Int. Agrophysics, 1999, 13, 221-225

EFFECT OF VARIOUS FERTILIZATION LEVELS ON THE CRACK RESISTANCE OF HORSE BEANS*

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Accepted February 6, 1998

A b s t r a c t. Static compression tests were carried out on horse bean seeds within the scope of tests on micro tensile tester, Model Zwick 1425. The maximum value of force [N] causing bean crack and sample deformation [mm] up to the bean crack moment, were determined. The variation of predetermined mechanical indicators was analysed depending on the mode of varied fertilization, bean moisture content and loading direction.

It was shown that varied fertilizer dose has significant effect on value of force causing bean damage and bean deformation up to crack.

K e y w o r d s: horse bean seeds, mechanical damage, fertilizer dose, moisture content

INTRODUCTION

In the process of harvesting, cleaning and drying, beans are often subjected to mechanical damage which causes a reduction in their biological value. The direct causes of damage are various forces (impact, friction, compression) acting on beans during processing, as well as the forces of internal stresses caused by the effects of temperature, water and other factors [5]. As confirmed by numerous authors [2-5] the moisture content of beans is one of the basic factors influencing the behaviour of beans under loads, as well as determining the number and the character of damage. Among biological, physical and thermal factors, an important role in the resistance to damage is played by bean hardness and resilience. The higher bean resilience the better resistance to damage and therefore higher their sowing value/potential. Particularly important here is the seed cover, its structure, position and chemical composition [1,6]. Therefore, it is useful to determine the effect of various modes of fertilization of horse bean plantations on the mechanical damage of beans.

METHODS AND SCOPE OF RESEARCH

Laboratory tests were performed on the Nadwiślański variety of horse bean. The material for tests was from a field experiment with varied levels of fertilization with nitrogen (0/50 /70; 40/50/70 kg/ha), phosphorus (40/0/70; 40 /120/70 kg/ha) and potassium (40/50/0; 40/50 /180 kg/ha).

The plants were harvested manually after reaching full maturity. Prior to each series of measurement the pods were moistened in a plastic-foil tunnel in order to obtain proper moisture content. The moisture content was determined

*Paper presented at 6 ICA

by means of the drier method according to PN69/R69950. After reaching the specific moisture content, beans were manually removed from their pods while selecting healthy beans of required size. The sample size for each mode of varied fertilization was 50 beans in three repetitions.

The measurements of bean resistance to mechanical damage in conditions of quasi-static loads were performed on a micro tensile tester Model Zwick 1425.

The block diagram of the measuring stand is presented in Fig. 1. The bean was suitably positioned on a tester base (A-bean side, B-bean longitudinal axis), then a moving beam, having a measuring head with a flat punch on its end, was started.

The speed of head punch, until the moment of initial stressing of the sample, was 0.25 mm/s. After this initial stressing (at F=40N) the stopped measuring head was re-started with a speed of 0.05 mm/s. In the compression process, each bean was strained until it cracked. The value of force causing bean cracks, sample deformation and the value energy of deformation were recorded by a printer. After bean damage the beam with its measuring head moved to a determined position with a initial speed of 6.7 mm/s.

TEST RESULTS

Laboratory tests were performed on the following parameters: average bean diameter 8.71 mm (coefficient of variation 1.7 %), average bean length 10.70 mm (coefficient of variation 1.5 %) and average mass of 1000 beans -510 g. Since beans having high moisture contents exhibited high plastic characteristics, which made a precise recording of the moment of bean damage impossible, the tests were carried out only for a moisture content range of 10 to 16 % (average coefficient of variation 3.3 %).

With force applied from two directions onto beans in the tested range of bean moisture content, beans exhibited a varied resistance to mechanical damage.

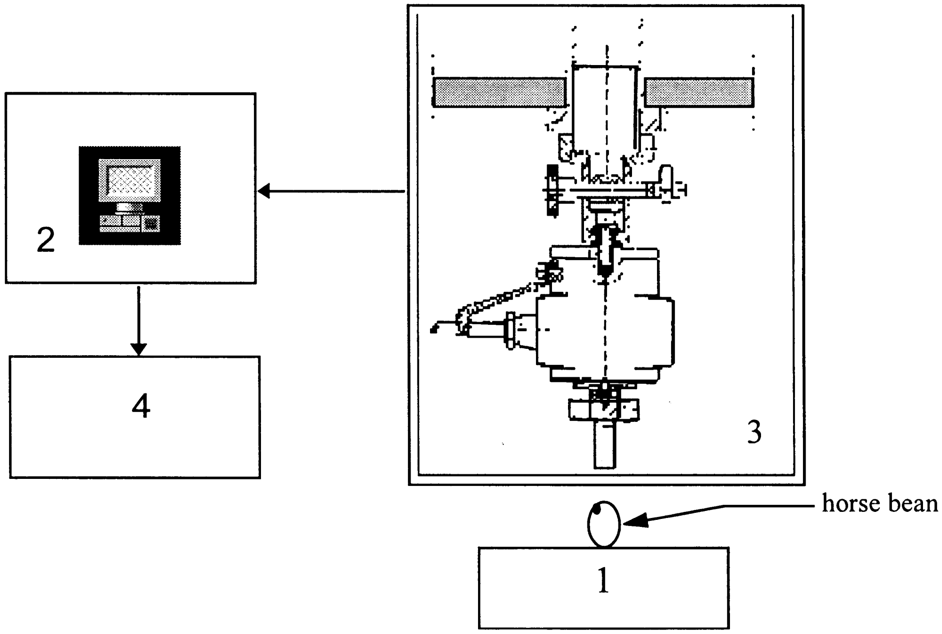

Fig. 1. Block diagram of measuring stand: 1-base, 2-measuring head with strain-guge transducer, 3-computer, 4-printer.

The highest resistance to mechanical damage in static loading conditions was recorded for beans of the lowest moisture content loaded from A side (bean side). With bean moisture content rising bean plasticity increased and their resistance to mechanical damage decreased (Fig. 2).

The curve showing the value of force F_{max} [N] causing horse bean cracks versus bean moisture content and load direction for the analysed fertilisation doses, can be expressed as a linear function:

$$F_{max} = a + bw \quad [N]$$

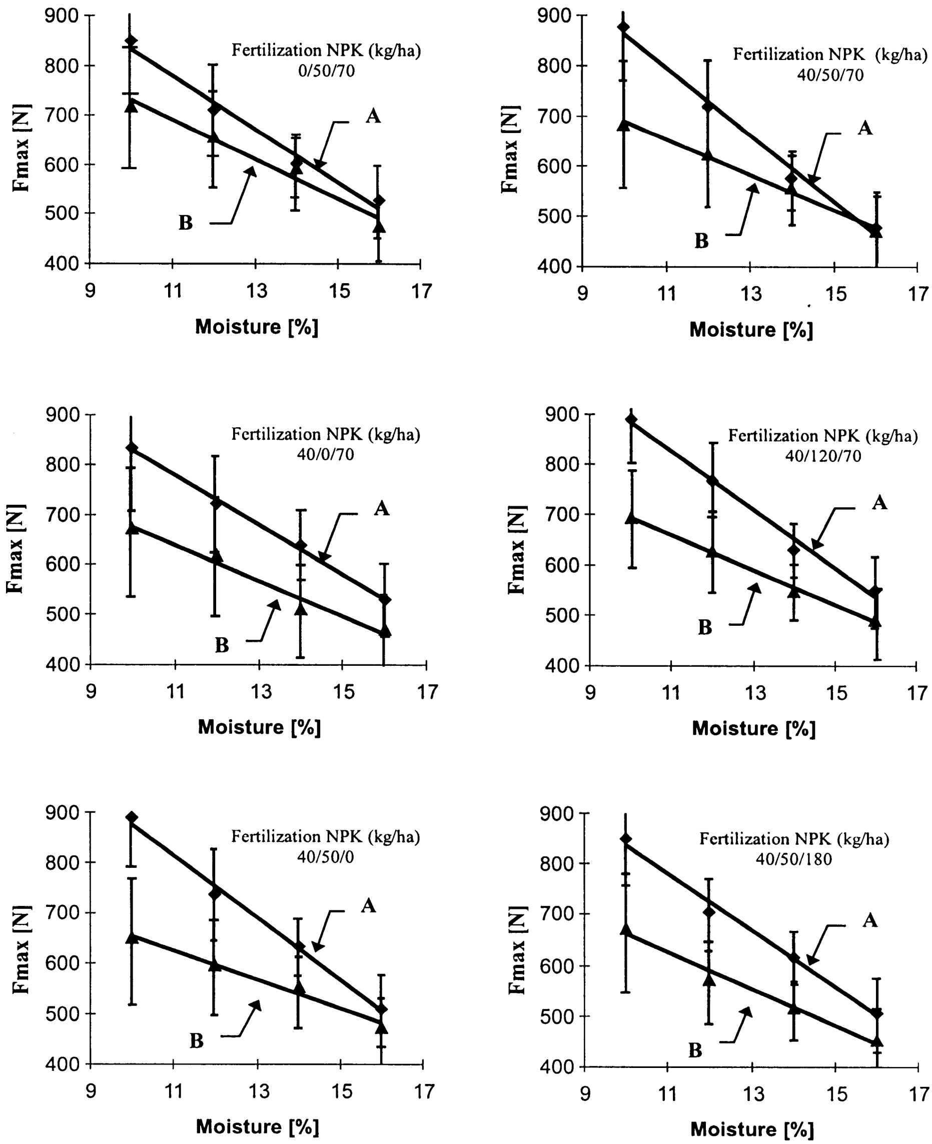

Fig. 2. The variation in values of force F_{max} [N] causing horse bean cracks versus bean moisture content, load direction and varied: nitrogen, phosphorus, potasium fertilization (loading direction A-bean side, B-bean longitudinal axis).

where: F_{max} - maximum force causing bean cracking, a, b - coefficients, w - moisture content [%].

The curve reflecting horse bean crack strain L_{max} [mm] versus beat for the applied doses is expressed by a linear function:

$$L_{max} = \exp(a + bw) \text{ [mm]}$$

where: L_{max} - maximum crack strain; a, b - coefficients; w - moisture content [%].

Table 1 presents the values of function coefficients.

The highest resistance to cracking was observed in beans from the plot with a fertilization dose: N - 40 kg/ha, P_2O_5 -120 kg/ha and K_2O - 70 kg/ha. The average value of cracking force was 489 N at bean moisture content of 16 % and as high as 890 N at bean moisture content of 10 %. Beans from the plot with a fertilization dose: N - 40 kg/ha, P_2O_5 -50 kg/ha and K_2O - 180 kg/ha exhibited the highest plasticity and the lowest resistance to damage. Refer to Table 2 for the average values of bean deformation (strain) for analysed doses versus bean moisture content and load direction.

Table 1. Statistical values of experimental dependences

Fertilization NPK (kg/ha)	Loading direction*	Coefficients					
		$F_{max} = a + bw$			$L_{max} = \exp(a + bw)$		
		a	b	R	a	b	R
0/50/70	A	1420.2	-57.1	-0.95	-1.75	0.11	0.94
	B	1128.1	-39.7	-0.94	-4.29	0.32	0.96
40/50/70	A	1531.3	-66.8	-0.98	-2.10	0.10	0.96
	B	1041.1	-35.2	-0.95	-4.20	0.30	0.97
40/0/70	A	1322.2	-49.4	-0.97	-1.70	0.10	0.94
	B	1020.2	-34.2	-0.96	-4.18	0.30	0.97
40/120/70	A	1431.5	-55.1	-0.98	-2.10	0.12	0.97
	B	1038.3	-34.6	-0.94	-4.30	0.31	0.96
40/50/0	A	1498.5	-61.8	-0.98	-2.40	0.20	0.96
	B	939.1	-28.5	-0.97	-3.50	0.30	0.94
40/50/180	A	1397.1	-56.1	-0.98	-1.98	0.12	0.93
	B	1049.1	-37.6	-0.93	-3.90	0.30	0.91

* Loading direction: A-bean side, B-bean longitudinal axis (on nucleus side).

Table 2. Average values of bean deformation L_{max} (mm) for analysed doses versus bean moisture content and load direction

Fertilization NPK (kg/ha)	Moisture (%)							
	10		12		14		16	
	A	B	A	B	A	B	A	B
0/50/70	0.53	0.41	0.61	0.59	0.72	1.12	1.02	2.92
40/50/70	0.49	0.41	0.59	0.59	0.76	1.06	1.08	2.79
40/0/70	0.53	0.39	0.63	0.52	0.75	0.96	1.02	2.48
40/120/70	0.49	0.37	0.58	0.49	0.76	0.98	1.04	2.42
40/50/100	0.45	0.51	0.55	0.79	0.71	1.22	1.19	2.87
40/50/180	0.52	0.48	0.62	0.67	0.77	1.33	1.13	3.18

Using the single-factor analysis of variance (ANOVA) it was shown that bean moisture content, the direction of loading and the fertilization dose had a significant effect on the value of force causing bean damage and on the crack strain. On the basis of test on uniform groups with 95 % of confidence interval statistically significant differences were found for all pairs of average moisture levels and force directions, as well as most fertilization doses.

CONCLUSIONS

1. In the tested range of moisture content (10 - 16 %) beans having the lowest levels of moisture content exhibited the highest resistance to cracks.

2. Beans from the plot with a fertilization dose: N - 40 kg/ha, P_2O_5 -120 kg/ha and K_2O - 70 kg/ha exhibited the highest resistance to cracking.

3. Lower resistance to cracking and higher strains (deformation) in the tested range of moisture content were recorded for loads applied along bean axis.

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