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EFFECT OF STATIC MAGNETIC FIELDS (SMF) ON THE VIABILITY AND FECUNDITY OF APHID *SITOBION AVENAE* (HOMOPTERA: APHIDIDAE) UNDER LABORATORY CONDITIONS

JUAN HE, HUAN-HUAN GAO, HUI-YAN ZHAO, WALTER MONIKA, ZU-AING HU and XIANG-SHUN HU

College of Plant Protection, Northwest A&F University, Yangling, Shaanxi, 712100, China

Abstract - The present study examines the effect of static magnetic fields (SMF) on aphids. The effect of a field of moderate-intensity (1 mT-1 T) SMF on the life of *Sitobion avenae* was estimated using the age-stage, two-sex life table. Static magnetic fields were 0.065 T and 0.176 T and exposure was for 0, 15, 30, 60, and 120 min. The results show that the development, mortality, and fecundity of *S. avenae* were significantly affected by SMF in the second generation after exposure to 0.176 T for 30 min and to 0.065 T for 60 min in comparison to the control group. We concluded that SMF affects the development and reproduction of *Sitobion avenae*.

Key words: Static magnetic field (SMF), *Sitobion avenae*, life table, Homoptera, Aphididae

INTRODUCTION

The magnetic field (MF), as an environmental factor, has significant influence on living organisms. Recent years have witnessed an overwhelming increase in the presence of electromagnetic fields (EMF) of a wide spectral range, due to industrial and household machines and appliances, high voltage power grids and medical devices. However, these radiations are only some of the products of modern civilization that produce additional MF, and these fields exceed the natural presence of this factor by several orders of magnitude.

Electromagnetic waves, nuclear magnetic resonance (0.15-2.0 T) and radiation all exert biological pressure (Haine, 1964; Shosuke, 1990; Jin 2006). Many authors have reported the effects of static magnetic fields on different living system – speed of circumnutation in cucumber (*Cucumis saticus* L.) tendrils (Ginzo and Décima 1995); sensitivity of Salmonella to gentamicin (Jihen et al., 2010); membrane rigidity (Kang et al., 2007), metallothionein content (Satoh et al., 1966); and tn α-amylase activity (Jia et al., 2009). In terms of insects, mortality (Ramirez et al., 1983), wing development (Biljana et al., 2001), behavior and metabolism (Pan et al., 2004), etc. have been studied for many years under the exposure of magnetic fields.

Sitobion avenae (Homoptera: Aphididae) is one of the most important and prevalent pests on wheat. They pierce the ears, stems, leaves, and other tender plant parts with their piercing, sucking mouthparts. *S. avenae* is known to transmit viruses from plant to plant, such as barley yellow dwarf virus, reducing yield and quality (Wang et al., 2008; Guo et al., 2010). Thus, the objective of this study was to evaluate the effect of static magnetic fields on *S. avenae* and to provide information on aphid

control; on the other hand, we hopeto learn how universal the principle of SMF influences is. Additionally, this study is new, basing itself on a age-stage sex life table to study the SMF influence on insects.

MATERIALS AND METHODS

Plant source

Wheat (*Triticum aestivum* Linn, variety XIAOYAN-22), was seeded in a plastic pot (15 by 15 by 20 cm) filled with nutrient substrate (a mixture of soil, sand, and soil-peat compound substrates) in a greenhouse, at 15-18°C and artificial light of 800 lux. The plants were watered every two days with vernalization after germination. Four-week-old uniform plants, which could be fixed a clip cap, were used to rear the aphids.

Insects

S. avenae were originally collected from the Insect Ecology and Integrated Pest Management Laboratory in Northwest A&F University, Yangling, Shaanxi, China, in April 2010. They were separately reared on plants and maintained in a small mesh fixed to the leafing using a clip cap (0.06 cm in diameter, 0.3 cm in height). The adult began parthenogenetic reproduction and third-generation nymphs (within 24 h old) were used in all experiments.

Application of static magnetic fields

Two intensities of Nd-Fe-B permanent magnets were obtained from the Shenzhen Magnetic Research Technology Corporation. These magnets can produce two moderate magnetic fields, 0.065 T and 0.176 T, and were used for the SMF tests (Jia et al., 2009). A Tesla meter (supplied by the College of Science, Northwest A&F University) was used to measure and standardize the induction of SMF. There is no shielding against the natural variation of terrestrial MF, because their intensity (0.03-0.06 mT) was insignificant compared to the applied SMF.

Each treatment comprised of 30 nymphs that were randomly divided into three groups of 10 nymphs each, and placed individually in glass Petri dishes (9 cm diameter and 1.5cm height) on the centre of Nd-Fe-B permanent magnets. They were continuously exposed for 0 min, 30 min, 60 min, and 120 min, respectively (Jia 2009; Prolic et al., 1995). After exposure, the *S. avenae* were individually held in small mesh bags fixed to the leaf using a clip cap (0.6 cm in diameter, 0.3 in height). There were up to 5 *S. avenae* on a leaf blade.

Development and life history

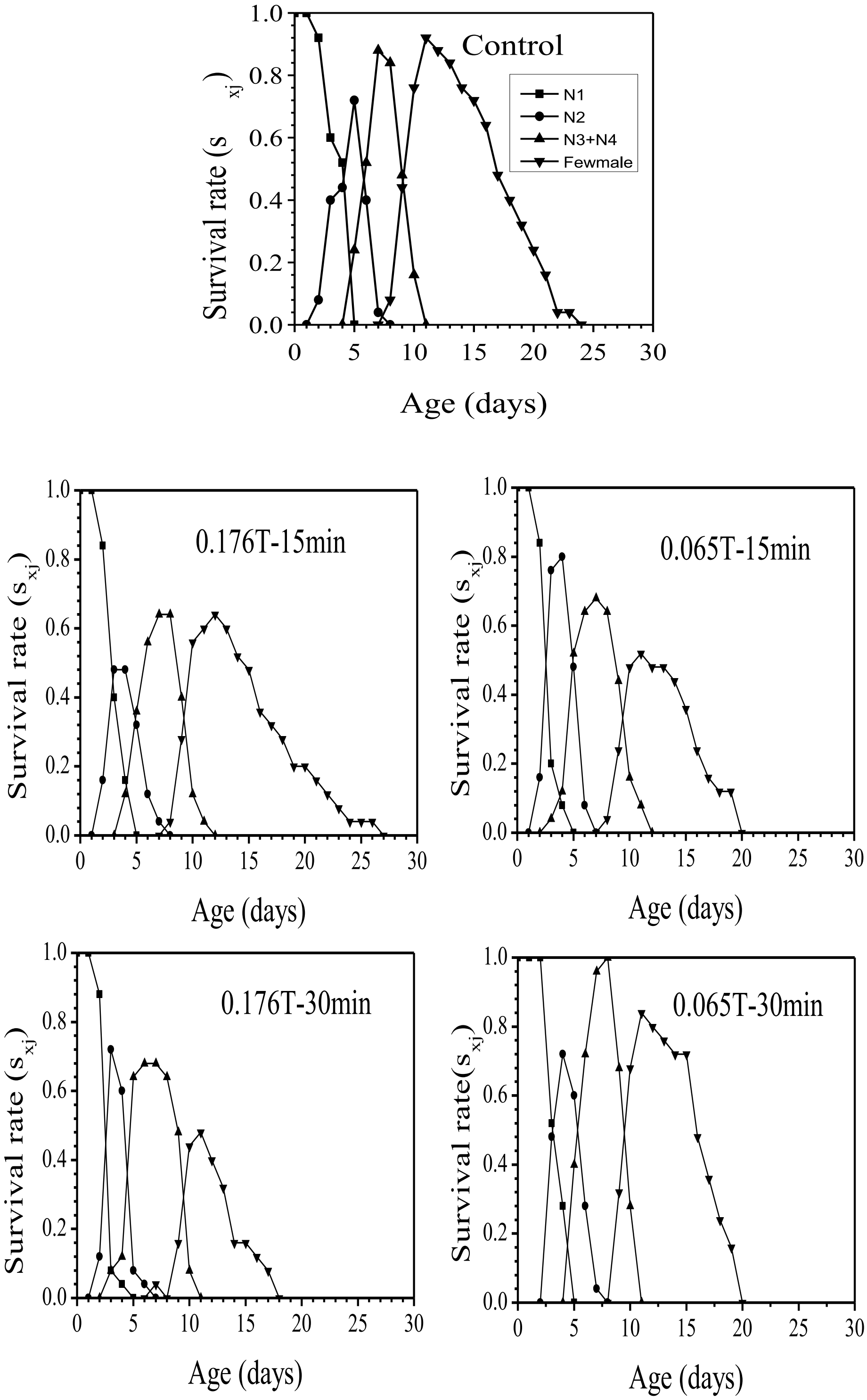
The *S. avenae* were placed in a greenhouse at 25 ± 1°C, 65 ± 5% RH, and a photoperiod of 16:8h (L:D). Newly emerged *S. avenae* adults were observed daily for reproduction and survival; all newborn nymphs were removed daily until the mature *S. avenae* died; the age-stage specific survival rates (s_{xj}) (where x is the age and j is the stage), and age-stage specific fecundity (f_{xj}) were recorded daily until the death of all parents or generation F_0. The next generation, F_1, was not exposed to SMF but reared in a similar manner to F_0.

Statistical analysis

To take the variable developmental rate among the individuals into consideration, life history data were analyzed according to an age-stage, two-sex life table (Chi and Liu, 1985; Chi, 1988) with the computer program TWOSEXMSChart (Chi, 2008). This program includes a routine for the estimation of standard error of population parameters using the Jackknife technique (Meyer et al., 1986). The age-specific cohort total fecundity and life expectancy (e_{xj}) were calculated. The results obtained from these measurements were compared by the Student t-test.

RESULTS

The significantly negative effect of SMFs on *S. avenae* can be observed in the curves of age-stage survival rate. The age-stage specific survival rates (s_{xj}) gives


Control
N1
N2
N3+N4
Fewmale
Survival rate (s xj)
Age (days)
0.176T-15min
0.065T-15min
0.176T-30min
0.065T-30min
Survival rate (s_{xj})
Survival rate(s_{xj})
Age (days)

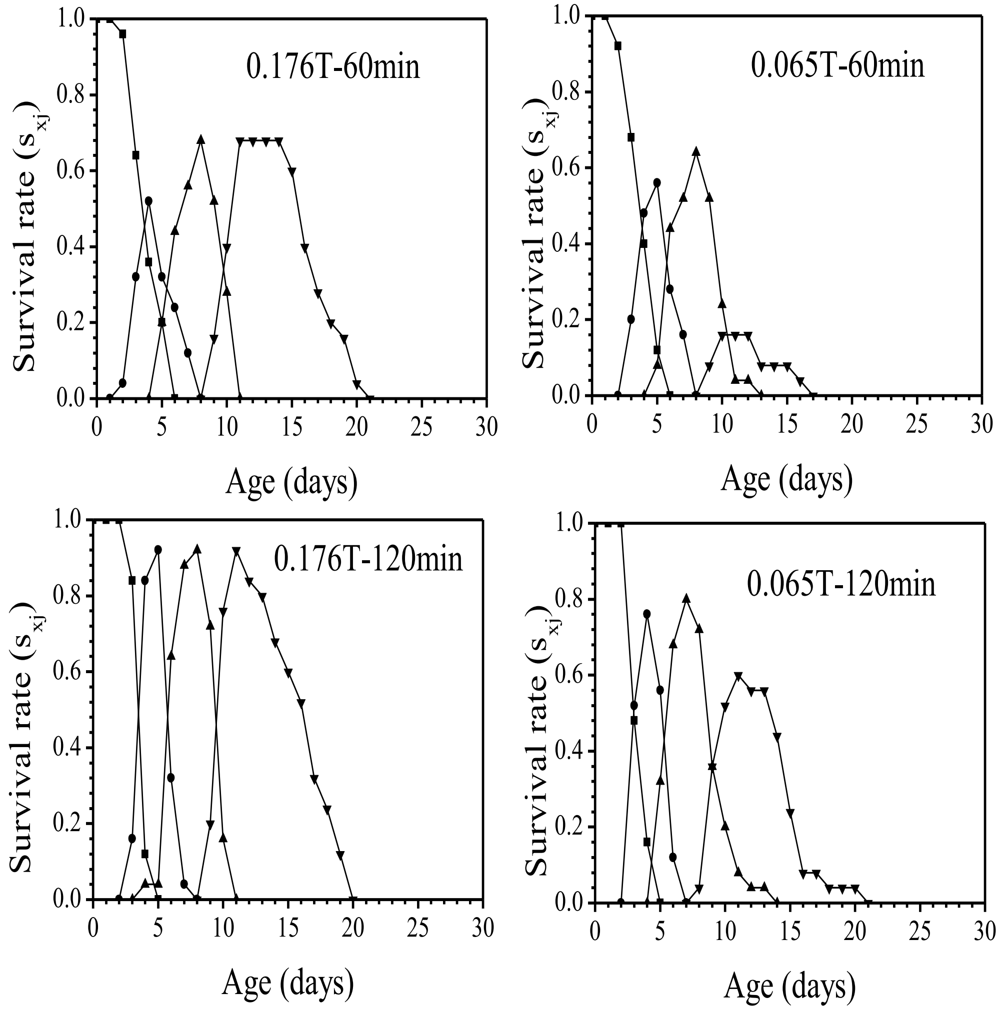


Fig. 1. Age-stage specific survival rate s_{xj} of *S. avenae*: control (without magnet exposure) and the influence of two magnetic intensities under four different time-treatments on the second generation

the probability that a newborn individual will survive to age *x* and stage *j* (Fig. 1). The mortality of 0.176 T, 30 min SMF-treated group was significantly different from the control groups (t= 2.310, $P < 0.01$), each instar s_{xj} was lower than its previous instar, and the most significant difference was that the adult mortality with 0.065 T for 60 min was up to 84% (t= 2.426, $P < 0.01$).

By taking the fertility of *S. avenae* into consideration, the effect of SMF exposure to 0.176 T for 30 min and 0.065 T for 60 min on reproduction was evident in both female age-stage fecundity and age-specific cohort total fecundity (Fig. 2). Consequently, lower fecundity curves in the adult stages were obtained in these two dosages. Comparison of the fecundity changes revealed no statistically significant differences between the control group and these two treatments.

The age-stage life expectancy of *S. avenae* in the SMF-treated group was shorter than that of the control groups (Fig. 3). In addition, the sizes of individual insects from the first instar were obviously

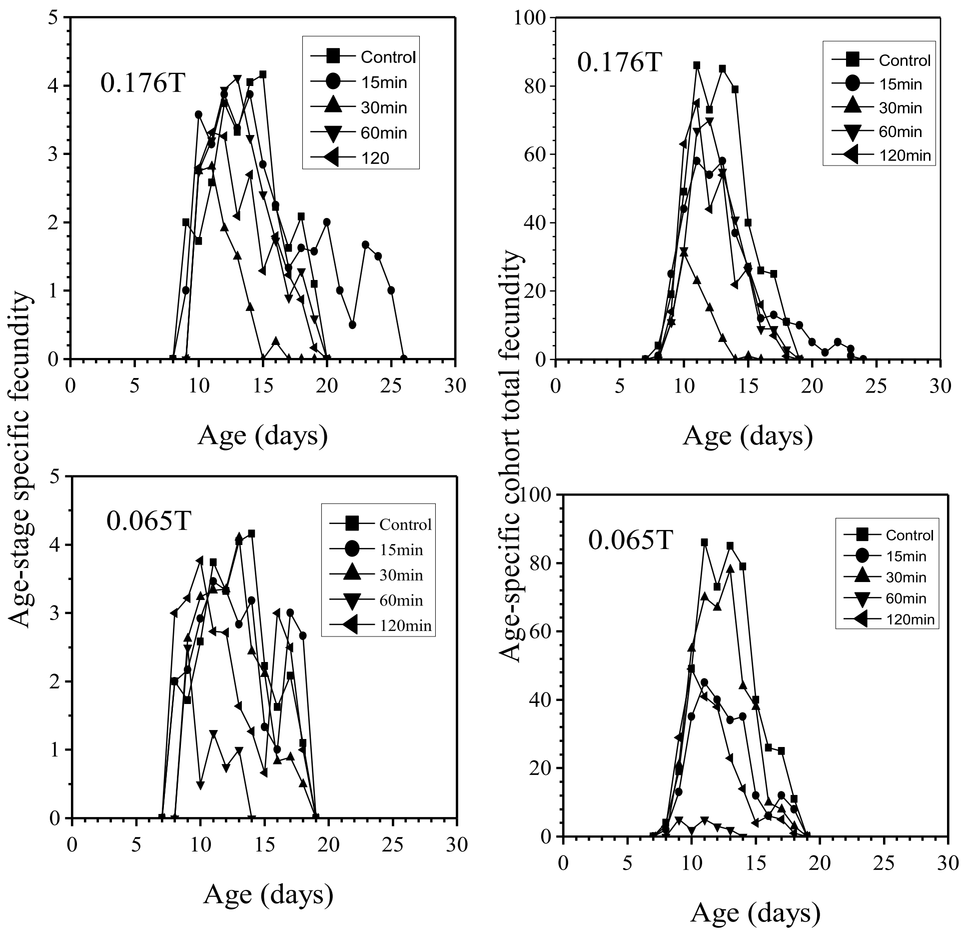


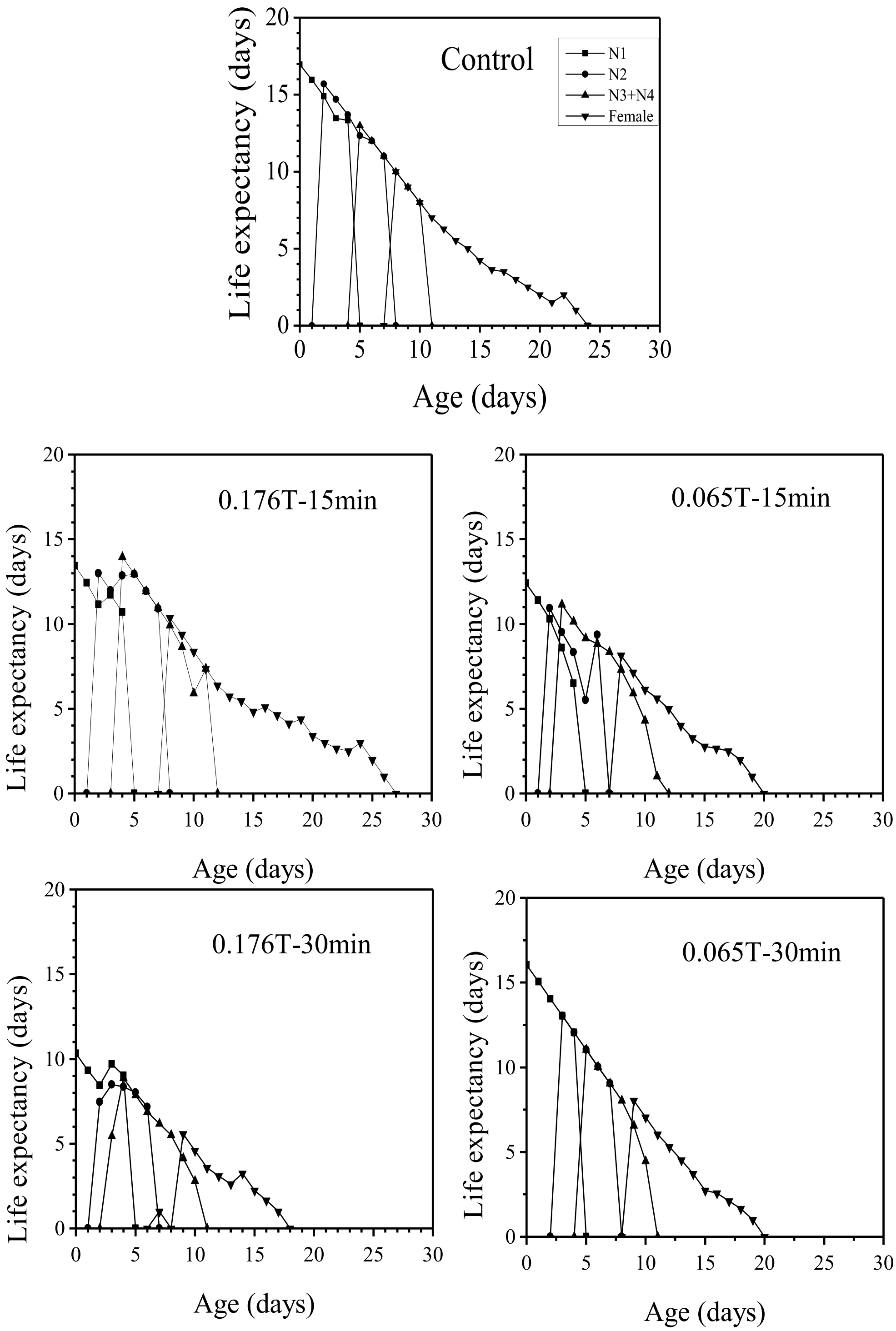
Fig. 2. The unexposed and exposed to magnetic field age-stage specific fecundity and age-specific cohort total fecundity of *S. avenae* of the second generation

smaller and the growth rates were slowed down in the magnetic field treatment compared with those in the control.

DISCUSSION

The environmental effects of magnetic fields are becoming increasingly important, thus, the number of experimental and theoretical research projects is continually growing The interaction of the electromagnetic field with a biological system is complex (Barnothy, 1964). Static magnetic fields (SMF) as a type of environmental pressure are capable of affecting a number of biological systems (Arthur, 2003). The influence of the MF has been studied by many authors: on termites *(Heterotermes indicola)* (Becker, 1976), cockchafers *(Melolontha vulgaris)* (Schneider, 1975), hornets *(Vespa orientalis)* (Kisliuk and Ishay, 1977), and bees (Martin and Lindauer, 1977; Korall, 1978; Gould et al., 1978; Kilbert, 1979; Gould, 1980; Leucht, 1984; Lindauer, 1985; Walker and Bitterman, 1985). In our experiment, the SMFs-treated *S. avenae* indicated a significant negative effect on survival rate, fecundity and life expectancy under the exposure of 0.176T for 30 min and 0.065 T for 60min.

Many studies have indicated that a magnetic field affects the development and viability of various insects. The influence of MF on *D. melanogaster* development has been proved; Ramirez et al. (1983)


Control
N1
N2
N3+N4
Female
Life expectancy (days)
Age (days)
0.176T-15min
0.065T-15min
0.176T-30min
0.065T-30min

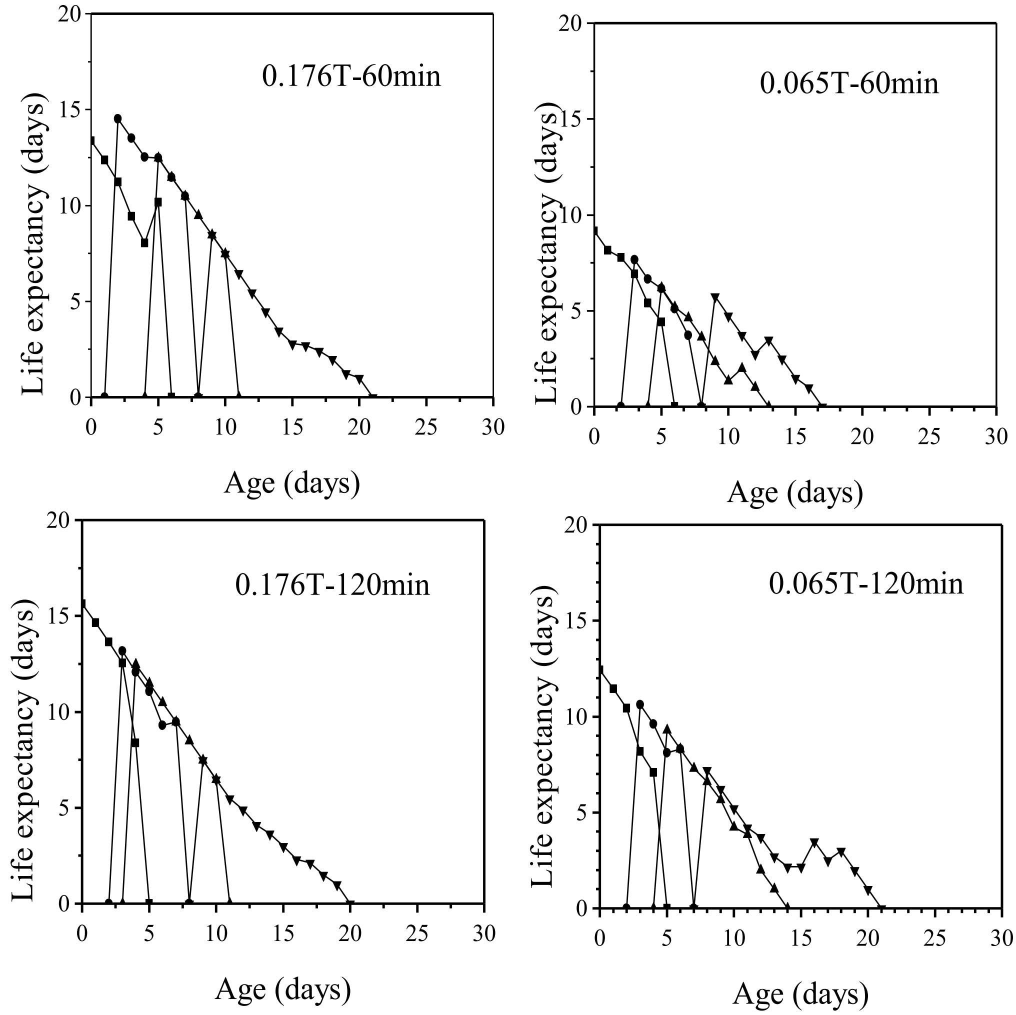


Fig. 3. Effects Age-stage life expectancies e_{xj} of *S. avenae*: control (without magnet exposure) and the influence of two magnetic intensities under four different time-treatments on the second generation.

reported that the mortality of eggs was lower and viability diminished progressively with a 0.045-T SMF. Gotz (1977) also studied the sex ration and occurrence of sex-linked recessive lethal mutations of *D. melanogaster*. However, these results could not be repeated by Walters (1987). Furthermore, MF had no effect during the exposure of 1.3-3.7 T on the gametogenesis of *D. melanogaster*. Likewise, the sexes of *Drosophila melanogaster* showed a decrease in wing size under the magnetic field exposure (Biljana et al., 2001); apparent biological effects of strong magnetic fields (9.4 and 14.1T) were observed in the hatching behavior of mosquito eggs (Pan et al., 2004).

In our work, the individual size of *S. avenae* was smaller than that of the control. In fact, environment stress heat and UV reduced growth in the aphid *Macrosiphum euphorbiae* (Thi et al., 2008); exposure to magnetic fields directly induced the transcription and biosynthesis of proteins, shortened the cell cycle, and accelerated cell division and development (Blank and Goodman, 1997). In addition, the individual size and the survival rate of *S. avenae* was different from the control. However, in our SMF-treatment pre-adult mortalities were similar to those reported for physical action. Bellossi (1986) observed an increment in the mortality of

SMF-treated mice compared with that of a control during the immature stage, but Martin et al. (1988) showed that a homogeneous, static magnetic field reduced the flying activity of bees and increased their life span by more than 60%. Likewise, in all treatments, each stage of e_{ij} showed a trend similar to the age-stage survival rate. The e_{ij} values are the life expectancy of individuals of age *i* and stage *j* that give the time an individual of age *i* and stage *j* is expected to live (Fig. 3). It can predict the survival of a population in these conditions, because it was counted using the age-stage survival rate (s_{xj}) without presuming that the population had reached a stable age-stage distribution (Ta et al., 2006).

Earlier research has studied the side effects of environmental stresses on target aphids by causing physiological, development, morphological (small size individuals) and immunological alterations. For example, light intensity, day length and temperature had an influence on the life table data of *Myzus persicae, Brachycaudus helichrysi, Macrosiphoniella* and *Aphis gossypii* (Wyatt et al., 1977). However, SMF had an influence on cell functions such as an ion-channel disruptor (Arthur, 2003); for example, a Ca^{2+} ion stimulates the secretion of neural hormones, which reach the effector glands and tissues through neurosecretory pathways (Blackman, 1933 and 1934). Furthermore, this response mechanism also exists in other biosystems, biomembranes (Rosen, 1993) and nocturnal melatonin (Schneider et al., 1994). Therefore, it could be hypothesized that the reduction of fecundity and fertility of *S. avenae* was caused by similar pathways.

In terms of our life table methods, although there were only females in parthenogenetic aphids, the age-stage, two-sex life table was used to reveal the significant overlapping (Fig. 1) in the cohort life table. Ignorance of the variable developmental rate among individuals will result in errors in life table analysis and estimation of population parameters (Chi, 1988). The development, mortality, fecundity, and reproduction of *S. avenae* were significantly affected by SMF in the second generation.

The static magnetic fields are able to change the development and reproduction in *S. avenae.* The results of the present study show that the age-stage specific survival rates (sxj) and age-stage specific fecundity (fxj) are more prominent after exposure to 0.176 T for 30 min and 0.065T for 60 min. Actually, studies have already demonstrated the relatively strong biological effects of MFs on the modulation of ion flow, interference with DNA synthesis and RNA transcription, interaction of normal cells with the hormones, neurotransmitters, and growth factors, as well as interactions with biochemical kinetics of cells (Liboff et al., 1984; Stuchly and Esselle, 1992; Frey, 1993; Yim and Jeong, 2006). Thus, we need more detailed examinations of the various molecular mechanisms and SMF-intensity to explain why some magnetic fields are more effective than others are.

In summary, Schenck (2005), Ueno and Shigemitsu (2007) suggested that magnetic fields exert physiological effects on animals. Our present work indicates that biological systems may react differently under the influence of different intensities of magnetic fields, and that SMF of a certain range can change the development of *S. avenae* through effects on its metabolism and neuroendocrine system; these could be taken into consideration for potential aphid physical control. According to the presented results, it can be stated that static magnetic fields may interact with exposure times and magnetic intensity.

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