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The influence of low frequency magnetic field upon cultivable plant physiology

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Abstract. The 16 Hz frequency and 5 mT magnetic flux density as well as alternating magnetic field influence the field germination physiological yield-forming features and the yield of sugar have been investigated. The profitable influence of the investigated factor at physiological yield-forming features, causing an increase in sugar beet root and leaf yield, was shown. The beneficial influence on the yield is especially clear in unfavourable weather conditions.

Key words: alternating magnetic field • yield-forming features • photosynthetic active radiation (PAR) • leaf area index (LAI) • yielding • sugar beet

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Introduction

The static or alternating magnetic field is a factor more and more often used for improving the quality of sowing material of many crop species. In contradistinction to generally used chemical substances (for example mordants or matrix substances), the magnetic field is not dangerous for the chemistry of seeds or for the environment.

Many papers have indicated the beneficial influence of bio-magnetic stimulation on growth, development and yield of many plant species. Plants grown from the treated seeds are better developed, have higher vigour, are more resistant to unfavourable environmental conditions, more quickly enter successive development stages and yield better [3, 9, 11, 15]. Higher yield is caused by better morphological yield-forming features, such as length of the ear, number and weight of seeds in the ear or weight of thousand kernels [10, 14].

Plant productivity depends on photosynthesis, which enable synthesis of organic substances and biomass accumulation. This process is limited by the size of plants, photosynthetic apparatus in the stand of grain and stability or longevity of leaves. These parameters are defined by special physiological indicators. Nowadays, scientists use modern research techniques which are non-destructive and enable physiological measurements of plant throughout the whole vegetation period.

This paper is intended to investigate the influence of the alternating magnetic field on physiological productivity of sugar beet plants.

Materials and methods

Trade sowing stock of 3 Polish varieties of sugar beet produced by Kutnowska Hodowla Buraka Cukrowego:

Table 1. Ground germination rate of sugar beet seeds (% of sown seeds). Average of 3 varieties

Combination	1998 year	1999 year	2000 year	Mean value of 3 years
Control	75.7	41.7	42.5	53.3
16 Hz	83.9*	45.9	58.4*	62.7*
LSD	6.73	4.86	10.23	6.82

LSD – the lowest significant differences. * – statistically significant difference.

Jastra – diploidal variety, PN Mono 1 – diploidal variety and Jamira – triploidal variety was used in the experiment. Air-dry seeds were exposed to a 16 Hz frequency, 5 mT magnetic flux density homogeneous alternating magnetic field for over 2 h. The equipment used to produce the alternating magnetic field was constructed from Helmholtz assembled from two reel coils arranged in different directions. The volume of homogeneous, pure magnetic field inside the apparatus (measured with Tesla Metr Halotronowy type CK1 produced by Centrum Techniki Morskiej in Gdynia, Poland) was around 30 cm^3. In the apparatus around 1200 crop kernels or around 1000 bigger seeds (for example sugar beet clusters) could be exposed simultaneously. As a control, seeds of the same varieties were used, but not treated with magnetic field. The seeds were sown nineteen days after treatment in 20 m^2 plots, 400 seeds in each plot. During the vegetation season, were measured:

- ground germination rate,
  during vegetation season four times were measured following parameters:
  - photosynthetic active radiation (PAR) – part of solar radiation absorbed in leaves and used by plants,
  - radiation use efficiency (τ) – part of solar radiation coming to the bottom of the stand and not used by plants,
  - leaf area index (LAI) – indicates how many times the assimilative stand of leaf area is higher than the ground area under stand,
- field stand of plants close to the harvest time,
- roots and leaves yield.

Ground germination rate was counted as per cent of germinated seeds 10 days after sowing. PAR and τ were measured with linear measuring PAR LI-191SA and LAI with LAI-2000 equipment. Both were produced by Light Interception Devia Co., USA. Yield of roots and leaves was measured by weighing in kilograms.

Research was done over the three successive years: 1998, 1999 and 2000 in experimental fields of Warsaw Agricultural University at Żelazna near Skierniewice. The weather conditions during particular years of the experiment were different. The year 1998 was very profitable for sugar beet vegetation. In 1999 weather conditions were very unfavourable and in the year 2000 the weather was an average of the climate of the Central Poland. Physiological features were measured on the 60, 86, 113 and 130 day after sowing at the same time of the selected day and in the same weather conditions (dry weather, little cloudiness) each year of the experiment. The dates of sowing and measurements in the particular years were approximately similar and differed in 2–4 days. The field stand of plants as well as the agricultural methods and fertilization were the same each year.

The results were statistically developed with an Anova computer program.

Results and discussion

In Table 1 the data show that the treatment of seeds with alternating magnetic field increases the ground germination rate by 17.6% on average, in comparison with untreated seeds. The higher field emergence (number of seedlings) is observed both in profitable and unprofitable weather conditions. The influence of magnetic field is different for the particular varieties Jamira reacts to bio-magnetic stimulation better than the other varieties. Higher field germination increases the chances of obtaining a high yield, which is observed in many plant species [4, 9, 13].

Leaf area index (LAI) is an important parameter of crop productivity appreciation. Most plant growth, development and yielding simulative models are based on LAI [8].

Data in Fig. 1 show that the leaf area of standing plants grown from the seeds treated with the alternating magnetic field is larger than in the stand of control plants. Even in the cases of unfavourable weather conditions – 1999 – LAI is higher than 3.5. In good weather conditions – 1998 – between 86th and 113th day of vegetation (July–August) LAI exceeds 5.5. The photosynthetic productivity of the stand depends on the photosynthetic apparatus area – in the case of sugar beet – on the leaves. Larger leaf area guarantees greater photosynthetic productivity. The LAI value is providing plants with the proper biomass production over 3, the optimal productivity between value amounts to 4–5 [2]. LAI of plants grown from the seeds treated with the alternating magnetic field is high enough for biomass production, even in unfavourable 1999. In the favourable year 1998, a very large stand leaf area testifies to plants producing a great number of well-developed

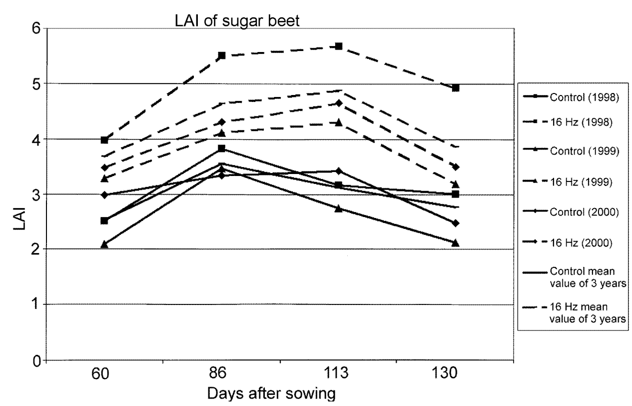

Fig. 1. LAI of sugar beet plants. Average of 3 varieties.

leaves and to a large assimilation area which allows to forecast a high yield. The control plants (grown from untreated seeds) have a considerably smaller assimilation area. In 1999, at the beginning and at the end of the vegetation season, LAI amounted to only little over 2, which does not provide the proper biomass accumulation. Moreover, the plants grown from the seeds treated with magnetic field for a longer time – until the 113th day of vegetation (the end of August) maintain a large leaf area, while in the case of control plants it decreases from the 86th day of vegetation (second half of July). General stand leaf area is very important for plants while using the photosynthetic active part of solar radiation [1].

It is the photosynthetic active part of solar radiation which is another indicator of photosynthetic productivity of the stand. During photosynthesis, better organized plants use only wavelenghts in the region 400–700 nm, called the photosynthetic active radiation (PAR). This light supplies the plants with the energy necessary for reduced nicotinamide adenine dinucleotide (NADH) and adenosine triphosphate (ATP) production and also for chlorophyll synthesis. On sunny days, PAR represents 38% and on cloudy days 58% of solar radiation coming to the earth surface. 90% of dry substances of plants is produced in the photosynthetic process. Without any environmental limits (diseases, pests, water and minerals accessibility) the biomass production is a linear function of PAR. Usually, 70–80% of solar radiation, falling on the leaf surface, is absorbed. The rest of solar radiation comes thought the leaves or is reflected [5]. 90% of the absorbed solar energy is dispersed as heat. Only 1–7% is used in the process of photosynthesis. There is a linear interdependence between CO_2 daily stand assimilation and absorbed PAR [7]. Plants with a high PAR value produce more biomass for a long time [6].

In Figure 2 the data show that the stand absorption of solar radiation increases during plant vegetation together with the development of photosynthetic apparatus, faster at the beginning of vegetation (for 86 days) and after that, slower. Then, part of the radiation which comes throught the stand and is not absorbed (τ), decreases. This is connected with leaf crown development and the proper position of leaf disposal towards the sun. As in the case of LAI, already from the beginning of vegetation, the PAR plants grown from the seeds treated with the alternating magnetic field is higher than the PAR of the control plants. A very low, below 70% PAR of control plants in 1999 indicates the weakness of development, condition and productivity of the plants caused by unfavourable weather conditions. In that year 1999 between two PAR values, of plants grown from stimulated seeds and of control plants, there is the biggest difference coming up to 92% on the 86th and 72% observed on the 130th day of vegetation. In favourable weather conditions – 1998 – these differences are only 54% and 45%, respectively. These data indicate that magnetic stimulation is more effective in the environmental conditions unfavorable for plants. Therefore, plants grown from the seeds treated with magnetic field absorb solar radiation better. This allows them to maintain a higher level of photosynthesis and biomass accumulation. This all has a positive effect on the yield of sugar beet.

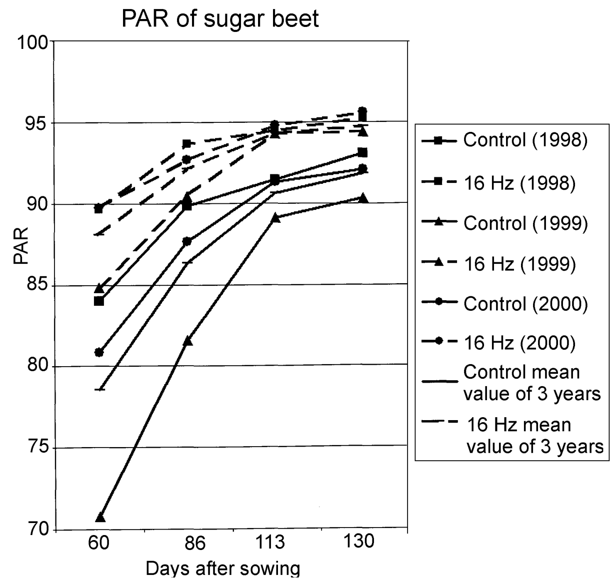

Fig. 2. PAR of sugar beet. Average of 3 varieties.

At the harvest time, the field stand of plant grown from the treated seeds is on the average 18% higher, but in 1999 almost 34% higher than the field stand of the control plants (Table 3). The mean root yield is 22% higher in comparison with the yield of the control plants. However, in the year 1998 (favourable weather

Table 2. Field stand of plants. Yield of roots and leaves of sugar beet plants. Average of 3 varieties

Combination	Field stand (heads)			Yield of roots (kg)			Yield of leaves (kg)		
	1998	1999	2000	1998	1999	2000	1998	1999	2000
Control	67.7	33.2	39	42.3	20.4	23.1	32.2	8.6	22.1
16 Hz	73.1	44.4*	47.3*	53.7*	26.1*	25.5	37.4*	12.6*	23.4
LSD	8.43	7.42	7.83	4.80	4.91	2.97	4.92	1.48	2.74

LSD – the lowest significant differences. * – statistically significant difference.

Table 3. Field stand of plants. Yield of roots and leaves of sugar beet. Average of 3 varieties and 3 years of experiment

Combination	Field stand (heads)	Yield of roots (kg)	Yield of leaves (kg)
Control	46.6	28.6	20.96
16 Hz	54.9*	35.1*	24.5*
LSD	5.76	2.22	1.8

LSD – the lowest significant differences. * – statistically significant difference.

conditions) the root yield from one plot of plants grown from the treated seeds is 11.4 kg larger in comparison with the yield from the plot of control plants (Table 2). This means growth of yield by 5.7 q/ha. In 1999, this extension amounted to 2.85 q/ha. This is a good result for such extreme environmental conditions. The soil in Żelazna is not very fertile and agronomic conditions are not optimal for the cultivation of sugar beet plants. Therefore, the root yield in comparison with the average yield of sugar beet in Poland – 40 t/ha – is low.

In the case of leaf yield the situation is the opposite. The largest influence of magnetic stimulation of seeds on the growth of yield is noticed in miserable environmental conditions. In the year 1999, the yield increased by 46.5%, and in 1998 by only 16.1% (Table 2). The mean root yield is 17% higher in comparison with the yield of control plants (Table 3). These results confirm the thesis that magnetic field has the best influence on the plants growing in unfavorable environmental conditions [16].

The positive influence of the magnetic field on plant yield especially grains [9, 11] but also groundnuts [17] and bean [12] is investigated by measuring the morphological yield-forming feature level. Good effects are explained by the acceleration of field germination and by the faster development of plants which allows better use of the vegetation period. The data presented in this paper allow to assume that magnetic stimulation with alternating, low frequency magnetic field has an influence on physiological yield-forming features. This allows the growth of yield even in unfavorable environmental conditions.

Conclusions

1. The alternating, low frequency magnetic field has a profitable influence on germination, development and yielding of sugar beet plants.
2. The alternating magnetic field has a profitable influence on physiological yield-forming features such as: leaf area index (LAI) and photosynthetic active radiation (PAR).
3. The alternating magnetic field increases sugar beet root and leaf yield.
4. The profitable effect of alternating magnetic field is clearer in the case of conditions which are poor for growth and development – in the weather conditions unfavorable for sugar beet vegetation.

References

1. Aufhammer W, Wagner W, Kuhl HP, Kubler E (2000) Radiation use by oil seed crops. J Agron Crop Sci 184:277–286
2. Bochenek A, Grzesiuk S (2002) Physiological assimilation of CO_2, water and light in the formation of crop. In: Górecki RJ, Grzesiuk S (eds) Fizjologia plonowania roślin. Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn, pp 160–185 (in Polish)
3. Hirota N, Nakagawa J, Kitaro K (1999) Effect of magnetic field on germination of plants. J Appl Phys 85;8:5717–5729
4. Kornarzyński K, Gładyszewska B, Pietruszewski S, Segit Z, Łacek R (2004) Estimation of alternating stimulating magnetic field on germination of durum wheat seeds. Acta Agrophys 4:59–68 (in Polish)
5. Łoboda T (2002) Ecological conditions of photosynthetic productivity of agrobiocenoses. In: Górecki RJ, Grzesiuk S (eds) Fizjologia plonowania roślin. Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn, pp 186–201 (in Polish)
6. Łoboda T, Pietkiewicz S, Czembor H, Wiewióra M (2000) Determination of crop productivity of selected varieties of brewing barley. Biul IHAR 215:141–152 (in Polish)
7. Monteith JL (1977) Climate and efficiency of crop production in Britain. Philos Trans R Soc Lond 281:277–294
8. Pietkiewicz S, Pala J (2002) Theory and practice of prognosis of crop production of cultivated plants. In: Górecki RJ, Grzesiuk S (eds) Fizjologia plonowania roślin. Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn, pp 523–551 (in Polish)
9. Pietruszewski S (1999) Influence of pre-sowing magnetic biostimulation of wheat seeds. Int Agrophys 13:497–501
10. Pietruszewski S, Konarzyński K, Łącek R (2001) Germination of wheat grain in the alternative magnetic field. Int Agrophys 15:269–272
11. Pittman UJ, Carefoot JM, Ormond DP (1977) Effect of magnetic seeds treatment on yield of barley, wheat and oats in Southern Alberta. Can J Plant Sci 57:37–45
12. Podleśny J, Pietruszewski S, Podleśna A (2004) Effectiveness of magnetic biostimulation of faba bean seeds cultivated under field experimental conditions. Int Agrophys 18:65–71
13. Prokop M, Konarzynski K, Pietruszewski S (2002) Prelimary studies on the effect of biostimulation of alternative magnetic field on germination of onion seeds. Inżynieria Rolnicza 2:323–327 (in Polish)
14. Rochalska M (1998) The influence of an alternative magnetic field on the quality of cereal seeds. In: Proc of the XIVth Int Wrocław Symp of Electromagnetic Compatibility, EMC/98, 23–25 June 1998, Wrocław, Poland. Institute of Telecommunications, Wrocław, pp 101–105
15. Rochalska M (2002) Improving of seeds quality with the frequent magnetic field. Field experiment. Acta Agrophys 62:113–126 (in Polish)
16. Rochalska M, Orzeszko-Rywka A (2005) Magnetic field treatment improves seed performance. Seed Sci Technol 33:669–674
17. Vakharia DN, Davariya RI, Parameswaran M (1991) Influence of magnetic treatment on groundnut yield and yield attributes. Indian Plant Physiol 34;2:131–136