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Efficiency of the magnetic treatment of broad bean seeds cultivated under experimental plot conditions

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A b s t r a c t. The tests were carried out in the Institute of Soil Science and Plant Cultivation in Puławy under experimental plot conditions in the years 2000-2001. The factor of the first order were two varieties of broad bean: Nadwiślański – a traditional form and Tim – a self-determining form, while the second factor was – 3 exposure doses of magnetic induction intensity: The magnetic treatment of the seed was done in the Department of Physics at the University of Agriculture in Lublin using a specially constructed device for the magnetic treatment of seeds prior to sowing equipped with an electromagnet with fluent regulation of magnetic induction. The research confirmed the positive effect of the magnetic treatment on the germination and emergence of both broad bean cultivars. Plant emergence was more regular after the use of the aforementioned treatment and occured 2-3 days earlier in comparison to the control plants. The magnetic treatment of broad bean seeds prior to sowing exerted a significant influence on the increase of seed yield. However, the efficiency of this treatment was dependent on the weather. The gain in seed yield resulting from the pre-sowing treatment of seeds with a magnetic field for both forms of broad bean was due to the higher number of pods per plant and the fewer plant losses in the unit area in the growing season.

K e y w o r d s: broad bean, magnetic field, emergence, plant development, yield

INTRODUCTION

In the modern agriculture of the XXIst century, increasing attention has been paid to the productive growth of cultivated plants which are also environmentally safe. Studies carried out show that the application of high quality, specially prepared seed is an important, yet still underestimated, yield-forming factor in the cultivation of many species of agricultural plants. In the treatment of seeds prior to sowing, chemical methods are frequently applied which consist mainly in treating the seed with various chemicals. These methods are recognised as harmful for the environment because they are not selective in respect of wildlife although the agro-chemicals introduced are often very efficient. Nowadays, with the proposal of the rational use of agricultural land, greater importance is attributed to some physical methods of the pre-sowing treatment of seeds [9,11,13,18,22] which are commonly regarded as being friendlier to the environment. These physical factors often only modify the course of some physiological processes in the seeds, which increases their vigour and contributes to the improved development of the plant [4,6,20]. Special attention should be paid to the magnetic field which can stimulate some processes occurring in the seeds and plants [12,14,16]. So far only limited research has been conducted on this issue concerning mainly cereals and root crops. This problem may be very important for legume cultivation because these plants are characterised by their low and rather variable seed yield over the years [10].

The aim of the research undertaken was to determine the influence of the magnetic treatment of seeds on the development and yield of the broad bean under experimental plot conditions.

MATERIAL AND METHODS

The research was conducted at the Institute of Soil Science and Plant Cultivation in Puławy in the years 2000-2001. The experiment was put as split-block system on the

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soil belongs to good rye complex. The mineral fertilization was P_2O_5-60 kg ha^{-1}, K_2O-80 kg ha^{-1} and 30 kg N ha^{-1}. The plot area for harvesting was 4 m^2. The first factor was two cultivars of the broad bean: Nadwiślański – the traditional form and Tim – the self-determining form; the second factor was the 3 exposure doses of magnetic field intensity: D0 – no bio-stimulation (control), D1 – 10750 Jm^{3}s (B = 30 mT, s = 15s), D2 – 85987 Jm^{3}s (B = 85 mT, s = 15 s). The magnetic treatment of seeds was conducted in the Department of Physics, of the University of Agriculture in Lublin, using a specially constructed appliance for the pre-sowing treatment of seeds with a magnetic field created by an electromagnet with fluent regulation of the intensity of the current flow [13]. Owing to the specific core construction and the independent six feeding coils, an alternating magnetic induction ranging from 30 to 100 mT in the 144 cm^2 area was obtained. The seeds were hand sown at about 8-10 cm depth, at a density of 40 plants m^{-2}. The plants were dressed with Funaben T two weeks before sowing followed by immediate harrowing to cover the seeds with soil and level the field area. Chemical weed control was executed after sowing by using Afalon in the dose 1.2 kg ha^{-1}, which was applied into the soil. At the later stage of lupine development, the weeds were eliminated mechanically. Over the vegetation period precise observations and measurements of plants were conducted as well as the extent of the damage caused by fungi and pests. The plants were calculated having fully shooted, just before harvest on a 1m^2 area. The following dates of the various phases of the plants' developmental phases were noted: full emergence, the beginning and end of flowering and browning of 5 and 80% of the pods. Moreover, an assessment of the infestation state of the seed was carried out according to a 9 – grade scale (1 being the highest infestation, 9 – no infestation). Throughout the full flowering time 10 randomly chosen plants were measured for their height up to the top, the leaves having been removed and the measurements of the area taken by the LI-3050A apparatus for leaf area measurement from the LICOR Company. The results obtained were converted into 1m^2 area. However, prior to harvest, 10 random plants were chosen from each plot to determine: the height up to the first and last pod, to the plant's apex, the number of pods per plant and the number of seeds. The following measurements were taken after the plant harvest: seed humidity, weight of 1000 seeds and seed yield converted to 14% moisture. The results were processed statistically with variance analysis using Statgraphics 4.0 program. The statistical analysis included theTukey semiinterval confidence at the significance level $\alpha = 0.05$.

RESULTS

The weather conditions during each year of the experiment varied significantly. The amount of precipitation and the mean day temperatures during the sowing-emergence period exerted a great impact on the uniformity of emergence. The year 2001 was unfavourable in this respect, when apart from a deficiency in precipitation, considerable falls of temperature from sowing to emergence were recorded; hence the start of the emergence of the broad bean was observed as late as 28 days after sowing (Table 1). In an analogical period of time in 2000, more abundant precipitation was noted and the mean day temperature was higher compared to 2001 so the broad bean emergence was recorded just 22 days after sowing. Consequently emergence was earlier and more uniform. Observations were also made regarding the effect of the magnetic treatment of seeds on the term of the appearance of the first emergence. In both years, the emergence of plants from those seeds pre-treated with the magnetic field was noted some 2 days earlier in comparison with the control. Significant differences were found in the emergence dynamics of plants from the seeds placed in a magnetic field and those not pre-treated magnetically before sowing (Fig. 1).

There was no difference between the broad bean cultivars in relation to the term of emergence. However, a significant difference occurred in the uniformity of emergence and the number of plants actually emerging. In both years of research more plants of the Nadwiślański variety emerged in comparison with the Tim variety this being the direct result of seed quality and their ability to germinate. The Nadwiślański variety of faba bean had 91and 96% energy and germination ability, whereas the Tim variety had 84 and 88%, respectively. The magnetic treatment of seeds affected to a greater degree the improvement of the poor germination of the Tim cultivar than was the case with the better germinating Nadwiślański variety.

A significantly higher percentage of the germinating plants grown from the treated seeds in comparison with the non-treated plants was noted especially from the start of the emergence of the broad bean. The magnetic treatment of seeds prior to sowing modified the growth and development of the broad bean. Generally, the plants grown from magnetically pre-treated seed were taller, especially over the period from emergence to flowering.The magnetic field changed the height of the self-determining variety of plants in greater measure than was the case with the traditional Nadwiślański variety. Differences in plant height were also observed between the varieties of broad bean examined. Plants of the traditional Nadwiślański cultivar were taller than those of the self-determining variety – the Tim – throughout the whole vegetation period.

Some differences were also reported in the leaf area in those plants grown from seed pre-treated with the magnetic field and those which had not been non-treated (Fig. 2). The leaf area of those broad bean plants grown from biostimulated seed was measured at the 3-4 leaf phase and at flowering; it extended in relation to the plants obtained from non-treated seed by 19.4 and 14.7%, respectively. However,

T a b l e 1. Weather conditions at different stages of the growth of the white lupine

Year	Sowing-emergence			Emergence - flowering			Flowering - pods setting			Pods setting - maturity			Sowing - maturity		
	number of days	CMT*	precipi-tations (mm)	number of days	CMT	precipi-tations (mm)	number of days	CMT	precipi-tations (mm)	number of days	CMT	precipi-tations (mm)	number of days	CMT	precipi-tations (mm)
Nadwiślański variety															
2000	22	189	81	36	597	38	10	167	13	58	1026	197	126	1994	329
2001	28	187	48	39	553	49	11	150	32	52	1014	165	130	1904	294
Tim variety															
2000	22	189	81	34	566	38	9	138	4	54	946	137	119	1839	237
2001	28	187	48	35	498	34	10	131	17	48	641	154	121	1757	253

* - sum of temperature.

at maturation, the leaf area diminished by 38% due to the earlier drying up of those plants grown from treated seed. Some significant differences concerning the formation of the leaf area were also reported with regard to the broad bean varieties examined.

The leaf area of the broad bean of the Nawiślański variety was equal to 0.8612 m^2 at flowering, while for the Tim variety it was 0.6924 m^2.

Plants grown from the treated seeds exhibited longer shoots with their pods being sometimes referred to as the fruiting part of the pod (Table 2). The length of the stem section was on average 4.8% for both cultivars. The length of the broad bean's stem is positively correlated with seed yield. As for the Tim, the self-determining variety, the pods were to be found on the the longer section of the stem, in contrast to the traditional variety – Nadwiślański.

During field observations, the earlier maturing of the plants was found to have been caused by the pre-treatment of the seeds with a magnetic field. However, no clear differences were stated in the course of any other developmental phases of the plants, including flowering.

Considering the competition for light, water and nutrients, the plant canopy changed significantly over the vegetation period. Throughout this time, many of the Tim variety in the canopy decreased more compared to the Nadwiślański variety. On average the 2 year study has shown that plant losses reached 9.2% for the traditional form and 7.8% for the self-determining form from emergence to harvest. The differences in plant losses between the two forms of broad bean were likely to have arisen from the various morphological structures of the plants. The traditional variety, the Nadwiślański, had a more solid morphological structure than the self-determining Tim variety. Therefore the inter-competition of the plants is different in relation to the traditional and the self-determining forms. The magnetic stimulation of the seeds clearly limited plant loss in the canopy to a greater measure in the case of the traditional Nawiślański than was the case for the self-determining Tim variety. Both doses of magnetic induction used in the experiment had a favourable influence in reducing plant loss during vegetation.

The weather had a serious impact on levels of broad bean yield in each year of research. The sufficient precipitation and the relatively high temperatures at the flowering and pod setting stages in 2001 had a positive influence on seed growth and as a consequence, the plants gave a higher yield than in 2000. In the analogical period of 2000, a water deficiency in the soil was recorded. In addition, high day temperatures and not too much precipitation over the ripening period contributed to a crop of healthy seeds which were attacked by fungal diseases albeit slightly.

Treatment of the sowing material of both broad bean cultivars gave a positive result on seed yield levels, yet this effect differed for each year of research. The interaction between the exposure dose of the magnetic induction and

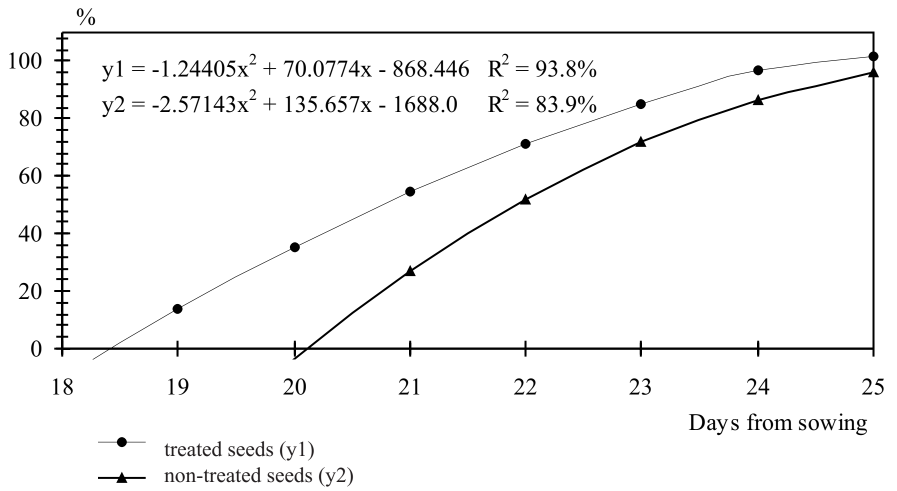

Fig. 1. Dynamic of white lupine emergence under experimental field conditions.

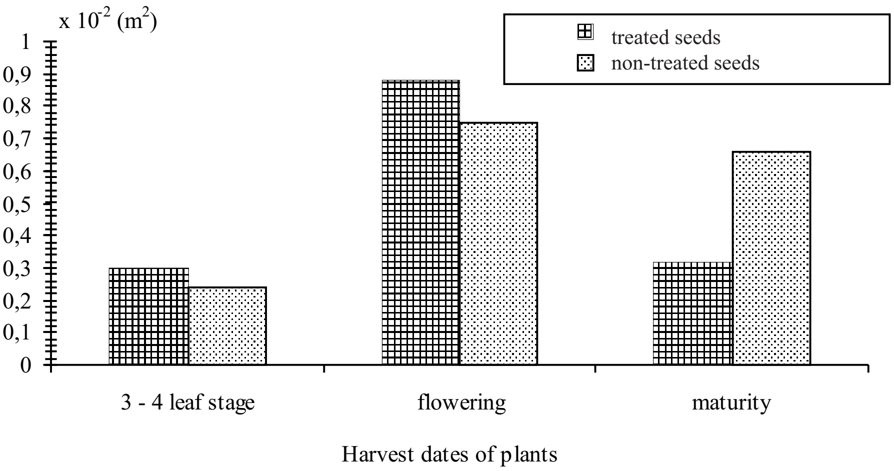

Fig. 2. Leaf area of plants grown from treated seeds and control.

broad bean cultivars in relation to the seed crop occurred in each year of the experiment. These significant differences were seen as being due to the pre-sowing treatment of seeds with a magnetic field in the varieties examined. In each year of the experiment, the self-determining variety, Tim, responded more strongly to the pre-sowing treatment of seeds than did the traditional variety Nadwiślański. For two years, the mean increase in the experimental seed crop of the Nadwiślański and Tim varieties as attributed to this treatment reached 11.5 and 12.9%, respectively. Both exposure doses of the magnetic field (D1 and D2) exerted a favourable impact on the increase of the seed crop of the broad bean cultivars. The increased seed yield was a consequence of the increased number of pods on the faba bean plants grown from treated seed (Fig. 3) as well as the reduced plant losses in the canopy at vegetation (Table 2). Accurate measurements of plants taken just before harvest showed that a plant Tim cv. obtained from non-treated seed produced about 11.3 pods, whereas plants grown from treated seed produced 10.4 pods per plant. For the Nadwiślański variety these values were lower: 10.9 and 9.8 pods per plant, respectively.

Each applied dose of exposure increased the number of pods per plant. However, for the self-determining Tim variety, a higher dose (D2) of magnetic field gave better effects, while for the traditional Nadwiślański, a lower dose (D1) was more efficient. No significant difference was reported in the mean number of pods per plant over any particular research year, therefore the results obtained are presented as an average over three years.

T a b l e 2. Value of some morphological and using features of the faba bean before harvest

Description	Plant losses during vegetation (%)	Length of stem with pods (m)	Number of seeds per plant	Number of seeds per pod	Mass of 1000 seeds (g)
Magnetic exposure dose					
D0	12.4a*	0.30a	32.4a	3.2a	456a
D1	7.2b	0.33b	36.4b	3.2a	449a
D2	7.0b	0.34b	38.6b	3.5a	458a
Varieties					
Nadwiślański	9.2a	0.28a	34.3a	3.3a	444a
Tim	7.8b	0.34b	37.4b	3.4a	399b

*values in columns marked with the same letters do not differ significantly.

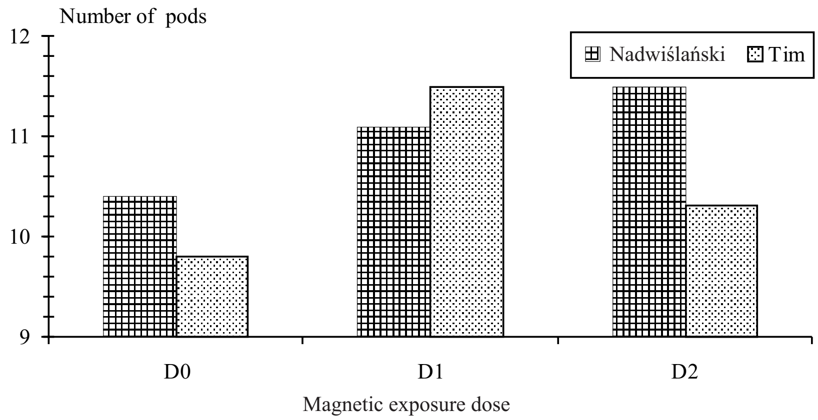

Fig. 3. Number of pods per plant dependent on magnetic exposure dose.

A detailed analysis of the post-harvest yield structure showed that the plants grown from the treated seeds produced more seeds than those obtained from the non-treated seeds (Table 2). The influence of the magnetic induction on the effects measured by the number of seeds per broad bean plant had a similar effect on the pods.

On the other hand, no influence was observed concerning this treatment on the number of seeds per pod or the weight of 1000 seeds. Some significant differences were stated in relation to the number of seeds per pod and the weight of 1000 seeds in the broad bean varieties studied. The self-determining variety of broad bean – Tim, gave significantly higher seed yields per plant compared to the traditional Nadwiślański variety (Table 3), but the seeds of the Tim variety showed a lower weight per 1000 seeds (399 g) than did the seeds of the Nadwiślański variety (445 g).

DISCUSSION

On the basis of the field experiments carried out, it was found that the magnetic treatment of broad bean seeds prior to sowing had a positive influence on the development of some morphological traits of the plants. The results obtained were a bit lower compared to those obtained in other experiments with some species of cultivated plants [12,14] although 10% more crop growth is of great importance in improving plant yield levels. The pre-sowing magnetic treatment of seeds as one of the physical methods for preparing seeds, affects plant development and plant yield in different ways in any given research year. This fact, in turn, points to the dependence of the efficiency of this treatment on the weather. These results are also confirmed by Pittman [16] in relation to some corn species.

Apart from the weather conditions mentioned above, some other factors, like seed moisture, influence the course of germination and the on-going development of plants grown from seed which has been treated by physical factors. Pietruszewski [15] observed the better germination of spring wheat grains which had been soaked in water prior to placing them in a magnetic field as compared to grains containing less water. This was explained by the higher ion mobility in the moister seeds after pre-sowing magnetic treatment. However, Podleśny [19] proved the evident interaction of other physical factors – laser radiation and seed humidity – with regard to the progress of germination and the growth and development of the broad bean.

T a b l e 3. Yield of faba bean seeds (kg m^{-2})

Variety		Magnetic exposure dose	Years		$\bar{x}$
			2000	2001	
Nadwiślański		D0	0.244	0.293	0.268
		D1	0.284	0.325	0.304
		D2	0.282	0.322	0.302
		$\bar{x}$	0.270	0.313	0.291
Tim		D0	0.182	0.221	0.201
		D1	0.212	0.250	0.231
		D2	0.218	0.244	0.231
		$\bar{x}$	0.204	0.238	0.221
Interaction	II/I		0.024	0.018	0.036
	I/II		0.046	0.044	0.062

Reports in the Polish and foreign bibliography on the subject demonstrate that although seeds of the cultivated plants respond to the physical factors, they do so primarily when the optimum exposure dose is applied [5,9,12,15,22]. Lower doses of magnetic induction usually stimulate seed germination and its further development; however sometimes they can cause mutations. The results of the studies of Rybiński *et al.* [21], concerning the use of laser light in research on barley, prove the existence of the boundary value of the energy dose up to a value which may cause seed treatment. When surpassed, this causes mutation and a reduction in morphological trait values as well as yield structure. In the studies conducted, both magnetic doses influenced the increase of the yield positively but a smaller dose (D1) affected the development and yield more favourably in the self-determining variety Tim, whereas a larger dose was required for the (D2) – traditional variety Nadwiślański. As with the results of Phirke *et al.* [12] and Pietruszewski [13] it is evident that the exposure dose of the magnetic field has a great influence on the effect of the height obtained. The increase in broad bean crops was a result of the greater number of pods per plant and the reduction in plant losses from the canopy during vegatation. The studies of Gurusama and Kalavathi [7] showed that treatment of cowpea seeds with a magnetic field increased the number of pods per plant.

The opinion prevails that physical factors greatly influence the initial growth and development of plants, in particular their germination and emergence. In the field of research outlined here, the enhancement of the emergence of both broad bean varieties was observed. In addition, emergence was more uniform which points to the positive impact of magnetic treatment on germination and emergence in the species examined. The acceleration of the term and increase of the emergence of plants as an effect of the magnetic induction of seeds has also been noted in vegetable and cereal cultivation by Chao and Walker [3] *et al*., Pittman and Ormrod [17] and Hirota *et al*. [8].

In the author's field of research, differences in height between those plants grown from treated seed and those grown from non-magnetically treated seed have been observed. However, the differences were not too great (especially during the main axis flowernig period). The magnetic field modified more the height of the plants of the Tim variety than that of the Nadwiślański variety. The opinion generally prevails that plants obtained from treated seed are taller than those from the control. The results of studies presented in literature do not confirm the explicit effect of the magnetic treatment of seed on plant height. However, some reports suggest that the greater height of plants grown from seed treated with a magnetic field in comparison with the control refer mainly to the initial period of development [1].

In the studies carried out, no significant impact on the accelaration of plant flowering from seed magnetically induced could be demonstrated. This is the direct result of the difficulties experienced in making field observations where many other factors, like the weather, affect the course of plant growth and development. However, a few days' accelaration in the maturity of the broad bean was recorded. The data provided by the literature illustrates that plants ripen more rapidly when the seed has been treated with some physical factors. Boe and Solunkhe [2] for instance proved that tomatoes ripen earlier as a result of the influence of a magnetic field, whereas Pitman [16] showed the same with reference to cereals. A disturbance of the 'biological clock' rythm which manifested itself with the faster flowering of maize and with its earlier maturity was observed by Gieroba *et al*. [5] in studies on the laser treatment of maize seeds. Broad beans have a long vegetation period; hence accelerating maturity is very important as seeds harvested late are poor both for sowing and as fodder.

Data found in the literature confirms that the effects of the impact of physical factors on the seeds of cultivated plants are more noticeable in those experiments conducted under controlled conditions than is the case for those conducted in the field [11]. More precise research explaining the magnetic treatment of seeds is lacking. Further study on the research discussed above needs to be undertaken.

CONCLUSIONS

1. The magnetic induction of seed exerted a positive influence on the germination and emergence of both broad bean varieties. Due to this treatment, plant emergence was more uniform and occurred 2-3 days earlier than in the control.

2. The treatment of broad bean seeds with a magnetic field prior to sowing had a significant influence on seed yield. The efficiency of the treatment differed in each

research year demonstrating the overall effect that the weather has.

3. Both of the magnetic exposure doses applied modified the growth, development and yield of the varieties studied. Concerning the traditional Nadwiślański form, the higher (D2) dose of magnetic induction affected yields more favourably than did the lower dose; however with reference to the self-determining variety – Tim – the best effects were found after using the lower dose (D1).

4. The increase of seed yield due to the pre-sowing treatment with a magnetic field of both the traditional and self-determining forms of the broad bean resulted from the greater number of pods per plant and the fewer plant losses per unit area of vegetation.

5. No significant differences were found in the course of most developmental phases of those plants grown from the treated and non-treated seeds. However, a few days' acceleration was reported concerning the maturity of plants obtained from those seeds pre-treated magnetically in comparison to the control.

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