo
Fax: +963-21-225105/213490 or 551860
Email: ICARDA@cgnet.com

Scientific Agriculture and Research Directorate
PO Box 113, Douma
Damascus

Turkey
Plant Genetic Resources Department
Aegean Agricultural Research Institute
PO Box 9, Menemen
35661 Izmir
Fax: +90-232-8461107

UK
Department of Biology
University of Southampton
School of Biological Sciences
Basset Crescent East
Southampton S09 3TU

USA
North Central Regional Plant Introduction Station
Agronomy Department
Iowa State University
Ames IA 50011

Western Regional Plant Introduction Station
USDA-ARS
Washington State University
59 Johnson Hall
Pullman, WA 99164-6402

Appendix II. Research contacts

Address	Area of expertise
Australia	
Prof. P. Cocks - Head Dept. of Crop and Pasture Science University of Western Australia Nedlands WA 6009 Tel: +61-9 380 2555 Fax: +61-9 380 1023 Email: bosscaps@uniwa.uwa.edu.au	Pasture ecology
Co-operative Research Centre for Legumes in Mediterranean Agriculture University of Western Australia Nedlands WA 6009 Fax: +61-9-380-1140 Email: clima@uniwa.uwa.edu.au Dr Dirk Enneking Email: enneking@uniwa.uwa.edu.au	Genetic resources documentation, plant analysis, ecological biochemistry
Steve Herwig	PhD project: Environmental Centre for Legumes in influence on ODAP levels in *Lathyrus* spp.
M.W. Perry	Crop physiology, environmental adaptation of grain legumes
Dr K.H.M. Siddique - Senior Grain Legumes Specialist WA Dept. of Agriculture Baron-Hay Court South Perth WA 6151 Fax: +61-9 368-2165 Email: msiddique@infotech.agric.wa.gov.au	Plant breeding
Bangladesh	

Dr Mophamed Abdul Malek - Director	
Dr Ahad Mian - Agronomist	Agronomy
A.N.M.M. Murshed	
Dr C.D.M. Sarwar - Senior Scientific Officer	Breeding
Pulses Research Centre	
Bangladesh Agricultural Research Institute	
Joydebpur, Gazipur 1701	
Fax: +880-2-841678	
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Bishan Lal Das Chowdhury - Asst. Prof.	Biochemistry
Rabiul Haque - Asst. Prof.	Biochemistry
Dept. of Biochemistry	
Bangladesh Agricultural University	
Mymensingh	
Dr M.A.Q. Shaikh - Director	Plant breeding
B.P. Lahiri - Senior Scientific Officer	Breeding, biochemistry
M.A. Majid - Senior Scientific Officer	Breeding
Dr A.K. Podder - Principal Scientific Officer	Soil microbiology
Dr M.A. Sattar - Principal Scientific Officer	Soil microbiology
Bangladesh Institute of Nuclear Agriculture	
PO Box 4	
Mymensingh	
Dr Harun K.M. Yusuf - Prof. of Biochem. and Human Nutrition	Biochemistry
M. Mamun Al Monsoor	Biochemistry
Badal Roy	
Department of Biochemistry	
University of Dhaka	
Dhaka - 1000	
Tel: +880-2-864708(0)	
Dr Anisul Haque - Assoc. Prof. and Head	Clinical biochemistry
Dept. of Neurology	
Institute of Postgraduate Medicine and Research, Shahbag	
Dhaka 1000	
Dr M.M. Rahman - Head	Agronomy
Dr Abu Bakr - Plant Pathologist	Plant pathology

R. Rahman
Pulses Improvement Programme
Regional Agricultural Research Station
Ishurdi, Pabna

Belgium

Dr Y.H. Kuo	Biochemistry
Dr F. Lambein	Biochemistry

Laboratory of Physiological Chemistry
Faculty of Medicine
University of Gent
Gent
Fax: +31-11-091-64-5342
Email: Fernand.lambein@rug.ac.be

Brazil

Roberto Carbonera	Agronomy

Cooperative Regional Trilicola Serra Ltda
Directoria Agrotecnica
Rua das Chacaras, 1513
Caixa Postal III
Suburbio Sal

Bulgaria

Dr Miho Mihov - Legume breeder	Breeding

Institute for Wheat and Sunflower
Dobrudja
Near General Toshevo

Canada

Dr C.G. Briggs - Chemist	Plant analysis, analytical techniques

Dept. of Pharmacy
University of Manitoba
Winnipeg, Manitoba
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Appendix III. List of acronyms and abbreviations

ACIAR	Australian Centre for International Agricultural Research
APO	Asia, Pacific and Oceania Office, IPGRI
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit, Germany [Federal Ministry of Economic Cooperation and Development]
CLIMA	Co-operative Research Centre for Legumes in Mediterranean Agriculture
CNR	National Research Council, Italy
ECP/GR	European Cooperative Programme for Crop Genetic Resources Networks
EU	European Union
FAO	Food and Agriculture Organization
IARI	Indian Agricultural Research Institute
ICARDA	International Centre of Agricultural Research in the Dry Areas, Syria
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IGAU	Indira Gandhi Agricultural University, India
IIPR	Indian Institute of Pulses Research, India
ILLRA	International *Lathyrus* and Lathyrism Research Association
INILSEL	International Network for the Improvement of *Lathyrus sativus* and the Eradication of Lathyrism
NARC	National Agricultural Research Center
NBPGR	National Bureau for Plant Genetic Resources, New Delhi
ODAP	ß-N-oxalyl-L-a, ß-diaminopropionoc acid
PGR	Plant genetic resources
UNDP	United Nations Development Programme
WANA	West Asia and North Africa
TIA	trypsin inihibitor activity
CIA	chymotrypsum inhibitor activity