

Controllable Alternating Magnetic Technology Research for Inducing Plants Breeding on Ground

Guo-wen HU^{*1, a}, Li-sheng ZHANG^{1,2, b}, Lin WANG^{1,2, c}, Yin-jie WANG^{1,2, d}

¹School of Electrical Engineering, Yancheng Institute of Technology, Yancheng 224051, Jiangsu, China

²School of Electrical and Information Engineering, Jiangsu University, Zhenjiang 212013, Jiangsu, China

*Corresponding author, e-mail: hugw@ycit.cn^a, 418592962@qq.com^b, lyct304@163.com^c, wangyj198874@163.com^d

Abstract

Controllable alternating induction magnetic field generation technology which induces plant seeds to breed on floor space has been developed. The incentive ferrite induction coil is used in the device to produce induced magnetic field. The common AC-DC-AC topology was adopted for the variable frequency power supply, realizing the VF. AC-DC-AC AC power inverter circuit adopts SPWM inverter frequency modulation and voltage regulation mode, realizing the effect of sinusoidal variable. In order to improve the conversion efficiency of the system electrical energy to magnetic energy, the RLC series resonant circuit is chosen in the circuit of output magnetic field. The induction magnetic field in the air gap is the work area for seeds experiment. Its adjustable frequency range: 20~200Hz, adjustable field range: 0~500Gs. The experimental study of rice seeds shows that different magnetic environment has a significant impact on the biological characteristics of rice seeds.

Keywords: controllable alternating magnetic field, floor space, magnetization, plant breeding

Copyright © 2013 Universitas Ahmad Dahlan. All rights reserved.

1. Introduction

Biological magnetism mainly studying the effect of magnetic field on biological characteristics and law of life activities is an emerging science. Having been researched and developed for many years, it has gotten extensive application in every field, especially in the areas of medicine, agriculture and biotechnology. Application of biological magnetism in the field of biological agriculture, there is no clear results especially for the effect of magnetic field on biological seeds. After different forms of magnetic treatment, the seeds original characteristics whether will change in the growth process, such as: bud time, growth rate, resistant, production etc. will change. It will be a major research significance for our modern agriculture development, if its change toward to our hope [1, 2].

The magnetic treatment technology of Seeds is that magnetic field is used to directly magnetize on crop seeds before planted. After magnetization handling, people can improve seeds quality and seedling quality, make root system well-developed, enhance the vitality of seeds, and enhance the pest-resistant ability of seeds. This treatment can also improve the crop metabolic function, promote crop to absorb water, fertilizer and make them grow rapidly in order to increase production. The technique is fit for the seeds of food crops, vegetables, cash crops, flowers, herbs and other plants. The experiments generally show that the magnetic treatment of seeds makes wheat yield increase by 8%, corn yield increase by 11%, and the average yield of vegetables increase by about 10% [3, 4].

According to increasing mechanism of seeds magnetic field processing, internationally, people generally consider that an enzyme plays an important role in crops growth, which is a semiconductor. Through the effect of the external magnetic field, a potential is formed on the surface of the enzyme. So the potential can improve the function and vitality of the enzyme in order to help the root of crops grow and absorb water, fertile.

At present in China, the three theories put forward by the Institute of Physics; Chinese Academy of Science is very representative. The first theory is the role of the magnetizing metal ions. The crops contain more than ten kinds of metal elements or ions, including eight kinds of Transition-metal magnetic ions, which play an important role in a variety of enzymes. Therefore, the magnetic force can promote the vitality of functional enzyme, help crop grow and gain yield.

The second theory is the interaction of the magnetic field and the biological plasma. The biological plasma in creature can interact with the magnetic field. Through the role of the magnetic field, the performance of some important significance ions will change. This phenomenon is called the biological effects. The third theory is bio-magnetic field relevant effect. The interactions between external magnetic field and biological magnetic field lead to the change of magnetic energy parameters in organism. Seeds can keep the micro-magnetic nature in a short period of time. When seeds are sown in the soil, they will biochemical, physically interact with soils. The ferromagnetic substances and paramagnetic substances in the soil can be attracted to their Surroundings by this micro-magnetic seeds so that seedling can grow healthily in the future [5].

In order to carry on aquatic seedling inducing breed experiment, controlled and alternating induction magnetic field generation device has been developed in this dissertation. The device mainly uses frequency conversion power incentive ferrite induction coil to produce induced magnetic field. Its adjustable frequency range: 20~200Hz, adjustable field range: 0~500Gs. Changing the magnetic field frequency, magnetic field intensity and application time, can provide different growth environment for the seeds, and can help us research the characteristics of seeds.

2. Research Method

2.1. Basic Structure Design of Controlled and Alternating Magnetic Field Generation Technology Circuit and Magnetic Circuit

The basic structure design of circuit in the technology device is shown in Figure 1. It is mainly composed of input power, rectifier circuit, inverter circuit, magnetic field output circuit, drive and control circuit, the auxiliary power supply circuit, the protection circuit, etc.

The controlled and alternating magnetic field generation technology device is composed of variable frequency power supply circuit, the magnetic field generating electric and magnetic circuits, the biological breeding magnetization sealed cabin, chassis. The magnetic field generating circuit and magnetic circuit are shown in Figure 2. The biological breeding magnetization sealed cabin is in the air gap in Figure 2.

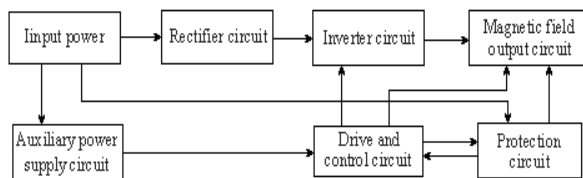


Figure 1. The Basic Structure Diagram of Alternating Magnetic Field Generator Circuit

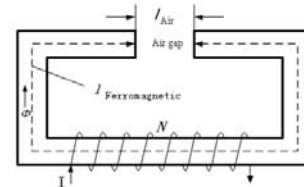


Figure 2. The Schematic Diagram of Magnetic Field Generating Circuit

There are two design forms of variable frequency power supply in controlled and alternating magnetic field generating technology device. The first is voltage variable frequency power supply. The second is current variable frequency power supply. The main difference between voltage variable frequency power supply and current variable frequency power supply is that DC power supply which is provided for inverter is filtering in different forms. The voltage variable frequency power supply is filtering by adopting larger filter capacitor. Its DC power supply is similar to the constant voltage source whose voltage is steady [6].

According to variable frequency characteristics and design requirements of controlled and alternating magnetic field generation technology device, excitation power supply adopts the design structure of voltage AC-DC-AC circuit. As is shown in Figure 3, AC-DC-AC variable frequency power supply uses uncontrolled rectifier to certificate and adopts SPWM inverter with frequency modulation and voltage modulation. The rectifier uses a diode to certificate in order to achieve a high input power factor. The DC voltage after the full-bridge rectifier is filtering through large capacity filter capacitor in order to obtain a straight DC voltage which is provided for the

inverter to convert. Finally, we can obtain adjustable amplitude and frequency AC voltage. The structure of circuit has a high input power factor and switching frequency of the inverter is high. The output harmonics are less. It is excellent performance and reliable. All these characteristics can achieve the work requirements of excitation power supply in the controlled and alternating magnetic field generation technology device.

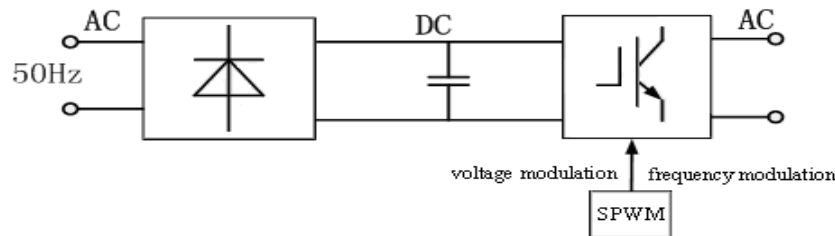


Figure 3. The Uncontrolled Rectifier the Circuit of Frequency and Voltage Modulation in SPWM Inverter

2.2. The Theoretical Calculation of Magnetic Circuit in the Controlled and Alternating Magnetic Field Generation Technology Device

The theoretical calculation of the magnetic circuit of the magnetic field is a very complex process. The reasons are as follows: (1) there is a magnetic flux leakage phenomenon in the magnetic circuit; (2) there is non-linear magnetization curve in the core; (3) there are magnetic saturation, hysteresis and eddy current in the alternating magnetic flux magnetic circuit. In engineering applications, commonly approximation method is adopted for solving. Approximate conditions are as follows [7]:

- (1) Consider only the main magnetic flux, that is to say, magnetic flux almost all concentrate in the magnetic circuit;
- (2) The part having the same cross-sectional area and the same magnetic media is divided into several, and the magnetic field is parallel to the centerline;
- (3) The magnetic flux uniformly distributed in any cross section of the magnetic circuit.

As is shown in Figure 2, if the magnetic circuit in such a shape is mainly divided into ferromagnetic materials and air gap and S is the cross-sectional area, N is the number of turns of the coil windings.

Therefore, we can approximately get magnetic flux: $\Phi = B \cdot S$ represents the magnetic induction intensity in the center line. The direction of B is the same to Φ . L_{fm} represents the magnetic circuit length of ferromagnetic part, and L_{air} represents the length of the air gap. According to Ampere's law, we can get:

$$\oint H \cdot dl = NI \quad (1)$$

The integral on the left of formula (1) is composed of ferromagnetic part and air gap part. And the magnetic field in the air gap can be approximately seen to be well-distributed. Therefore:

$$\oint H \cdot dl = \int_{l_{magnet}} H_{magnet} \cdot dl + \int_{l_{air}} H_{air} \cdot dl = NI \quad (2)$$

Assuming linear integrator trace H direction and along the magnetic path centerline path, both the direction of magnetic field of each point in the center line and dl are approximately same, in order to eliminate the integral, drawn:

$$H_{magnet} \cdot l_{magnet} + H_{air} \cdot l_{air} = NI \quad (3)$$

The intensity of the magnetic induction in the ferromagnetic: $B = \mu_0 \mu_r H$, μ_r is its relative magnetic permeability, the intensity of the magnetic induction in the air: $B = \mu_0 \mu_r H$, so substituting into equation (3) can be obtained:

$$B_{magnet} \cdot \frac{l_{magnet}}{\mu_0 \mu_r} + B_{air} \cdot \frac{l_{air}}{\mu_0} = N \cdot I \quad (4)$$

Based on the flux continuity principle, the input flux must be equal to the output flux. Approximately date of the flux at every section is same in the ferrite loop. Assuming the sectional area the flux flow through the air gap is equal to the flux the sectional area flow through the ferrite the cross-sectional area, there is $B_{magnet} = B_{air}$, which can be drawn:

$$B_{air} = \frac{\mu_0 NI}{l_{air} + l_{magnet} / \mu_r} \quad (5)$$

In practical applications, ferromagnetic materials and air gap length ratio ranges from 10 to 50. So $L_{air} > L_{magnet} / \mu_r$, and formula (5) are approximate:

$$B_{air} \approx \mu_0 NI / l_{air} \quad (6)$$

We can also be expressed as:

$$H_{air} \approx NI / l_{air} \quad (7)$$

We referring to the formula (6) and formula (7), the magnetic circuit of the controllable alternating magnetic field generating is designed.

Due to serious fringe magnetic leakage, the effective area of magnetic flux has an increase. Assume that $S_{average}$ is the average effective area after air gap magnetic flux is modified, then $B_{magnet} = B_{magnet} \cdot S_{average} / S_{magnet}$ is substituted into the formula (5) can be obtained:

$$B_{air} = \mu_0 NI / \left(l_{air} + \frac{l_{magnet}}{\mu_r} \cdot \frac{S_{average}}{S_{air}} \right) \quad (8)$$

The hysteretic loss is closely related to the area of the hysteresis loop, the material and its size is vital for the eddy current loss. Based on the above view, ferrite magnetic material, because of its hysteresis loop is relatively narrow and less conductive characteristics is used.

The magnetic induction coil design for obtaining a strong and uniform spatial distribution of magnetic field is essential. Choice of different magnetic materials in the magnetic circuit, the strength of the magnetic field is affected. The soft-magnetic ferrite material is used as a coil core to achieve the experiment requirement, the steroidal magnetic circuit shown in Figure 2 [8].

The appropriate size of the air gap is opened on steroidal core side, which is the magnetic field generation areas and workspace. Due to the reluctance of the air is much larger than the core, to get as strong a magnetic field must be to minimize the size of the air gap, taking into account the requirements of the experimental subjects, such as biological seed and aquatic seedlings, etc, and therefore the design of the magnetic circuit: the length of air gap is 30mm, 450 turns of the coil with a diameter 2mm copper enameled wire, designed maximum current 10A.

As is shown in Figure 2, the magnetic field generator of controllable alternating magnetic field generation device is a winding coil of with iron core. It is equivalent to an inductance L and a resistor R in series, and the equivalent impedance: $Z = R + j\omega L$. The equivalent resistance R of Coil is small, and can be neglected. The inductance of winding coil

increases as the frequency increases in current flowing through coil. The output magnetic field strength of winding coil with iron core changes as the current changes in coils.

In order to improve the system's magnetic field output, L - C resonator is used as the output circuits, as shown in Figure 4. It consists of different capacity of the capacitor and the coil, which are controlled to form tuned circuits on different frequency points by the intelligent switch circuit, to reduce the consumption of inductance, increase the efficiency of the magnetic field output. At the same time, the L - C series resonant circuit in Figure 4 access to the magnetic field output inverter circuit in Figure 5.

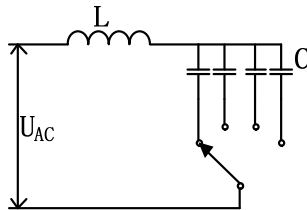


Figure 4. Control Circuit of Magnetic Field Output

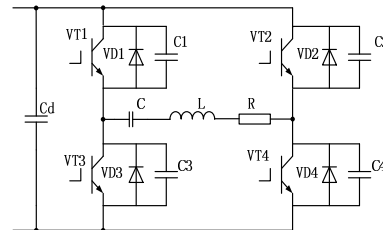


Figure 5. Inverter Circuit of Magnetic Field Output

The series resonant inverter circuit in Figure 5 is called the voltage inverter. As is shown in Figure 5, the input capacitance C_d is parallel in the inverter input end. The uncontrollable rectifier output circuit of the input power supply and the rectifier circuit in Figure 1 is connected with the input end in Figure 5. Therefore, the voltage inverter input end in Figure 5 can be regarded as a constant voltage source. If L - C and R values of the series resonant circuit remain unchanged, when the 4 switch angle and switching frequency of voltage inverter in Figure 5 is control, we can control the output size and frequency of magnetic field in L - C magnetic field output circuit.

2.3. The Control System Design of the Controllable Magnetic Field Generator

In order to control the alternating magnetic field generator for reliable operation, the controlled and alternating magnetic field generator output circuit and the whole device control systems use DSP single chip microcomputer measurement and control technology, adopting digital PID control method in control systems. The hardware circuit of control system use TI2000 series TMS320F2812 DSP single-chip microcomputer control chip as the system's main control chip. TMS320F2812 chip belongs to the 32 bit fixed point DSP chip, and the function is more powerful. It is suitable for industrial automatic control and digital power electronics applications, intelligent instrumentation, motor servo control system. The controlled and alternating magnetic field generator output circuit and the whole device control systems can be looked at as a linear control system, therefore using the measurement and control system of PID in Figure 6 [9].

The $r(t)$ in Figure 6 is a given value of the controlled and alternating magnetic field generator. The $y(t)$ is a actual output value of the controlled and alternating magnetic field generator. The $e(t)$ is a the control deviation value of the $r(t)$ and measurement feedback value of the $y(t)$, namely $e(t) = r(t) - k y(t)$. The $u(t)$ of PID controller output is the result to proportion and integral and differential operation for $e(t)$. In the continuous time domain, the controller algorithm expression is shown in a formula (9) in Figure 6 PID control system [10]:

$$u(t) = k_p \left[e(t) + \frac{1}{T_i} \int_0^t e(t) dt + T_d \frac{de(t)}{dt} \right] \quad (9)$$

Type: k_p is proportional coefficient; T_i is the integral time constant; T_d is the differential time constant.

After the type (9) were discrete, we can get the discrete PID expression (10):

$$u(k) = k_p e(k) + k_i \sum_{j=0}^k e(j)T + k_d \frac{e(k) - e(k-1)}{T} \tag{10}$$

Type: k_i is the integral coefficient, $k_i = k_p / T_i$; The k_d is differential coefficient, $k_d = k_p T_d$; The $u(k)$ is the controller output value for k time sampling; The $e(k)$ is the deviation value of input control system for k time sampling; The $e(k-1)$ is the deviation value of input control system for $(k-1)$ time sampling; T is the sampling period.

The PID control system feedback circuit in Figure 6 is mainly composed the holzer current sensor sampling circuit. The output coil current of the controlled and alternating magnetic field generator is feedback sampled by holzer current sensor sampling circuit, and then is converted to a voltage signal. The AC voltage feedback signal from the holzer current sensor be sent to the AD port of DSP by signal processing circuit processes, and through the DSP single-chip microcomputer controller further controls the output of the controlled and alternating magnetic field generator.

2.4. The Testing Waveforms of Controllable Alternating Magnetic Field Generator

The PID control system in Figure 6 consists of DSP single chip microcomputer control chip. The test waveforms of DSP chip output control signals SPWM are shown in Figure 7. The output SPWM control waveforms of DSP control chip in Figure 7 is used in unipolar modulation. CH1 and CH2 is a pair of complementary control switch signal with 50Hz low frequency. CH3 and CH4 is a pair of complementary control switch signal with 3KHz high-frequency.

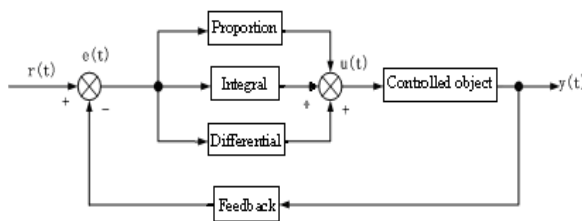


Figure 6. The PID Control System Principle Diagram of Controllable Alternating Magnetic Field Generator

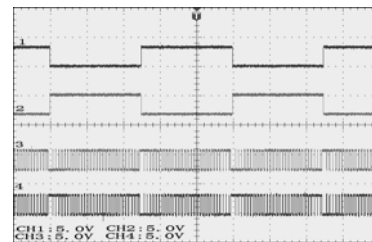
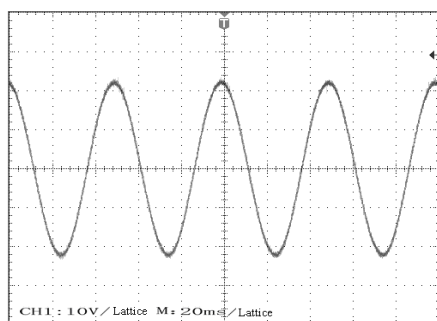
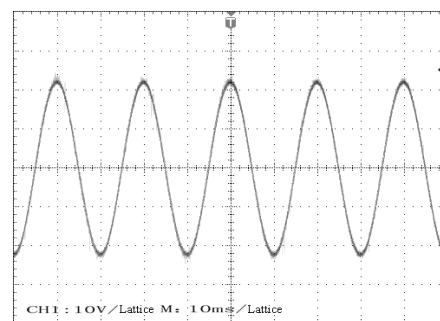


Figure 7. Control Signal Waveforms of DSP Chip Output SPWM



(a) Output voltage waveforms when 20 Hz



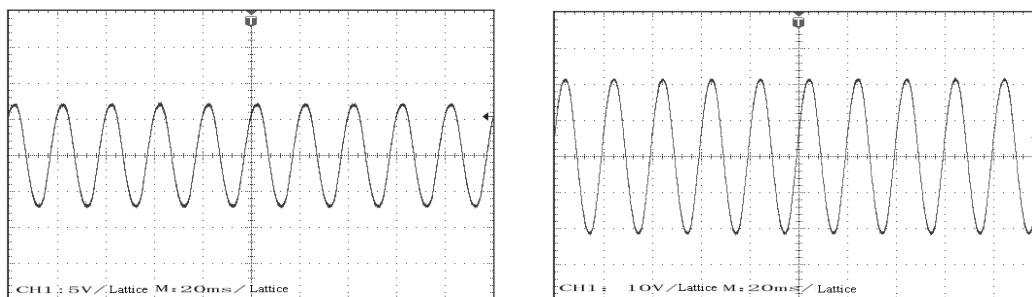
(b) Output voltage waveforms when 50 Hz

Figure 8. Experimental Waveforms when same Output Voltage and Different Output Frequency

The system realizes the control of alternating magnetic field frequency and intensity, while the induction magnetic field strength changes with the current changes in the coil, so through the voltage changes of the coil ends can be indirect judgment magnetic induction strength changes. The system test waveforms are shown in Figure 8 under the same output

voltage, different output frequency. The system test waveforms are shown in Figure 9 in the same output frequency, different output voltage.

As is shown in Figure 8 (a) and (b), by watching the output voltage waveforms of two different stages, we can smoothly adjust output voltage frequency in maintaining the output voltage amplitude unchanged.



(a) Voltage waveforms when output 7V

(b) Voltage waveforms when output 22V

Figure 9. Experimental Waveforms when same Output Frequency and Different Output Voltage

As is shown in Figure 9 (a) and (b), by watching the output voltage waveforms of two different stages, we can smoothly adjust output voltage amplitude changes in keeping the output voltage frequency unchanged.

3. Experiment Results and Analysis of Controllable Alternating Magnetic Field Generation Technology

3.1. The Experiment Test Data of Magnetic Field Intensity of the Controllable Alternating Magnetic Field Generator

The test date of controllable alternating magnetic field intensity is shown in Table 1 by controllable magnetic field generator generation. As is shown in Table 1, frequency range can reach 20-50Hz, magnetic field strength can reach 0-500Gs.

Table 1. The Induction Magnetic Field Test Data

Frequency (Hz)	Field intensity (Gs)	20	50	100	150	200
0		0	1	2	5	4
50		50	48	53	57	45
100		92	97	102	104	99
150		154	152	148	150	157
200		194	203	198	206	199
250		251	254	247	245	249
300		304	310	308	307	289
350		356	341	348	352	349
400		401	407	398	399	402
450		459	462	446	442	453
500		504	509	507	498	503

3.2. The Rice Breeding Experiment and Analysis of the Controllable Alternating Magnetic Field Generation Technology

In the experiment respectively put three different kinds of rice seeds into treatment group and control group to observe the test results. Each species take 100 seeds, treatment group and control group respectively for 50 seeds. Those seeds after cleaning and disinfection placed in a room temperature environment to experiment. The experimental data were shown in Table 2-5.

The experimental data in Table 2 and Table 3 were got when the controlled alternating magnetic field generating device send out the frequency of 50Hz, 10Gs field strength situation, and placed the seeds in the device ten minutes, then filled with water in the plastic basin gauze and the gauze was closer to the surface of the water, and in the place with enough light to germinate. Ten days after got the experimental data.

Table 2. Seed Germination Data

Varieties	Xi Feng			Zhong Bai IV			Qiu Guang		
	Treatment group	Control group	Growth rate%	Treatment group	Control group	Growth rate%	Treatment group	Control group	Growth rate%
Germination rate (grain)	45	38	18.4	46	40	15	43	39	10.2

The experimental data in Table 4 and Table 5 were got when the controlled alternating magnetic field generating device send out the frequency of 50Hz, 30Gs field strength situation, and placed the seeds in the device after ten minutes, then filled with water in the plastic basin gauze and the gauze was closer to the surface of the water, and in the place with enough light to germinate. Ten days after got the experimental data.

Table 3. The Growth of Rice

Varieties	Seedling fresh weight /g			Root length /cm			Height of seedling /cm		
	Treatment group	Control group	Growth rate%	Treatment group	Control group	Growth rate%	Treatment group	Control group	Growth rate%
Xi Feng	0.17	0.15	12.5	2.10	1.86	6.6	11.7	10.9	6.6
Zhong Bai IV	0.15	0.13	14.3	2.79	2.33	18.0	9.9	8.7	13.4
Qiu Guang	0.10	0.08	22.2	4.17	3.16	27.6	12.5	10.3	19.0

Table 4. Seed Germination Data

Varieties	Xi Feng			Zhong Bai IV			Qiu Guang		
	Treatment group	Control group	Growth rate%	Treatment group	Control group	Growth rate%	Treatment group	Control group	Growth rate%
Germination rate (grain)	45	37	21.6	47	40	17.5	44	38	15.7

Data shown in Table 2 and Table 4 appears that, through comparative analysis the rice seed germination experiment data can be seen: in the frequency of 50Hz, the germination rate under 30Gs magnetic field strength environment is significantly higher than under 10Gs magnetic field strength environment. Comparative analysis the table 3 and table 5 rice growth process experimental data can be seen: in the frequency of 50Hz, under 30Gs magnetic field strength environments the rice growth faster and growing well than under 10Gs magnetic field strength environment. So be aware, under the 50Hz frequency, 10~30Gs magnetic fields the rice seeds germination rate and growth speed are proportional to the magnetic field strength.

Table 5 The growth of rice

Varieties	Seedling fresh weight /g			Root length /cm			Height of seedling /cm		
	Treatment group	Control group	Growth rate%	Treatment group	Control group	Growth rate%	Treatment group	Control group	Growth rate%
Xi Feng	0.18	0.15	20.0	2.31	1.86	24.1	12.0	10.9	10.1
Zhong Bai IV	0.16	0.13	23.0	2.87	2.33	23.1	10.2	8.7	17.2
Qiu Guang	0.11	0.08	37.5	4.24	3.16	34.2	12.6	10.3	22.3

4. Conclusions

In this paper, through controlled alternating magnetic field generating technology and device in the ground space produced different magnetic field environments to realize the influence of plant induced breeding. The research shows that:

- (1) In the ground space, under the 50Hz frequency, 10~30Gs magnetic field, the rice seeds germination rate and growth speed are proportional to the magnetic field strength.
- (2) The test result is obviously better than traditional biological magnetization induced breeding technique of fixed magnetic poles, through controlled alternating magnetic field generating technology.
- (3) In the ground space, used controlled alternating magnetic field generating technology and device to make different magnetic environments to control plant seed induced breeding process, promoted the growth of plant seeds process, and finally reached the aim of improving plant yield.

References

- [1] Jun ZHANG, Shu-guang LI, Song-qing HU. Advanced Research and Application of Magnetic Treatment Technology. *Journal of Qingdao University*. 2002; 15(4): 71-74.
- [2] Li-hua ZHANG, Jian YANG. The Present and Future of Physical Agriculture. *Jilin Agricultural Sciences*. 2003; (03): 63-68.
- [3] Liang-long HU, Li-jia TIAN, Zhi-Chao HU. Application of Physical Agriculture Techniques in Cleaned Seeds Treatments. *Journal of Anhui Agricultural Sciences*. 2007; 35(13): 3778-3779.
- [4] Qiong LIU, Li-hua CHEN, Kun-lun CHENG. Seed Magnetizing Treatment Technology Application Prospect. *Machinery for Cereals Oil and Food Processing*. 1998; (06).
- [5] Shi-Zhou LIU, Guang-bo WEN, Ren-ping XIE. Seed Magnetization Technology. *New Agriculture*. 2007; (08).
- [6] Guo-Cheng CHEN. *PWM Inverter Technology and Application*. Beijing: China Electric Power Press. 2007.
- [7] Ya WU. Development of Prototype of AC Magnetic Field Generator for Treatment Human Tumor with Magnetic Fluid Hyperthermia. Southeast University Master's Degree Thesis. 2004.
- [8] Jordan Andreas, Scholz Regina, Wust Peter. Magnetic Fluid Hyperthermia (MFH): Cancer Treatment with AC Magnetic Field Induced Excitation of Bio-compatible Super-paramagnetic Nano-particles. *Journal of Magnetism and Magnetic Materials*. 1999; (201): 413-419.
- [9] Yonghua Tao. *Model PID Control and Its Application*. Beijing: Machinery Industry Press. 2002.
- [10] Yat Ming Tin. *Research of Wireless Sensor Network Energy Saving Optimization Technology*. Master's Degree Thesis of Anhui University of Science and Technology. 2009.