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THE LOSS OF VIGOUR AND SOWING VALUE OF YELLOW LUPIN SEEDS (*LUPINUS LUTEUS* L.) AS A RESULT OF MECHANICAL HARVESTING

ABSTRACT

The aim of the study was to determine the effect of mechanical harvest on the seed quality of yellow lupin. Two effects were studied: the cultivar of yellow lupin (the indeterminate cultivar - Mister and the determinate cultivar - Perkoz) and harvest methods: hand-picked plants with manual shelling of seeds as a control and mechanical shelling with a plot harvester. In comparison with manual shelling of seeds, the mechanical harvest reduced the seed germination and increased the number of abnormal seeds both cultivars. Determinate cultivar was more sensitive, because the loss of its quality was higher (germination of 10%) than indeterminate cultivar (6%). Perkoz had also higher electrical conductivity, with the mean value of 34.3 $\mu S \times cm^{-1} \times g^{-1}$. Manual shelled seeds were characterized by a significantly lower leakage of exudates (24.9 $\mu S \times cm^{-1} \times g^{-1}$), and hence, it exhibited greater vigour than mechanical harvested seeds. Most relations of Pearson correlation coefficient between vigour tests and germination were strong or practically functional.

Key words: decreased germination, lupin, seed damages, seed vigour

INTRODUCTION

The role of lupins in modern agriculture is very significant. In addition to their applications in agriculture, lupins are exploited in horticultural practice,

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for example as ornamental plants in rustical gardens. There are also attempts to introduce lupins into human food chain as potential vegetable crops (Wiszniewska and Pindel, 2013).

In all processes ranging from pre-harvest on the farm, through processing and to the final stage of seed storage, quality control plays an important role to assure the production of high quality seed (Krzyzanowski, *et al.*, 2006). Seed quality is a relatively broad term and it encompasses several factors: seed health, varietal and physical purity, germination, vigour, and size (or weight). In theory seed germination, vigour and size (three aspects of seed quality) may have both direct and indirect influence on crop yield (Ellis, 1992). One of the factors reducing seed quality is mechanical damage. Seed injuries are caused by weathering, fungi, insects, artificial drying and mechanical damage during harvest, handling, threshing and storage (Krzyzanowski, *et al.*, 2006). Vearasilpa, *et al.*, (2001) concluded that the seeds which were more mechanically damaged were larger and had a thinner seed coat. The large size of legume seeds makes them vulnerable to mechanical damage by the header at harvest and during subsequent handling. This damage is not always visually apparent (Matthews and Holding, 2005). Even little damage done to seeds during processing may rapidly affect seed viability and cause seed vigour to decrease and increase the number of abnormal seedlings (Schenidt, 2000). Farmers are interested in buying and cultivating vigorous seeds in order to improve crop performance in the field (Ghassemi-Golezani and Hosseinzadeh-Mahootchy, 2009).

The aim of this study was to determine the effect of mechanical harvest on the seed quality of two cultivars of yellow lupin.

MATERIAL AND METHODS

Field establishment

The trial was conducted on the basis of the experiment which was carried out in 2011 and 2012 at the experimental farm of the Poznań University of Life Sciences in Złotniki (52°29’ N, 16°49’ E, POLAND) on grey-brown podsolic soil under ordinary growing conditions. Four replicate plots of 20 m^2 were prepared by ploughing and power-harrowing. A fertiliser (P_2O_5 80 kg ha^{-1} and K_2O 120 kg × ha^{-1}) was applied to the seedbed. Inoculated seeds were drilled in early April: the Mister cultivar at a rate of 130 kg × ha^{-1} and the Perkoz cultivar at a rate of 150 kg × ha^{-1}. The weeds were controlled by treatment with 2.0 l × ha^{-1} of linuron (Agan Chemical Manufactures Ltd.). Two effects were studied: the cultivar of yellow lupin and harvest methods: hand-picked plants with manual shelling of seeds (Ma) as a control and mechanical shelling with a plot harvester (Me). The two species were: the indeterminate cultivar Mister (I) and the determinate cultivar Perkoz (D). One-stage harvesting consisted in manual shelling and natural drying of seeds to obtain 14-15% moisture from the area of 1 m^2. One-stage harvest was done with a Wintersteiger combine harvester during the phase of full ripeness of the seeds with 14-15% moisture from the area of 19 m^2. After the harvest all samples were stored in brown paper bags under cool conditions. All analyses pertaining to the viability and vigour of the seeds were based on the seed samples collected from each experimental plot. The analyses were made in a laboratory at the Department of Agronomy, Poznań University of Life Sciences, from January to February.

The standard germination test (ISTA, 2006)

Germination was determined on 100 randomly chosen seeds from each replication. A standard germination test was conducted according to the between-paper method. The seeds were placed equidistantly apart from each other on moist germination paper. The paper was rolled up and placed in a thermostat at a temperature of 20ºC. After 10 days the number of normal seedlings (germination) and abnormal seeds were counted (decayed and ungerminated seeds were treated as abnormal seeds). The seeds were visually assessed and the results were presented as percentage.

Electrical conductivity test (ISTA, 2006)

50 randomly chosen weighed seeds from each replication were soaked in distilled water in 250 cm^3 beakers and kept in a thermostat at 20ºC for 24 hours. After stirring the liquid the electrical conductivity of the solute with the seeds was measured (without removing the seeds from the beakers). The electrical conductivity of the leachate was measured with an Elmetron CC-551 micro-computer conductometer. The results were recorded in $\mu S \times cm^{-1} \times g^{-1}$.

The seedling growth test (Dąbrowska, et al., 2000)

During the seedling growth test a roll of moistened germination paper with 25 seeds was placed in a thermostat at 20°C. After 10 days, when the test was complete, the length (cm) of normally sprouted seedlings was measured. The value was calculated as the sum of the length of all sprouted seedlings, which was divided by 25.

The seedling speed growth test (Dąbrowska, et al., 2000)

The seedling speed growth test was the continuation of the seedling growth test. In order to measure the growth rate normal seedlings from each roll were dried at 80°C for 24 hours, they were weighed and their dry mass was divided by the number of normal seedlings from the roll. The results were recorded in mg.

The vigour index

The vigour index was calculated as the product of the results of the seedling growth test in cm and the average germination in %.

Statistical analysis

All the data were processed in analysis of variance (ANOVA) with the SAS package (SAS Institute, 1999). The means of treatment were compared by means of Tukey's least significant difference test (LSD) at P<0.01 and P<0.05. The relationship between the seed characteristics was determined with the Pearson correlation coefficient.

RESULTS

Table 1

The effect of the harvesting method on seed germination (%)

Cultivar (C)	Harvesting method (H)	Germination	Abnormal seeds
I	Ma	88	12
	Me	82	18
	Mean	85	15
D	Ma	99	1
	Me	89	11
	Mean	94	6
LSD (C)		2.4**	2.4**
Mean (H)	Ma	93	7
	Me	85	15
LSD (H)		2.2**	2.2**
LSD (CxH)		2.2*	2.2*

I: indeterminate cultivar Mister; D: determinate cultivar Perkoz; Ma: manual shelling of seeds;
Me: mechanical (plot harvester)
LSD (C) is the least significant difference between cultivars; LSD (H) is the least significant difference between harvesting methods.
* significant P<0.05.; ** significant P<0.01; N.S.: not significant.

Both factors of the experiment influenced on seed germination (Table 1). The greatest average germination was found in the seed of the determinate cultivar Perkoz (D) - the germination was 94%, the number of abnormal seeds was 9% lower than that of the indeterminate cultivar Mister (I). The germination and the number of abnormal seeds differed depending on the cultivar and in combination with specific harvesting methods. Mechanical harvest (Me) decreased the seed germination and increased the number of abnormal seeds both cultivars, as compared with the manual shelling of seeds (Ma). Cultivar D was more sensitive, because its loss of quality was higher (germination of 10%) than in cultivar

I (6%). On average, Me decreased germination and increased the number of abnormal seeds by 8%.

Table 2

The effect of the harvesting method on seed vigour

Cultivar (C)	Harvesting method (H)	Electrical conductivity test [µS × cm^{-1} × g^{-1}]	Seedling growth test [cm]	Seedling speed growth test [mg]	Vigour index
I	Ma	19.9	6.28	26.6	553
	Me	26.4	5.48	28.3	449
	Mean	23.2	5.88	27.5	501
D	Ma	29.8	7.05	26.5	698
	Me	38.8	6.51	26.3	579
	Mean	34.3	6.78	26.4	639
LSD (C)		2.91**	N.S.	N.S.	97.2*
Mean (H)	Ma	24.9	6.67	26.6	623
	Me	32.6	6.00	27.3	514
LSD (H)		2.27**	N.S.	N.S.	74.0*
LSD (CxH)		N.S.	N.S.	N.S.	N.S.

I: indeterminate cultivar Mister; D: determinate cultivar Perkoz; Ma: manual shelling of seeds;
Me: mechanical (plot harvester)
LSD (C) is the least significant difference between cultivars; LSD (H) is the least significant difference between harvesting methods.
* significant P<0.05.; ** significant P<0.01; N.S.: not significant.

The factors in interaction did not influence the vigour of yellow lupin seeds, which was measured with different methods (Table 2). In the analysis of variance of the cultivars showed a significant difference in the electrical conductivity rate. Cultivar D with the mean of 34.3 µS × cm^{-1} × g^{-1} had higher electrical conductivity. Ma was characterized by significantly lower leakage of exudates (24.9 µS × cm^{-1} × g^{-1}), and hence its greater vigour in comparison with Me. The seedling growth test and the seedling speed growth test showed no significant differences in the seed vigour of both cultivars harvested with different methods. The greatest average vigour index was found in seeds D (639), as compared with seeds I (501). Me significantly decreased the vigour index by 17.5%.

Pearson's linear correlation between the respective vigour tests and germination of mechanical harvest showed that these parameters were correlated to a varied extent (Table 3). The strongest relations both cultivars, where the correlation coefficient was greater than 0.75, were found between: the vigour index and the seedling growth test, the vigour index and the electrical conductivity test, the vigour index and the germination, the seedling growth test and the germination, the electrical conductivity test and the germination.

Table 3

The correlation coefficients among the parameters under analysis for mechanical harvesting

C	Parameters compared	Germination	Electrical conductivity test	Seedling growth test	Seedling speed growth test	Vigour index
I	Germination	1				
	Electrical conductivity test	-0.908[D*]	1			
	Seedling growth test	0.769[D]	-0.662[C]	1		
	Seedling speed growth test	0.474[B]	-0.394[B]	0.053[A]	1	
	Vigour index	0.943[D]	-0.841[D]	0.936[D]	0.313[B]	1
D	Germination	1				
	Electrical conductivity test	-0.962[E*]	1			
	Seedling growth test	0.944[D]	-0.936[D]	1		
	Seedling speed growth test	0.697[C]	-0.724[C]	0.737[C]	1	
	Vigour index	0.973[E]	-0.958[E]	0.994[E]	0.731[C]	1

C: cultivar; I: indeterminate cultivar Mister; D: determinate cultivar Perkoz
*Interpretation of Pearson's linear correlation coefficient:
[A] $0 \le p < 0.2$ – practically no relation between characters
[B] $0.2 \le p < 0.5$ – poor relation between characters
[C] $0.5 \le p < 0.75$ – medium relation
[D] $0.75 \le p < 0.95$ – strong relation
[E] $0.95 \le p < 1.00$ – practically functional relation

Table 4 includes regression equations and coefficients of determination concerning the dependence between the germination and the electrical conductivity test and the seedling growth test. The dependences between the parameters under analysis were rectilinear for both cultivars under investigation. The calculation of regression coefficients leads to conclusion that the increase of 1 $\mu S \times cm^{-1} \times g^{-1}$ electrical conductivity value both cultivars caused the decrease the germination of yellow lupin seeds from 0.84 % (the D cultivar) to 1.55 % (the I cultivar). As results from the coefficients of determination R^2, the interdependence between the parameters was high and reached 82–92%.

Table 4

The regression equation and the coefficient of determination of changes in the germination depending on the electrical conductivity test and the seedling growth test (mechanical harvesting)

C	Regression equation	R^2
	Electrical conductivity test	
I	$y = -1.558x + 122.56$	0.82
D	$y = -0.8441x + 121.91$	0.92
	Seedling growth test	
I	$y = 10.117x + 26.07$	0.59
D	$y = 4.8326x + 57.677$	0.89

C: cultivar; I: indeterminate cultivar Mister; D: determinate cultivar Perkoz:

Also, the correlation between the germination and the seedling growth test was rectilinear (Table 4). This dependence concern both studied cultivars. However, it is necessary to stress the fact that depending on the cultivar, the germination of yellow lupin seeds can be expected to increase from 4.8% to 10.1% along with an increase in the length of seedlings by 1 cm. The interdependence between the seed parameters under study was different and it was the strongest in the determinate cultivar D (R^2 = 0.89%), whereas in the traditional cultivar I the value of R^2 coefficient was 0.59%.

Table 5

The regression equation and the coefficient of determination of changes in the vigour index depending on the germination, electrical conductivity test and the seedling growth test (mechanical harvesting)

C	Regression equation	R^2
	Germination	
I	y = 0.0864x + 41.878	0.88
D	y = 0.0414x + 64.678	0.94
	Electrical conductivity test	
I	y = -0.0449x + 46.944	0.70
D	y = -0.0464x + 66.264	0.91
	Seedling growth test	
I	y = 0.0065x + 2.4909	0.87
D	y = 0.0083x + 1.6268	0.98

C: cultivar; I: indeterminate cultivar Mister; D: determinate cultivar Perkoz

The analysis of variance with assessment of curvilinear effects concerning the germination of yellow lupin seeds and the seedling growth test proved that the values of those parameters increased rectilinearly as the vigour index increased (Table 5). The comparison of the yellow lupin cultivars under investigation shows that the determinate cultivar D exhibited the strongest correlation between the vigour index and the seed germination and between the vigour index and the seedling growth test. The strong correlation was also proved by the coefficients of determination (R^2) which ranged from 94 to 98% in that cultivar.

The research revealed that there was a rectilinear dependence between the value of electrical conductivity and the vigour index both cultivars under investigation (Table 5). The values calculated in regression equations lead to the finding that regardless of the cultivar type an increase in the vigour index led to a decrease the value of the electrical conductivity test. However, it is necessary to stress the fact that the cultivar D revealed greater strength of those correlations, which was expressed with the coefficient of determination (0.91%).

DISCUSSION

Lupin is a legume which is primarily valued for its high protein content, which is similar to that of soybean, and for its full range of essential amino acids and important dietary minerals. In contrast to soybean lupin can be grown in more temperate or cool climates and it can be considered as the strongest potential competitor of soybean (Dueñas, *et al.*, 2009). Lupin seeds are used as a source of protein for animal and human nutrition in various parts of the world (De Cortes Sanchez, *et al.*, 2005). The large size of soybean and lupin seeds make them vulnerable to mechanical damage during harvest, which can influence their quality.

The germination test is widely accepted and frequently used as an indicator of the quality of a seed lot. However, under field/greenhouse conditions the germination test overestimates the performance of seeds because it is performed under optimal conditions for each species. Furthermore, it is inadequate for discriminating between seed lots in terms of the speed and uniformity of seed germination (Copeland and McDonald, 2001). In order to overcome these inconveniences, the seed vigour concept was proposed (Contreras and Barros, 2005). Legumes with large, normally living cotyledons are good candidates for the electrical conductivity vigour test to indicate field emergence, because they still germinate in the laboratory even with considerable areas of dead tissue on their cotyledons provided that critical areas of the embryo remain living (ISTA, 2003).

In this conducted experiment Me decreased the seed quality both cultivars of yellow lupin. Cultivar D had higher electrical conductivity even though it had better germination percentage and vigour index. The seed damage done by Me to this cultivar was probably higher, because the loss of its germination was higher than in the seeds of cultivar I. In the experiment conducted by Maryam and Oskouie (2011) there were significant differences in mechanical damage percentage and in seed germination between the soybean cultivars tested. The results which implied a significant difference between the cultivars under study in terms of mechanical damage show that the character of mechanical damage is one of the traits related to the cultivar. In fact, this character is related to seed coat characteristics, i.e. the more integrated the seed coat is and the higher the lignin content is, the more resistant it is to mechanical damage and if the seed coat is thinner and more fragile, the susceptibility to mechanical damage increases. The lignin content in the seed coat is correlated with the index of seed resistance to mechanical damage (Capeleti, *et al.*, 2005). Legume crops have a thick seed coat, which makes germination difficult. If the seed damage was not deep and did not reach the embryo, it could make germination easier, but the exudation can be higher, similar to scarification. Seed scarification (a technique of physical damage to the seed coat to reduce hard seeds while keeping the seeds viable) is used to soften hard seeds (Kimura and Islam, 2012). When damage is close to the embryonic axis, the probability of producing abnormal seedlings rises, but if damage occurs far from the embryonic axis, the possibility of producing normal seedlings increases (Maryam and Oskouie, 2011). Matthews and Powell (2006) claim that the seed lots with little testa damage imbibe slowly, show little imbibition damage and have high emergence. This emphasizes the importance of the integrity of the testa in determining the vigour of some species of legume grain and hence the need to minimize damage to the testa during harvest and processing. In the experiment by Maryam and Oskouie (2011) the cultivar of soybean with the best germination percentage also had the highest percentage of mechanical damage and the highest result of the electrical conductivity test. These authors claim that in the electrical conductivity test which evaluates seed vigour and viability, a damaged seed coat allows seed matters to exit and a damaged seed has higher exudation and a higher rate of electrical conductivity. But Matthews and Powell (2006) claim that high levels of leakage are characteristic of low vigour lots with acceptably high levels of laboratory germination but with low field emergence, particularly in cold, wet soils. A characteristic feature of legume seeds is a great diversity between the planned and the really obtained in field conditions seed germination ability, which has an impact on plant emergence in the field (Faligowska and Szukała, 2008). Vigour tests are used to indicate the relative emergence performance of seed lots more reliably than with a standard germination test (Matthews, *et al.*, 2009).

CONCLUSIONS

Mechanical harvest leads to loss about a few percent of seed's sowing value and vigour. The amount of these losses depends on cultivar.

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