Int. Agrophysics, 2004, 18, 261-267

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Estimation of genetic variation of traits and physical properties of seeds for grass pea mutants (*Lathyrus sativus* L.)

W. Rybński[1], *B. Szot*[2], *and L. Pokora*[3,4]

[1]Institute of Plant Genetics, Polish Academy of Sciences, Strzeszyńska 34, 60-479 Poznań, Poland
[2]Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, P.O. Box 201, 20-290 Lublin 27, Poland
[3]Centre of Laser Technology, Wiosny Ludów 49, 02-495 Warszawa, Poland
[4]Department of Physical Therapy, Medical University, Jagielońska 13, 85-667 Bydgoszcz, Poland

Received June 30, 2004; accepted August16, 2004

A b s t r a c t. As a result of mutation induction by using two chemomutagenes-sodium azide (NaN_3) and N-nitroso-N- methylurea (MNU) as well as laser light, numerous mutants of grass pea (*Lathyrus sativus* L.) were obtained. Initial material for the study was constituted by seeds of two Polish cultivars – Derek and Krab. For analyses of trait variation in a field trial and of the physical properties of seeds, 20 morphological mutants were chosen as well as the two above mentioned initial cultivars. The results obtained from the field trial indicate a broader genetic variation of traits for the mutants as compared to the initial cultivars. Some of the most interesting and desirable mutants were characterized by a decrease of plant height, a higher location of the lowest pod, and a reduction of lateral branches and biomass. Those traits resulted in better lodging resistance as well as in more uniform and earlier maturity. With reference to parameters of yield structure, some of the mutants exceeded their initial forms. A broad spectrum of variability was also observed for the physical properties of seeds, such as: seed thickness, weight of 1000 seeds and resistance to static compression. The mutants, in comparison to the initial cultivars, were characterized by higher or lower values of compressive strength as expressed by force, deformation and energy.

K e y w o r d s: grass pea mutants, physical properties of seeds, variation of traits

INTRODUCTION

The genus *Lathyrus* is highly numerous and comprises 187 species and subspecies spread over the Old as well as the New World (Allkin *et al*., 1983). Among those, grass pea (*Lathyrus sativus* L.) is the most commonly used for nutritional purposes, in the form of seeds. Other species, like *L. cicera, L. clymenum* and *L. ochrus* are used both for seed production and for green fodder (hay). Remaining, better known species such as *L. tingitanus*, *L. latifolius* and *L. sylvestris* are used solely for the production of green fodders. Sweet pea, *L. odoratus*, is grown for decorative purposes, also in Poland. Overall, under the climatic conditions of Poland, there are 15 species (Dziamba, 1997), though only two of them have any economic significance – African everlasting pea (*Lathyrus tingitanus* L.) and, in particular, grass pea (*Lathyrus sativus* L.).

Grass pea is one of the oldest cultivated species and was known as far back as 8000 years before Christ (Lambein and Kuo, 1997). The history of grass pea cultivation in Poland is not known. According to Milczak *et al*. (1997), grass pea first appeared in Poland (in the region of Podlasie) accompanying lentil as a weed as far back as the 17th century, together with Tartar settlements. In 1991, Milczak *et al*. (2001), through selection from local grass pea populations, developed two promising lines with symbols 'Der' and 'Kra' which, after a series of multi-year field experiments, were registered as original cultivars – Derek and Krab.

Grass pea has low habitat requirements and can be successfully grown on soils of classes IV, V and even VI, with seed crops up to 3.5 ton per hectare (Grela and Skórnicki, 1997). Considering the fact that light and sandy soils predominate in Poland and constitute about 60% of all arable land, and that such soils are often too poor for the cultivation of such high-protein leguminous plants as bean or broad bean, grass pea, in such a context, assumes the status of a competitive alternative. This effect is undoubtedly related to the extraordinary resistance of the plant

*Corresponding author's e-mail: wryb@igr.poznan.pl

to drought, and, according to literature data, it can be grown at levels of precipitation as low as 380 mm (Campbell *et al*., 1994; Ali M. Abd El-Moneim *et al*., 2000).

Apart from the unquestionable advantages mentioned above, grass pea is also characterized by a number of less favourable features, such as strong lodging, indeterminate character of growth, or excessively long period till ripeness, as well as the presence of anti-nutritional substances in seeds (Rybiński and Pokora, 2002). Hence, one of the conditions for a broader introduction of the species in Polish agriculture is the genetic improvement of a number of unfavourable characteristics. Apart from effects of recombination, such a possibility is offered by mutation induction (Rybiński *et al*., 1994) through the introduction of additional variability of features, represented by mutants.

The objective of the study presented herein was the evaluation of variability of agricultural traits and physical properties obtained for seeds of mutants which could constitute interesting initial material in breeding programs aimed at the creation of new and improved varieties of grass pea.

MATERIAL AND METHODS

The initial material for mutagenic treatments was constituted by seeds of two Polish cultivars of grass pea – Derek and Krab. As a result of seed irradiation with laser light at dose 30 min and mutation induction through the use of two chemomutagenes-sodium azide (NaN_3) and N-nitroso-N-methylurea (MNU), a selection of mutated genotypes was performed in generation M_2. In generation M_3 the progeny of the selected forms was sown, together with the initial cultivars, in order to verify the changes observed in generation M_2. After multiplication of stabilized mutants, both the initial cultivars, 17 mutants of the Krab cultivar and 3 mutants of the Derek cultivar were selected for a field experiment set up according to the random block method with three replications. Seeds were placed in experimental plots with 20 cm spacing in rows 40 cm apart. Immediately after sowing, Afalon, a herbicide, was applied on the plots. No mineral fertilization was applied during the growth and development of the plants. Throughout the vegetation period, morphological description of the mutants was carried out, and the time of blooming and ripening (LDD) was determined. Determinations performed after the harvest covered the height of plants (WS), location of the lowest pod (WOS), number of branches (LR), number of pods per plant (LSR), number of full and empty pods per plant (LSZNR, LSPR), pod length and width (DS, SZS), number and weight of seeds from a main stem pod (LNSPG, MNSPG), and number and weight of seeds from a plant (LNR, MNR). The results obtained were processed statistically, determining the values of LSD, general means, mean squares, extreme values, and coefficients of variability. Relationships between the features were expressed by values of correlation coefficients.

The collected seeds were also analyzed in terms of their physical properties. The first stage of the determinations included seed thickness and the weight of 1000 seeds. Seed thickness was measured using an adapted dial gauge and an electronic slide caliper with an accuracy of 0.01 mm. To obtain detailed distributions of this property in air dry seed samples, 300 replications were made on the same seeds selected at random. The weight of 1000 seeds was determined by means of an LN-S-50A seed counter in three replications.

The resistance of individual seeds to static loading was determined by means of the INSTRON model 6022 strength tester, according to a method developed earlier, in 50 replications (Szot *et al*., 1994). The results obtained were used to determine the compressive strength of the seeds. The results of the determinations were expressed in values of force (N), strain (mm) and energy (mJ).

RESULTS AND DISCUSSION

Induction of mutation and mutation breeding may be a significant complement for conventional plant breeding methods. Geneticists and breeders can use mutation methods to induce additional variability of traits in breeding programs aimed at the creation of new cultivars (Campbell *et al*., 1994; Ahloowalia and Małuszyński, 2001). Table 1 presents the results of variance analysis for the traits and mutants under study. The extreme values indicate a broad range of variability of particular traits in the mutants. The variability obtained for the mutants exceeds the values obtained for the initial cultivars (Table 2), both in the direction of reduction and increase in the values of the traits studied. In the case of plant height, the values for the mutants varied from 89.9 to 129.4 cm, with plant height for the initial cultivar, Krab, being 108 cm. The mean value of the trait of the height of the lowest pod location was 25.9 cm, and the range of variability for the trait was from 19.3 to 41.9 cm. Mutants developed an average of 12.2 ramifications and 75.5 pods per plant, with a broad range of variability of the trait. An especially broad range of variability was observed for the number and weight of seeds per plant, and a markedly narrower one for pod length, and particularly for pod width. A special note should be taken of mutants with a modified time to maturity, especially with a reduced time to maturity. These results were partially reflected in the values of the coefficient of variability. The highest values were obtained for the height of the lowest pod location, the number of branches , weight of seeds from main stem pod, and weight of seeds per plant, and the lowest for the number of days till maturity and for pod width. The mean values for the traits analyzed and for each of the objects studied are presented in Table 2. Note should be taken here of mutants with reduced height, with a high location of the lowest pod, with

T a b l e 1. General means, variation range, coefficient of variability and mean squares from analysis of variance for tested genotypes together and analyzed traits

Traits	Degree of freedom	General means	Variation range		Mean squares	Coefficient of variability W (%)
			Min.	Max.		
Plant height (WS)	21	102.70	89.90	129.40	327.40**	3.54
First legume height (WOS)	21	25.90	19.30	41.90	71.32**	6.97
No. of branches/plant (LR)	21	12.20	8.70	19.40	21.60**	9.55
No. of pods /plant (LSR)	21	75.50	37.10	127.70	1070.50**	3.12
No. of pods with seeds/plant (LSZNR)	21	66.30	36.00	124.50	1001.44**	4.99
No. of empty pods/plant (LSPR)	21	9.10	0	18.40	81.44	5.77
Pod length (cm) (DS)	21	3.45	2.89	3.80	0.144	4.55
Pod width (cm) (SZS)	21	1.23	1.14	1.32	0.009	2.85
Seeds/pod/main stem (LNSPG)	21	3.15	2.32	4.14	0.629	4.05
Seeds weight/pod/main stem (g) (MNSPG)	21	0.31	0.19	0.46	0.017	11.50
Seeds/plant (LNR)	21	182.70	96.30	407.80	12002.71**	5.94
Seeds weight/plant (g) (MNR)	21	17.10	9.20	32.00	89.14**	9.01
Days to maturity (LDD)	21	122.10	116.00	130.00	32.74**	0.98

**significant at α=0.01.

a reduced number of lateral branches, and with a higher number of pods per plant. In terms of pod length and width, only mutant K 63 exceeded its initial cultivar - Krab. Only mutant K 37 was characterized by a greater number of seeds per pod, and in terms of weight of seeds per pod mutants K 46, K 63 and K 64 exceeded their parent form. One can also identify mutants which exceeded the initial cultivar, Krab, in terms of two traits, *ie* the number and weight of seeds per plant – those were mutants K 3, K 7, K 56 and K 63. Under the climatic conditions of Poland, the duration of the vegetation period is an especially important trait in plants. Mutants K 25, K 37, K 46, K 63 and D 4 can be rated among those that reached maturity the earliest. The study showed that mutation induction can be an effective method for the extension of genetic variability of traits in grass pea. This is supported also by the results obtained by Nerkar (1972) and by Waghmare and Mehra (2000). The mutants obtained in this study were characterized by trait variability exceeding that observed in the case of the initial cultivars, Derek and Krab, both in the positive and in the negative directions. Mutation induction is especially important for species whose natural variability is relatively limited (Sawicka, 1993). In Poland, such species include grass pea whose gene pool is represented on by sparse local populations in the region of Podlasie and by the two original cultivars, Derek and Krab.

The relationships between the traits analyzed are characterized by the coefficient of correlation (Table 3). Plant height was significantly and positively correlated with the height of the lowest pod location, with the number of branches, with the number of pods per plant, the number of empty pods per plant, pod length and width, weight of seeds per plant, weight of 1000 seeds, and the number of days till maturity. One of the traits which have a significant effect on the yield of seeds is the number of pods per plant. This trait was significantly and positively correlated with the plant height, the number of branches, the number and weight of seeds per plant, and the number of days till maturity, and negatively correlated with pod width, number and weight of seeds per pod, and with the weight of 1000 seeds. The last of those traits was significantly and positively correlated with, among other things, the length and width of pods and with the weight of seeds per pod and per plant. A negative correlation was observed for the number of seeds per pod and per plant, and for the number of pods per plant. Under the climatic conditions of Poland, forms with a shortened period till maturity are preferable. The number of days till maturity was significantly and positively correlated with plant height, number of pods per plant, and number and weight of seeds per plant.

Seed damage may occur even prior to harvest, when under certain unfavourable environmental conditions internal damage is observed in the course of the seed filling process, especially due to a high gradient of moisture in the seeds (Grundas *et al*., 1990; Geodecki and Grundas, 2003). Mechanical damage may occur at any stage of further treatment of seeds, beginning with harvest (cracking, breaking of seed fragments), through transport and storage, up to final processing (grinding or fragmentation). Evaluation of the physical properties of seeds was preceded with a determination of their moisture content (Table 4). Moisture content was similar only in two mutants (K 7 and K10), and overall the seed moisture content only slightly exceeded the level of 12%. The values of force causing the destruction of the structure of grass pea seeds depend on the seed moisture content and with increasing moisture the resistance of the seeds to static loading drops rapidly (Szot *et al*., 1998). In the experiment presented here, the moisture content of the seeds of the cultivars and mutants studied was almost identical, which permitted the comparison of the

T a b l e 2. Means for analyzed traits of mutants and initial cultivars – Krab and Derek

Mutants and cultivars	WS (cm)	WOS (cm)	LR	LSR	LSZNR	LSPR	DS (cm)	SZS (cm)	LNSPG	MNSPG (g)	LNR	MNR (g)	LDD
KRAB	108.1	24.8	10.4	64.1	52.3	11.8	3.63	1.27	3.44	0.39	176.8	19.2	126
K 3	107.0	22.1	15.3	91.2	86.2	5.0	3.46	1.24	3.10	0.33	211.1	21.4	130
K 6	92.5	25.9	14.0	77.1	68.3	8.8	3.45	1.22	3.31	0.29	177.5	14.0	120
K 7	100.9	26.9	16.2	81.3	76.8	4.5	3.35	1.23	3.31	0.32	208.5	20.6	124
K 10	106.7	23.8	13.5	90.7	72.9	17.8	3.40	1.24	2.59	0.25	146.2	13.6	120
K 11	99.7	26.2	13.9	60.1	53.9	6.2	3.58	1.31	3.13	0.39	146.3	14.2	124
K 12	91.3	26.3	13.5	72.9	56.9	16.0	3.46	1.21	3.10	0.26	144.2	11.6	128
K 13	102.4	26.5	12.4	70.2	61.5	8.7	3.34	1.28	2.52	0.33	130.5	15.7	122
K 14	89.9	19.3	12.0	78.3	67.0	11.3	2.89	1.14	2.86	0.20	181.1	13.9	120
K 25	127.9	41.9	11.2	62.0	50.7	11.3	3.31	1.29	2.32	0.25	96.3	10.3	119
K 29	105.5	25.7	14.1	76.8	68.0	8.8	3.10	1.17	2.84	0.25	161.8	13.0	120
K 37	103.6	26.1	8.9	45.1	45.1	0.0	3.45	1.23	4.14	0.33	169.7	21.6	118
K 46	97.2	28.3	9.7	37.1	36.0	1.1	3.70	1.31	3.18	0.46	112.3	13.9	116
K 50	129.4	35.9	12.5	94.7	79.0	15.7	3.61	1.25	2.55	0.33	174.4	22.2	124
K 56	100.4	22.8	8.6	63.4	57.0	6.4	3.72	1.29	3.40	0.37	212.8	23.2	124
K 59	103.8	27.0	10.8	73.7	58.3	15.4	3.43	1.23	3.04	0.30	154.4	16.6	122
K 63	100.4	22.7	13.1	95.4	89.0	6.4	3.80	1.30	3.28	0.43	250.6	32.0	119
K 64	96.3	24.1	11.4	73.4	65.0	8.4	3.61	1.32	3.24	0.40	179.3	22.4	126
DEREK	115.0	20.9	19.4	127.7	124.5	3.2	3.66	1.14	3.96	0.26	407.8	25.8	124
D 4	93.8	27.0	9.6	64.5	54.3	10.2	3.27	1.17	2.88	0.19	142.2	9.2	119
D 11	92.4	24.7	8.7	72.2	66.3	5.9	3.55	1.22	3.85	0.31	227.2	17.3	122
D 13	92.5	21.5	9.5	89.0	70.6	18.4	3.31	1.17	3.31	0.24	210.3	15.8	120
LSD $\alpha = 0.05$	5.98	2.98	1.92	3.88	5.45	8.86	0.25	0.06	0.21	0.06	17.83	2.60	1.96

T a b l e 3. Correlation coefficient matrix of the investigated traits

Traits	WS	WOS	LR	LSR	LSZNR	LSPR	DS	SZS	LNSPG	MNSPG	LNR	MNR	M 1000[1]	LDD
WS	1.000	0.623**	0.629**	0.262*	0.201	0.348**	0.370**	0.289*	0.174	0.237	0.039	0.389**	0.397**	0.277*
WOS		1.000	0.475**	0.037	0.029	0.052	0.014	0.515**	-0.104	0.009	0.012	0.110	0.105	-0.074
LR			1.000	0.484**	0.441**	0.401**	0.332**	0.156	-0.371**	0.298*	0.033	0.618**	0.545**	0.074
LSR				1.000	0.981**	0.520**	0.027	-0.262*	-0.176	-0.178	0.542**	0.403**	-0.103	0.380**
LSZNR					1.000	0.345**	0.051	-0.274*	-0.076	-0.116	0.628**	0.455**	-0.126	0.346**
LSPR						1.000	-0.091	-0.059	-0.515**	-0.347**	-0.147	-0.059	0.058	0.345**
DS							1.000	0.842**	0.018	0.785**	0.106	0.744**	0.664**	0.251
SZS								1.000	-0.025	0.667**	-0.174	0.480**	0.670**	0.108
LNSPG									1.000	0.124	0.682**	0.065	-0.481**	-0.053
MNSPG										1.000	0.035	0.781**	0.752**	0.184
LNR											1.000	0.413**	-0.430**	0.264*
MNR												1.000	0.624**	0.291*
M 1000													1.000	0.048
LDD														1.000

[1]M 1000 – weight of 1000 seeds; the other explanations as in Table 1, *significant at $\alpha = 0.05$, **significant at $\alpha = 0.01$.

results obtained. The mean value of seed thickness for mutants of the Krab cultivar was from 4.2 to 5.5 mm, while that for the initial cultivar was 5.3 mm (Table 4). Corresponding values for the Derek cultivar and its mutants were 4.7-5 mm and 4.8 mm, respectively. This indicates a greater seed thickness in the Krab cultivar as compared to the Derek cultivar, and a broader range of variability in the mutants as compared to the initial cultivars. Studies carried out by Szot *et al*. (1998) indicated that seeds of the Krab cultivar were thicker than those of the Derek cultivar, which was also reflected in the weight of 1000 seeds which was greater for Krab than for Derek. The thickest seeds were characteristic of mutant K 50. The values of the coefficient of variability for this trait in the Krab and Derek cultivars was similar to the values for their mutants, at 7-10.3% and 5.2-6.9%, respectively.

Considerable differentiation of the mutants as compared to their initial cultivars was observed for the weight of 1000 seeds. The value of this parameter was distinctly higher for Krab than for Derek. This was reflected in the weight of 1000 seeds for the particular mutants of the two cultivars. The range of values of this parameter for the mutants of the Krab cultivar was from 95.1 g for mutant K 14 to 228.5 g for K 13. Overall, three mutants were characterized by a higher weight of 1000 seeds as compared to their initial cultivar – Krab. For the Derek cultivar, all the mutants were characterized a distinctly higher values of this parameter.

The assessment of the physical properties of seeds involved also their resistance to mechanical loading (Table 5). The mean value of force causing the destruction of individual seed structure was slightly lower for the Krab cultivar than for Derek. The values of this property for the mutants of the Krab cultivar varied from 238 to 328.4 N, and from 234.3 to 286.1 N for the mutants of the Derek cultivar. Three mutants (K 3, K 13, K 50) exceeded the value obtained for the Krab cultivar, and one mutant (D 13) exceeded that for the Derek cultivar.

In terms of compressive strength as measured by the mean value of strain, higher values of this property were characteristic of the Krab cultivar as compared to the Derek cultivar. Strength measurements carried out on grass pea seeds at 8% seed moisture content showed nearly identical, though somewhat lower values for the Krab and Derek cultivars (Szot *et al*., 1998). Like in the study by Szot *et al*. (1998) the degree of deformation was greater in the Krab cultivar as compared to Derek. The mutants were characterized by an expanded range of variability of the degree of deformation as compared to the initial cultivars. For the mutants of the Krab cultivar, the range of the variability was from 0.46 to 0.75 mm, and for the mutants of the Derek cultivar, from 0.44 to 0.47 mm. Among the mutants of the Krab cultivar, five of them were characterized by higher deformation values than the initial cultivar, while

T a b l e 4. Estimation of seed thickness and weight of 1000 seeds for grass pea mutants and their initial cultivars – Krab and Derek

Cultivars	Seed moisture (%)	Thickness (mm)				Weight of 1000 seeds (g)
		Mean values	Min.	Max.	W* (%)	
KRAB	11.6	5.3	4.5	6.2	8.5	196.2
K 3	11.3	5.0	3.9	6.0	9.5	189.2
K 6	11.0	5.0	4.0	5.9	8.5	173.2
K 7	12.7	4.7	3.7	5.9	9.2	173.0
K 10	12.3	4.7	3.2	5.6	10.3	131.9
K 11	10.6	5.1	4.4	6.0	8.5	183.7
K 12	11.1	4.7	3.3	5.6	9.7	153.3
K 13	10.8	5.0	4.3	5.7	7.4	228.5
K 14	11.4	4.2	3.3	5.2	9.1	95.1
K 25	10.9	4.8	3.7	6.1	9.3	164.6
K 29	11.0	5.0	3.5	6.1	9.8	144.5
K 37	11.0	4.8	4.0	5.9	7.6	129.9
K 46	11.1	5.3	4.3	5.9	6.6	200.5
K 50	10.8	5.5	4.2	6.1	7.0	215.7
K 56	10.2	5.1	3.9	5.8	9.2	171.1
K 59	10.8	4.9	4.1	5.8	7.9	157.0
K 63	10.8	4.9	4.0	6.3	8.9	188.2
K 64	11.4	4.9	3.9	6.1	9.1	169.3
DEREK	11.1	4.8	3.9	5.8	8.9	124.9
D 4	11.4	5.0	4.4	6.0	6.9	140.2
D 11	10.9	5.0	4.3	5.6	5.9	144.1
D13	11.0	4.7	4.1	5.2	5.2	140.6

W* – coefficient of variability.

the Derek cultivar was exceeded in this respect by all its mutants, although on a very similar level.

Compressive strength as measured by the values of energy was higher in the Krab cultivar and lower in the Derek cultivar. For the mutants of the Krab cultivar, the mean values of this property varied within a relatively broad range of 56-110.9 mJ, while for the mutants of the Derek cultivar the corresponding range of variability was 41.1-55.1 mJ.

Differences in seed or grain resistance to mechanical damage are observed not only between various cereal species like barley, rye, triticale and wheat (Stępniewski and Szot, 1994), but also within a single species, where the structure of endosperm is the factor determining the differences. For hard wheat grains (*Triticum durum*), the maximum force causing damage was significantly higher than for other types of wheat (Szot *et al.*, 1994). Therefore, we can assume that the differences observed between the mutants and their initial cultivars in terms of sensitivity to mechanical loading have the nature of genetic changes related to the internal structure of the seeds.

CONCLUSIONS

1. Mutation induction with additional use of stimulate dose of laser light proved to be an effective method for the expansion of variability of traits in grass pea, evidenced by the obtaining of mutants characterized by improved traits and qualities as compared to the initial cultivars.

2. The obtained variability of morphological traits and parameters of yield structure had a bi-directional character. With respect to the traits analyzed, some of the mutants were below the level of their initial cultivars, while others were characterized by distinctly higher values. From the viewpoint of breeding, it is the variability which brings genetic improvement of the most desirable traits that is significant.

3. Dry seeds of grass pea of the two cultivars can be considered to be very resistant to mechanical loading. The compressive strength of dry seeds as expressed by the value of force was slightly higher in the case of Derek as compared to Krab. In terms of the degree of deformation and the energy used, higher values were obtained for the Krab cultivar. The range of variability of the traits mentioned indicates a significant expansion of their variability as compared to the initial cultivars.

4. Considering the fact that the analyzed mutants and cultivars originate from a single field experiment and were harvested at the same stage of maturity (manual threshing), the differences in the reaction to mechanical loading between the mutants and their initial cultivars may be related to genetic changes in the internal structure of mutant seeds. However, substantiation of this conclusion requires additional analyses of the microstructure of the surface, the seed coat and the cotyledon of the seeds.

T a b l e 5. Resistance to mechanical loads of seeds in grass pea mutants and their initial cultivars – Krab and Derek

Cultivars	Seed moisture (%)	Resistance to squashing											
		Force (N)				Deformation (mm)				Energy (mJ)			
		Mean values	Min.	Max.	W* (%)	Mean values	Min.	Max.	W* (%)	Mean values	Min.	Max.	W* (%)
KRAB	11.6	279.2	140.4	415.5	28.0	0.53	0.20	1.50	43.2	67.0	15.3	315.4	79.9
K 3	11.3	316.0	137.6	633.6	25.8	0.72	0.36	1.37	40.9	110.9	36.2	331.3	68.8
K 6	11.0	252.2	83.5	426.9	31.7	0.49	0.28	1.28	43.4	61.8	8.2	258.3	85.3
K 7	12.7	278.7	89.0	523.0	33.1	0.73	0.28	1.50	38.6	104.7	9.4	323.7	71.4
K 10	12.3	279.1	106.7	533.5	26.6	0.51	0.32	1.12	37.0	66.8	22.9	275.8	74.1
K 11	10.6	279.4	111.5	438.4	22.5	0.52	0.26	1.44	49.2	75.9	12.9	350.2	88.6
K 12	11.1	268.0	144.0	479.5	25.7	0.47	0.29	1.27	35.2	62.6	13.6	370.3	82.9
K 13	10.8	294.1	100.7	520.5	28.9	0.51	0.25	1.29	46.1	72.3	12.3	259.4	69.6
K 14	11.4	238.0	131.3	585.6	27.1	0.51	0.31	1.33	48.5	61.1	20.2	376.2	98.1
K 25	10.9	274.5	88.1	402.9	25.1	0.48	0.26	1.16	39.2	60.9	11.7	177.3	49.7
K 29	11.0	254.5	96.1	407.9	26.8	0.47	0.24	1.24	31.5	56.0	7.9	255.1	63.5
K 37	11.0	254.7	174.4	317.0	18.0	0.49	0.43	0.53	10.6	58.3	38.5	84.9	26.1
K 46	11.1	279.7	82.6	434.0	23.6	0.46	0.21	0.83	25.5	58.5	7.1	171.1	42.1
K 50	10.8	328.4	227.0	571.5	18.5	0.53	0.34	1.48	32.8	75.8	32.4	277.0	56.0
K 56	10.2	260.1	168.5	421.5	21.2	0.58	0.37	1.18	29.5	73.1	27.5	277.3	55.7
K 59	10.8	267.5	178.2	387.0	18.2	0.49	0.31	1.41	38.7	68.9	30.2	306.1	65.7
K 63	10.8	260.5	112.4	427.5	23.8	0.64	0.31	1.20	32.1	81.4	14.9	247.9	53.5
K 64	11.4	247.3	113.9	416.0	23.8	0.75	0.37	1.46	40.8	98.3	24.4	294.1	69.6
DEREK	11.1	282.8	158.2	478.0	24.8	0.43	0.26	0.67	22.8	51.1	22.1	161.1	43.3
D 4	11.4	262.9	65.1	393.5	18.8	0.47	0.20	0.79	18.9	54.8	5.1	91.4	26.9
D 11	10.9	234.3	96.7	309.0	19.5	0.44	0.20	0.76	19.4	41.1	7.5	65.9	29.2
D13	11.0	286.1	120.5	374.5	16.8	0.45	0.31	0.66	15.5	55.1	11.5	83.6	26.4

W* – coefficient of variability.

REFERENCES

Ahloowalia B.S. and Małuszyński M., 2001. Induced mutations – A new paradigm in plant breeding. Euphytica, 118, 167-173.

Ali M. Abd El-Moneim B., Dorrestein M., and Mulugeta W., 2000. Improving the nutritional quality and yield potential of grasspea (*Lathyrus sativus* L.). Food Nutri. Bull., 21(4), 493-496.

Allkin R., Mcfarlane T.D., White R.J., Bisby F.A., and Adey M.E., 1983. Names and synonyms of species and subspecies in the Vicieae. Vicieae Database Project Publications, No. 2, 25-39.

Campbell C.G., Mehra R.B., Agrawal S.K., Chen Y.Z., El Moneim B., Khawaja H.I.T., Yadow C.R., Tay J.U., and Araya W.A., 1994. Current status and future strategy in breeding grasspea (*Lathyrus sativus* L.). Euphytica, 37, 167-175.

Dziamba S., 1997. The biology and agrotechnics of chicking vetsch (in Polish). Int. Sci. Conf. *'Lathyrus sativus* – cultivation and nutritive value in animals and human'. Radom, June 9-10, 27-33.

Geodecki M. and Grundas S., 2003. Characterization of geometrical features of single winter and spring wheat kernels (in Polish). Acta Agrophysica, 2(3), 531-538.

Grela E.R. and Skórnicki H., 1997. Chemical composition of flat pea (*Lathyrus sativus* L.) seeds in local cultivars from Radom region (in Polish) Int. Sci. Conf. '*Lathyrus sativus* – cultivation and nutritive value in animals and human'. Radom, June 9-10, 59-70.

Grundas S., Styk B., and Velikanov L., 1990. Susceptibility to mechanical damage of wheat grain and its quality assessment (in Polish). Bull. IHAR, 190, 135-142.

Lambein F. and Kuo Y.H., 1997. *Lathyrus sativus*, a neolythic crop with a modern future? An overview of a present situation. Int. Sci. Conf. '*Lathyrus sativus* – cultivation and nutritive value in animals and human'. Radom, June 9-10, 6-12.

Milczak M., Pędziński M., Mnichowska H., and Szwed-Urbaś K., 1997. Creative breeding of chickling vetsch (*Lathyrus sativus* L.) – summation of first-stage of investigation (in Polish). Int. Sci. Conf. '*Lathyrus sativus* – cultivation and nutritive value in animals and human'. Radom, June 9-10, 13-22.

Milczak M., Pędziński M., Mnichowska H., Szwed-Urbaś K, and Rybiński W., 2001. Creative breeding of grass pea (*Lathyrus sativus* L.) in Poland. Lathyrus Lathyrism Newsletter, 2, 101-104.

Nerkar Y.S., 1972. Induced variations and response to selection for low neurotoxin content in *Lathyrus sativus* L. Indian J. Genet. Plant Breeding, 32(2), 175-180.

Rybiński W., Patyna H., and Przewoźny T., 1994. Mutagenic effect of laser and chemical mutagens in barley (*Hordeum vulgare* L.). Genetica Polonica, 34(3), 337-343.

Rybiński W. and Pokora L., 2002. The influence of helium-neon laser and chemomutagen (MNU) on variability of traits in M_1 progeny of grasspea (*Lathyrus sativus* L.). Acta Agrophysica, 62, 127-134.

Sawicka E., 1993. Induced mutations in Andean lupine (*Lupinus mutabilis* Sweet) (in Polish). Lublin Botanical Garden Papers, Monographs, 3, 1-101.

Stępniewski A. and Szot B., 1994. Strength features of basic cereal species. Report No. 94-G-081, Milano, AGENG, 1-4.

Szot B., Sosulski F.W., and Stępniewski A., 1994. Mechanical strength of vitreous and mealy varieties of Canadian and Polish wheats. Int. Agrophysics, 8, 339-342.

Szot B., Milczak M., and Wąsik A., 1998. Characteristics of the physical properties grass pea (*Lathyrus sativus* L.) (in Polish). Lentil and everlasting pea, 60-65.

Waghmare V.N. and Mehra R.B., 2000. Induced mutations in grass pea (*Lathyrus saticus* L.). Lathyrus Lathyrism Newsletter, 1, 21-24.