**Improving Human Nutrition Through Agriculture:
The Role of International Agricultural Research**

October 5-7, 1999

Role of ICARDA in improving the Nutritional Quality and Yield Potential of Grasspea (*Lathyrus sativus* L.) for Subsistence Farmers in Developing Countries

Ali M. Abd El-Moneim[1], B. van Dorrestein[1], M. Baum[1] and W. Mulugeta[2]

[1]International Center for Agricultural Research in the Dry Areas (ICARDA), P.O.Box 5466, Aleppo, Syria

[2]Ethiopian Agricultural Research Organization (EARO), Sheno Agricultural Research Center, P.O.Box 112, Debre Berhan, Ethiopia

A Workshop hosted by the International Rice Research Institute, Los Banos, Philippines organized by the International Food Policy Research Institute

IFPRI

Role of ICARDA in improving the Nutritional Quality and Yield Potential of Grasspea (*Lathyrus sativus* L.) for Subsistence Farmers in Developing Countries

Ali M. Abd El-Moneim, B. van Dorrestein, M. Baum and W. Mulugeta

ABSTRACT

Lathyrus sativus (grasspea or chickling pea) is a popular food and feed crop in certain Asia and African countries such as Bangladesh, China, Ethiopia, India, Nepal, and Pakistan, because of its resistance to drought, flood and moderate salinity and because of its need for low inputs. When other crops fail under adverse climatic conditions *L. sativus* can become the only available food source for the poor section of the population and sometimes is a survival food during famine. Although seeds of *L. sativus* are tasty and protein rich, around 30g/100g edible seeds and contain a high amount of free *l*-homoarginin, which can act as a precursor of lycine in higher animals. Over consumption can cause an upper neuron disease known as neurolathyrism, an irreversible paralysis of the lower limbs. The neurotoxic agents of this disease was identified as 3-*N*-oxalyl-*L*-2,3 diaminopropionic acid (ß-ODAP) or its synonym BOAA (ß-N-oxalyamino-*L*-alanin). The level of this compound in the dry seeds varies widely depending on genetic factors and environmental conditions.

The ability of *L. sativus* to provide an economic yield under most adverse conditions has made it a popular crop in subsistence farming in many developing countries, and it offers a great potential for use in other parts of the world. In West Asia and North Africa (WANA) region, where under low rainfall, 250-300 mm, conditions there is tendency for increasing monoculture of cereals such as barley. The incorporation of grasspea in the rotation can make the production system more sustainable by improving soil fertility and by breaking the disease and pest cycles.

The International Center for Agricultural Research in the Dry Areas (ICARDA) is placing special emphasis in improving this crop using the biodiversity available in the genetic resources. The objectives in the crop improvement program on this species are to improve its yield potential and nutritional quality through the reduction of its neurotoxin ß-ODAP content. Low neurotoxin lines having 0.07 to 0.02% ß-ODAP were developed using conventional breeding methods and by developing somaclonal variants. These lines were distributed to national program for testing under different environmental conditions. The low neurotoxin strains could have a great impact on human and livestock nutrition in those resource-poor countries with vast areas of land under semi-arid conditions.

INTRODUCTION

Lathyrus sativus L. or grasspea (*Khesari* in India and Bangladesh, *guaya* in Ethiopia, *san li dow* in China, *pois carré* in France) has been cultivated in South Asia and Ethiopia for over 2500 years (Bell, 1989) and is used as food and feed. It is a popular drought tolerant crop as food and feed-stuff in drought-prone areas of Africa and Asia (Khan et al., 1993 and Abdelmoneim et al., 1997). Its ability to provide economic yield under adverse conditions has made it a popular crop in subsistence farming in many developing countries and it offers a great potential for use in marginal low rainfall areas. Despite its tolerance to drought, grasspea is not affected by excessive rainfall and can be grown on land subject to flooding (Sinha, 1980). In Bangladesh, India, Nepal and Pakistan it is often broadcast into a standing rice crop where it flourishes on the residual moisture left after the rice has been harvested. It is a very hardy crop with penetrating root-system and can be grown on a wide range of soil types including very poor soils and heavy clays. This hardiness and its ability to fix atmospheric nitrogen make the crop one that seems designed to grow under adverse conditions.

For more than 100 million people in drought-prone areas of Asia and Africa consider grasspea as a traditional popular crop, because of its easy cultivation, its relative resistance to drought, flood, moderate salinity and insect attack and its good yield of tasty portion-rich seeds, with about 30g per 100g edible seeds (Rutter and Percy, 1984 and Abdelmoneim et al., 1997). When other crops fail due to adverse conditions, grasspea can be the only available food source for the poorest section of the population, and sometimes a survival food in times of drought-induced famine.

Since grasspea is the cheapest food legume that most low-income families can afford, it is a common component of their traditional diet. Its seeds also contain a high amount of free *l*-homoarginin, which acts as precursor of lycin in human nutrition (Quereshi et al., 1977). These same seeds contain a neurotoxic non-protein aminoacid that can cause irreversible spastic paraparesis (paralysis) of the legs when it is consumed as a major portron of the diet over a 3 to 4 month period (Spencer and Schaumberg, 1983, Spencer et al., 1986). Recent outbreaks of famine in areas where grasspea could be a promising food crop for sustainable agriculture, have been followed by outbreaks of this upper motorneurone disease in epidemic proportions: Bangladesh in 1942-45 and in 1972-74 (Haque et al., 1991). China in 1973 (Liu and He, 1990); Ethiopia in 1976-77 (Haimanat et al., 1990) and in 1997-98 (Lambien, personal communication).

The causative agent for neurolathyrism was confirmed as 3-(N-oxalyl)-L-2,3-diaminopropionic acid (ß-ODAP) or its synonym BOAA: *B*-N-oxalyl-*L*-alanin (Spencer et al., 1986 and Roy and Spencer, 1989), and the biochemical pathway of the toxin has been elucidated (Lambien et al., 1990 and Kuo and Lambien, 1991). However, no biological role of ß-ODAP in the plant has yet been proposed. The concentration of ß-ODAP in ripe seeds is very variable and is influenced by genetic and environmental factors (Lambien et al., 1993 and Abdelmoneim and Cocks, 1993). Water stress can double the toxin level, while salinity in the soil may reduce the toxin level in the seeds (Haque et al., 1992).

Despite grasspea's obvious advantages, until recently relatively little effort has been made towards the improvement of this very hardy pulse crop. Indeed, the history of grasspea has been one in which it has been banned by many countries due to its toxicity. In spite of this, grasspea is still produced in significant quantities in many parts of the world. Improvement of this crop is now being addressed at ICARDA through its germplasm enhancement program.

ICARDA s Role in Improving Nutritional Quality of Grasspea

The International Center for Agricultural Research in the Dry Areas (ICARDA), which has a mandate for improve the productivity of dryland agriculture in West Asia and North Africa (WANA) region, and more recently Central Asia and Caucasian Countries (CAC), is placing special emphasis in improving this crop. ICARDA has a breeding program for the improvement of cool-season food and forage legumes including grasspea. It also holds a rich collection of *Lathyrus* spp. germplasm (1883 accessions amongst them 1560 *L. sativus*) from different parts of the world. Using this precious resource, ICARDA is collaborating with national partners, to develop new grasspea lines with the objectives to improve its yield potential, adaptability and nutritional quality through reduction of its neurotoxin ß-ODAP to the safe level for human consumption and animal feed.

Since 1989-90 grasspea breeding program at ICARDA has aimed to reduce the neurotoxin ß-ODAP concentration by four approaches.

i. Germplasm evaluation
ii. Genetic detoxification (hybridization program)
iii. Exploitation of somaclonal variation (plant biotechnology)
iv. Soil micronutrients, Zn^{++} and Fe^{++}

i. Germplasm Evaluation

An extensive screening program was initiated in 1989-90 for five years to explore the possibility of identifying toxin-free lines from germplasm of different origins. Results indicated that no accession of any *Lathyrus* species was ß-ODAP free, although in several lines the ß-ODAP content was low. This appears to be species related, since samples of *L. cicera* ranged from 0.03 to 0.22% with a mean of 0.16. *L. sativus* showed the biggest range from 0.02 to 2.4% with a mean of 1.3%, while *L. ochrus* lines were highest in ß-ODAP ranging from 0.46 to 2.5% with a mean 1.4% in the ripe seeds (ICARDA, 1995). Four lines of *L. sativus*, viz, IFLLS 522 (Syria), IFFLS 588 (Cyprus), IFLLS 516 (Turkey) and IFLLS 563 (Turkey) were found low ß-ODAP content in the seeds ranging from 0.02 to 0.07%. The level presumed safe for human consumption is <0.2% (Dahia, 1976).

Analysis of a large number of germplasm accessions of *L.sativus* revealed that samples originated from Bangladesh, Ethiopia, India, Nepal, and Pakistan are high in ß-ODAP content in the dry seeds in a range from 0.7 to 2.4%, whereas samples from North Africa, Syria, Turkey and Cyprus have significantly lower ß-ODAP, ranging from 0.02 to 1.2%.

ii. Genetic Detoxification (hybridization program)

Because the low neurotoxin lines have undesirable traits such as late flowering, susceptibility to insects and diseases and low yields, a hybridization program was initiated in 1991-92 with objective of improving the yield potential, adaptability and to increase nutritional quality by transferring low neurotoxin character to locally-adapted germplasm originating from grasspea producing countries, e.g. Bangladesh, Ethiopia and Pakistan.

The ICARDA breeding program has made significant progress in selecting low neurotoxin high yielding lines and locally adapted. This work is carried out by a multidisciplinary team involving the breeder, pathologist, entomologist, biotechnologist and animal nutritionist. The major avenue of dissemination for the elite lines and segregated populations developed by the breeding program for selection under target environments is through ICARDA International Legume Nursery Program.

Research activities with Ethiopian National Program commenced in the 1998-99, growing season. ICARDA supplied Ethiopian National Program with 100 improved lines of *L. sativus*. These lines were planted at Holetta Research Station for quarantine in 1997-98. In 1998-99, these lines were tested at two locations, Inewari and Molale. Eight high yielding lines were selected at Inewari and 14 lines with high yield and cold tolerance were selected at Molale. Also nine lines were selected with 40% less in ß-ODAP content than the checks (Adet local, Ginchi local, Inewari local and Molale local. ICARDA also supplied Ethiopian National Program with 120 samples of segregated populations of crosses between Ethiopian landraces and ICARDA's low ß-ODAP lines for selection under Ethiopian conditions.

Recently in 1999, the UK/CGIAR Competitive Research Facility (CRF) of the DFID, is funding ICARDA to implement a project with Ethiopian Agricultural Research Organization (EARO) on "Improving Yield Potential and Quality of Grasspea (*L. sativus*): a Dependable Source of Protein for Subsistence Farmers in Ethiopia". The project goals are alleviation of malnutrition, reduction of food shortages of dietary protein, and the increase of food quality and quantity for rural subsistence farm households in Ethiopia. This project will aid the promotion of grasspea as a safe source of dietary protein, thereby removing the stigma of neurolathyrism associated with this hardy and promising crop.

ICARDA also expanding its activities in improving the nutritional quality of grasspea to some countries in Asia. For example, through the GRDC project ICARDA supplies Bangladesh Agricultural Research Institute with segregated populations for selection of lines with reduced concentration of ß-ODAP combined with disease and insect resistance. ICARDA is collaborating with the National Agricultural Research Institute, Islamabad, Pakistan in forage and fodder aspects of grasspea and in analytical aspects as well as development of high yielding and reduced ß-ODAP adapted lines. For Nepal, target crosses between locally adapted lines and ICARDA's low neurotoxin lines was made and segregated populations were supplied for selection low neurotoxin and local adaptation.

iii. Exploitation of somaclonal variation

Biotechnological methods are being made to develop toxin-free lines of *L. sativus*. Recently, exploitation of somaclonal variation from landraces of Ethiopia and Pakistan has helped in isolating some somaclones differing in various characters with respect to flower colour, leaf size, seed colour, pod length and number of seeds per pod. Somaclones with low ß-ODAP less than 1% have been developed. These somaclones are being tested under different environments to study the stability of the neurotoxin content in the ripe seeds.

iv. Soil micronutrients Zn^{++} and Fe^{++}

The neurotoxin of *L. sativus* is proposed to function as a carrier molecule for Zinc ions (Lambien et al., 1994). Soils, depleted in micronutrients from flooding by monsoon rains (Indian subcontinent) or otherwise poor in available zinc and with high iron content (Ethiopia vertisols), may be responsible for the high level of neurotoxin in ripe seeds and subsequently for high incidence of human Lathyrism. This may explain why landraces originated from Bangladesh, Ethiopia, India, Nepal and Pakistan have higher ß-ODAP content than those of North Africa, Turkey, Syria and Cyprus.

Zinc deficiency in the soil is an agronomic problem in Bangladesh, especially the monsoon-washed soils where grasspea is grown during the dry winter. Zinc deficiency in-patients is also a widespread phenomenon in Bangladesh and Ethiopia leading to a number of symptoms like loss of hair, nail deformation, diarrhoea and mental retardation (Mannan and Rahim, 1988). ICARDA, through the DFID project in collaboration with EARO, is placing more emphasis on the soil and other environmental conditions that can lead to a solution for neurolathyrism. More balanced fertilization of the soil may reduce toxin-increasing stress factors for the plants and at the same time increase productivity.

Gresspea Improvement Program at ICARDA will continue to develop high yielding, adapted lines containing very little or zero amount of the neurotoxin ß-ODAP. The feasibility of introgression of low neurotoxin character from other closely related species like underground chickling (*Lathyrus ciliolatus* L.) will also be addressed. Our attempts to apply plant biotechnological methods to develop toxin-free lines of grasspea will continue. Somaclonal variation from land races from Bangladesh, Ethiopia and Pakistan will be continue to identify somaclones with very low neurotoxin.

Development of low or zero neurotoxin lines will lead to the grasspea consumption in a safe-level and remove the stigma of neurolathyrism from this hardy crop.

ACKNOWLEDGEMENTS
ICARDA's current collaboration with Ethiopia in improving the yield potential and quality of grasspea is sponsored by the Department for International Development (DFID) of the United Kingdom.

REFERENCES

Abdelmoneim, A.M. and P.S. Cocks. 1993. Adaptation and yield stability of selected lines of *Lathyrus* spp. under rainfed conditions in West Asia. Euphytica **66**: 89-97.

Abdelmoneim, A.M., M.C. Saxena, A. El-Saleh and H. Nakkoul. The status of breeding grasspea (Lathyrus sativus L.) for improved yield and quality at ICARDA. *In*: "Lathyrus and Lathyrism, a decade of progress" (Eds: R. Tekle Haimanat and F. Lambien) University of Ghent, Belgium. 1997. pp. 81-83.

Bell, E.A. 1989. Lathyrus neurotoxin: history and overview. *In*: The Grasspea: Threat and promise. Proceedings of the International Network for the Improvement of *Lathyrus sativus* and Eradication of Lathyrism. Third World Medical Research Foundation, New York, pp. 86-97.

Dahiya, B.S. 1976. Seed marphology as an indicator for low neurotoxin in Lathyrus sativus. Qual. Plant.-Pl. Fds.hum.Nut. **25**:391-394.

Haimanat, R.T., Y. Kidane, E. Wuhib, A. Kalissa, T. Alemu, Z.A. Zein and S.P. Spencer. 1990. Lathyrism in rural North Western Ethiopia: A highly prevalent neurotoxic disorder. Int. J. Epidemiol. **19**: 664-672.

Haque, A., M. Hossain, and G. Wouters. 1991. Epidemiological and clinical study of Lathyrism in Bangladesh: a preliminary report. Bangl. J. Neurosci. **7**: 60-71.

Haque, R., M. Hussaina and F. Lambien. 1992. Effect of salinity on the neurotoxin ß-ODAP and other free aminoacids in *Lathyrus sativus*. Abstract, Second International Lathyrus/Lathyrism Conference in Ethiopia. p 21.

International Center for Agricultural Research in the Dry Areas (ICARDA), 1995: Germplasm Program (Legumes) Annual Report for 1995, pp. 167-169.

Khan, J.K., N. Kebede, Y.H. Kuo, F. Lambien, and A. De Bruyn. 1993. Analysis of the neurotoxin ß-ODAP and its α-isomer by pre-column derivatization with phenylisothiocyanate. Aanal. Biochem. **208**: 237-240.

Kuo, Y.H., and F. Lambien. 1991. Biosynthesis of the neurotoxin *B*-N-oxalyl-α-*B*-diaminopropionic acid in callus tissue of *Lathyrus sativus*. Phytochemistry. **30**: 3241-3244.

Lambien, F., G. Ogena, and H.Y. Kuo. 1990. *B*-Isoxazolinone-alanin is involved in the biosynthesis of the neurotoxin *B*-N-oxalyl-L-α-*B*-diaminopropionic acid. Phytochemistry **20**: 3797-3796.

Lambien, F., J.K. Khan, H.Y. Kuo, C.C. Campell and I.C. Briggs. 1993. Toxins in seedlings of some varieties of grasspea (*Lathyrus sativus*). Nat. Toxins **1**: 246-249.

Lambien, F., R. Haque, J.K. Khan, N. Kebede and Y.H. Kuo. 1994. From soil to brain: Zinc deficiency increases the neurotoxity of *Lathyrus sativus* and may affect the susceptibility for the motorneurone disease neurolathyrism. Toxicon **32**: 461-466.

Liu, X. and F. He. 1990. *Lathyrus sativus* and Lathyrism in China. *Lathyrus* Lathyrism Newsletter. **2**: 2.

Mannan, A. and A. Rahim. 1988. Zinc in nutrition, pp. 1-412. Dhaka: Bangladesh Agricultural Research Council.

Quereshi, M.Y., D.J. Pilbea,, C.V. Evans and E.A. Bell. 1977. The neurolathyrogen – amino-*B*-oxalylaminopropionic acid in legume seeds. Phytochemistry. **16**: 477-479.

Rutter, J. and Percy, P. 1984. The pulse that maims. New Scientist 103: 22-23.

Roy, D.N., and S.P. Spencer. 1989. Lathyrogens. *In*: Toxicants of Plant Origin; Cheeke, P.R. Eds: CRC Press: Boca Raton, FL, 1989; Vol 111, pp. 169-201.

Sinha, S.K. 1980. Food Legumes: distribution, adaptability and biology of yield. Food and Agricultural Organization of the United Nations. FAO, Rome, Italy, pp. 156.

Spencer, P.S., and H.H. Schaumburg. 1983. Lathyrism: a neurotoxic disease. Neurobehav. Toxical. Teratol. 5: 625-629.

Spencer, P.S., A. Ludolph., M.P. Dawivedi, D.N. Roy, J. Hugon and H.H. Shaumburg. 1986. Lathyrism evidence for role of the neuroexitatory amino acid BOAA. Lancet ii: 1066-1067.