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STIMULATION OF GERMINATION AND GROWTH IN SOYBEAN SEEDS BY STATIONARY MAGNETIC FIELD TREATMENT

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ABSTRACT

The effects of stationary magnetic field on seeds are studied using two soybean varieties and three magnetic induction values: 100, 150 and 200 mT during 30 seconds of exposure. The germination percent, root and stem length as well as fresh and dry mass were measured under laboratory conditions, at the second week after sowing. The plant grown from treated samples (100 and 150 mT) and non-treated (B=0) were also evaluated under field conditions. The values of plant height (65 days after sowing) and the values of pod number, pod length and yield at 110 days (at the end of the plant cycle), were obtained. The results showed the enhanced of the germination percentage and root length of the Conquista and Incasoy-24 varieties treated with stationary magnetic field of 150 mT and 100 mT respectively. The rest of the parameters evaluated did not show differences with respect to the non-treated sample. These respective exposure regimes also provoked a significant stimulation on the yield and an inhibition on the plant height at 110 days, while the magnetic treatment of 100 mT enhanced significantly the plant height of Incasoy-24 variety at 65 days after sowing ($P<0.05$).
Keywords: Bioelectromagnetics, Legume, Plant, Yield

INTRODUCTION

The magnetic seed treatment has been developed as a physical tool to enhance the post-germination plant responses. Most papers report post-sowing physiological effects related with certain parameters of the pre-sowing exposure regime (magnetic induction "B" and exposure time "t_E") (Pietruszewski et al., 2007). A variable success of these researches has been found because the interaction mechanisms between the physical agent and the biological material are not completely understood nor the influence of other factors that modify its action (Podlesny, 2004).
The main advantage of the magnetic field treatment of seed, among others, is the easy manipulation with minimum risk to cause damage with respect to others organs like the leaves, stems or roots. On the other hand, the magnetic seed treatment has been disclosed around the world due to the impact on seed recovery applications for specific plant species, when seeds have a low quality (Fraga et al., 2007; Balouchi and Modarres-Sanavy, 2009). Several hypotheses to explain the effects of the magnetic seed treatment have been proposed, which relate not only to the morpho-physiological modifications during the first and second week after sowing (De Souza et al., 2006) but to other parameters like the yield components.
Among other hypothesis, the most accepted refers to variations in water uptake (Shine et al., 2011), considering the osmoregulatory effects predicted by simulation models (García and Arza, 2001; Socorro and García, 2012), an increase in the cytosolic peroxidase (Shine et al., 2012), as well as variations in the mineral nutrients content obtained experimentally (Sujak and Dziwulska-Hunek, 2010).
The researches carried out under field conditions show differences in later stages of the plant life cycle. These are: leaf number per plant in *Paulownia tomentosa* Baill (Alikamanoðlu et al., 2007), enhancement of yield in wheat (*Triticum aestivum* L.) (Kordas, 2002), sweet beet (*Beta vulgaris* L.) (Rochalska et al., 2009), legume seeds (Podlesny et al.,

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2004) and tomato (*Solanum lycopersicum*) (De Souza et al., 2006).

These effects observed at later stage of the plant life cycle are discussed through the analysis of stimulant effects from post-germination process (root length increment, speedy leaf shoot, among others), which allows a higher plant development during the posterior phases.

The aim of this paper was performed to characterize the effects of pre-sowing stationary magnetic field of soybean (G. *max*) seeds on the germination and growing during the plant cycle.

MATERIALS AND METHODS

The diagram of Fig. 1 shows the magnetic treatment device formed by six bobbins joined to an iron block creating a closed circuit (except for a 2 cm air gap where seeds are placed). The electric current intensity "I" in the bobbins provokes a stationary magnetic field which crosses the iron and the gap describing closed magnetic induction lines. The range of homogeneous magnetic field obtained in the gap is 0-230 mT, which depends on the electric current values inside the bobbins.

The soybean (*Glycine max* (L.)Merrill cv: Conquista, cv: Incasoy-24) was selected as experimental material. The samples were treated with three Magnetic Induction "B" values (100, 150 and 200 mT), during 30 seconds of exposure. These treatments and the non-treated sample or control (B=0) allowed to perform four experimental variants for each variety. The seeds were immediately placed and distributed after treatment in petri dishes (four replicates), so that each one was containing 40 seeds per dish. The germination percentage was evaluated in the 5th and 8th day, while other physiological parameters, like root and stem length as well as fresh and dry mass per plant were evaluated in the 8th day after sowing. A multivariate cluster analysis was carried out on the experimental results of the five parameters and the eight variants (four variants per variety).

The experiments under field conditions were carried out during summer-autumn seasons (August-November). Two Magnetic Induction values were used: B=100, 150 mT during 30 seconds of exposure and the control (B=0) per two varieties forming six variants. Three repetitions per variant were sowed (immediately after treatment) through a randomized block design. The plant height was measured at 65 days after sowing while other parameters like pod number per plant, pod length and yield were also evaluated at 110 days after planting.

For the statistical evaluation of the results, significance was defined by a probability level of P < 0.05. Data were analyzed by one-way analysis of variance (ANOVA) followed by a Duncan multiple comparison test using a version of Statistica pl.5.0 software for Windows.

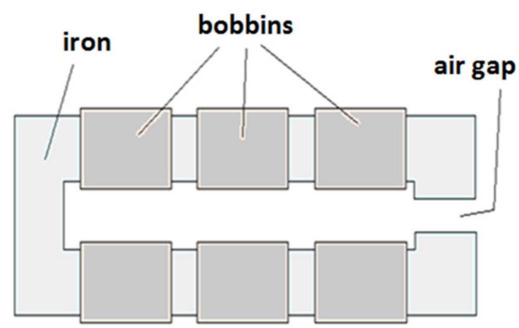

Fig 1: Scheme of magnetic treatment device. An iron with rectangular form is joined to six bobbins while the seed are placed in the air gap

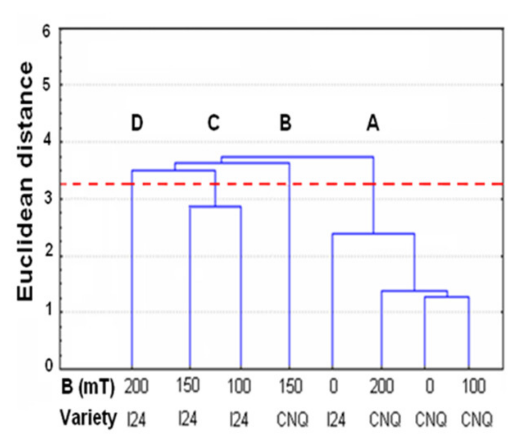

Fig 2: Cluster analysis diagram. The Euclidean distance value is represented by the dashed line. CNQ: Conquista, I24: Incasoy-24

RESULTS

The clusters analysis for the five physiological parameters in the eight combinations (four variants per each variety) is shown in the Figure 2. The diagram allows establishing four different groups using the value 3.25 as Euclidean Distance. The Conquista variety contains the treatments 100, 200 mT and the non-treated variant in the same group (A), while the value B=150 mT was included in the group B. The values for the Incasoy-24 variety showed that all treatments were located in different groups with respect to the non-treated variant.
The differences were found in the parameters: germination percent and root length. For the rest of the variables evaluated no differences were observed. Data are shown in Table 1.These results have highlighted the exposure 30 sec-150 mT as adequate regime to enhance significantly the germination and root length of Conquista variety. For Incasoy-24 variety, magnetic induction of 100 mT provoked increments in these parameters, while 200 mT also impacted on the root length increments.
The experiments under field conditions showed that treatments chosen from the laboratory influenced the plant height at the end of the plant cycle in both varieties, as well as the yield (Table 2). This effect was not observed neither in the pod number per plant nor in the pod length.
The plant height at the end of the plant cycle showed a significant inhibition in both varieties. Nevertheless, in contrast to this result, the yield was significantly enhanced finding effect in Incasoy-24 variety with 150 mT and Conquista variety with 100 and 150 mT.

Table 1: Values of the parameters evaluated in the second week after sowing (CNQ: Conquista, I24: Incasoy-24)

		B (mT)			
		0	**100**	**150**	**200**
CNQ	GP (%)	90.0 a	91.0 a	97.5 b	91.2 a
	SL(cm)	7.0 a	6.3 a	7.2 a	7.1 a
	RL(cm)	7.9 a	7.5 a	10.4 b	8.6 a
	FM(mg)	290 a	290 a	340 a	300 a
	DM(mg)	34 a	34 a	31 a	32 a
I24	GP (%)	90.0 a	96.3 b	94.0 a	91.3 a
	SL(cm)	10.9 a	11.2 a	10.9 a	10.6 a
	RL(cm)	10.4 a	13.6 b	11.7 a	13.9 b
	FM(mg)	390 a	410 a	450 a	440 a
	DM(mg)	24 a	27 a	27 a	26 a

Different letters represent significant differences according to the Duncan Test ($P<0.05$). GP: germination percentage, SL: stem length, RL: root length, FM: fresh mass per plant, DM: dry mass per plant.

Table 2: Values of morpho-physiological parameters evaluated under field conditions

		B (mT)		
		0	100	150
CNQ	PH (cm)	58 a	64 a	61 a
	FPH (cm)	100 b	97 b	93 a
	PNP	17 a	18 a	24 a
	PL (cm)	4.3 a	4.6 a	4.3 a
	Y (t/hA)	1.60 a	1.63 a	1.83 b
I24	PH (cm)	37 a	56 b	46 a
	FPH (cm)	67.7 b	50.0 a	66.0 b
	PNP	17 a	17 a	21 a
	PL (cm)	3.77 a	3.63 a	3.37 a
	Y (t/hA)	1.19 a	1.39 b	1.81 b

Different letters represent significant differences according to the Duncan Test (P<0.05). PH: plant height (65 days) FPH: final plant height (110 days), PNP: pod number per plant, PL: pod length and Y: yield.

DISCUSSION

The results found on the germination and root growth during the second week after sowing showed that the magnetic treatment responses differed among verities. These differences are explained by tissue biochemical composition or/and physical mechanisms at molecular level, which are associated to the interaction with the magnetic field (Galland and Pazur, 2005). For this reason, the exposure regime should be designed for each soybean variety.

The enhancement of root length at the beginning of the plant life cycle is a main factor for the seedling growth. A longest root impacts on a higher area for water and nutrients uptake (Azcon-Bieto and Talón, 2000) which favors the physiological process in later stages. The Conquista variety was the most sensitive to the 150 mT treatment with respect to the other magnetic induction values (100 and 200 mT), while Incasoy-24 showed a higher magneto-sensibility for 100 mT.

The root growth is related to the germination stages following the radicle emergence, when the imbibition (physical stage) is finished and a biological process starts where cellular division occurs. The root length was the only parameter significantly stimulated with respect to the control. This lets to suppose that the magnetic treatment strongly impact on water uptake by the embryo tissue, during the imbibition stage. This situation caused a higher cellular turgor in the radicle of the seedling coming from treated seeds.

Although mechanisms of magnetic field action on seed tissue are still discussed, some results obtained by simulation have shown differences on the ionic concentrations and membrane potential caused by stationary magnetic field action of 200 mT during 30 seconds (Socorro and García, 2012) as well as other experimental results have shown water uptake increments by treated seeds using magnetic field until 300 mT (Shine, *et al*, 2011).

The same values that provoked stimulant effects under laboratory conditions in both varieties also provoked the increase of the yield during the harvested (grain mass per area) which was also associated to a plant height inhibition. This relationship allows us to suppose that root length increment at the second week after sowing (due to magnetic field action of 100 mT) could increase the plant capacity of Incasoy-24 for a higher growth. The high development leads to increase of yield despite that effect in biomass is related with a loss of plant height at the end of the plant cycle. For the Conquista variety, the differences between 100 mT and control were not observed during the growth. The inhibition was shown at the end of the life cycle when the higher amount of photoassimilates was used for the grain filling.

The biomass increments found in advanced stages by other researches during the plant growth are analyzed by the relationship between root length increments and the water and nutrient uptake in the earlier stages (Stange et al., 2002). In the same way root length enhancement favors the ions assimilation like magnesium which compounds the chlorophyll molecule (Isaac *et al.*, 2011) and therefore impacts on the higher photo-assimilates productions and dry biomass increments.

Pietruszewski (1996) proposed that magnetic seed treatment is associated to a parameter called "doses", which depend on the magnetic induction square and the exposure time. For this reason the low intensity magnetic treatment could require a higher exposure time value. Other paper shows stimulant effects on soybean seeds using low magnetic induction values (near 1 mT) with high exposure time values (until 10 minutes) (Parsi, 2007). Nevertheless in this paper high induction values (100-200 mT) were used with only 30 seconds. This exposure time was chosen considering the possibility of implementing methodologies in the magnetic seed treatment to higher scale where the use of low exposure time values is more adequate from a practical point of view.

The high magnetic induction values (200-240 mT) used by Yao et al. (2005) provoked increment in the germination, growth and development in cucumber (*C. sativus*) seedling coming from treated seeds. On the other hand they also found increments in lipid oxidation and ascorbic acid content. The magnetic field effects on the enzymatic activity during the imbibition (when seed only absorbs water and the cellular division do not occurs) can impact on the plant development in the second week after sowing. Nevertheless this mechanism can also impact on a most organic substance degradation like respiration rate increment (Rochalskaand Orzeszko-Rywka, 2008), which rebounds on the no obtaining of biomass increments, such as the results collected in the Table 1.

CONCLUSIONS

- The magnetic induction values of 150 mT for Conquista variety and 100 mT for Incasoy-24 during 30 second of exposure, incremented the germination percentage and root length during the second week after sowing under laboratory condition.
- The exposure regime values provoking a stimulant effect under laboratory conditions were also found to stimulate yield and inhibit plant height on soil-grown plants.
- No effect was detected on the stem length as well as fresh and dry mass per plant during the second week after sowing, neither on the pod number nor pod length at the end of the plant cycle.

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