Evaluation of different soil parameters and wild boar (Sus scrofa [L.]) grassland damage

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Abstract

Presented in this paper are the correlations between different soil parameters [presence of grubs, earthworms, pH, content of P₂O₅, K₂O and organic matter (OM) in soil] and wild boar (Sus scrofa [L.]) damage to grasslands. The soil samples and damage assessments were performed at six locations in the Kočevje region, which is a densely wooded part of South East Slovenia. A significant positive correlation was discovered between the extent of damage due to wild boar rooting in grasslands and the number of grubs (r=0.73), the weight of grubs (r=0.69) and the content of P₂O₅ (r=0.87) in the soil. The quantity and weight of grubs in soil were significantly influenced by soil pH, the content of CaCl₂ (r=0.71/0.72), P₂O₅ (r=0.90/0.91), and OM (r=0.74/0.77); while the quantity and weight of earthworms in soil were influenced by the content of K₂O (r=0.81/0.84). A moderate yet insignificant correlation (r=0.48/0.56) was discovered between the number and weight of earthworms in soil and the extent of grassland damage. Grubs represent a more important source of protein for wild boars than earthworms; consequently, reducing the quantity of grubs in soil could minimise the extent of damage caused by boars.

Introduction

Almost 60% of Slovenia is covered by forest, making it the third most forest-abundant country in Europe, after Finland and Sweden. Various game species wreak havoc on agricultural production (particularly in the Eastern regions of Slovenia), with the most prevalent being wild boar (Sus scrofa [L.]), red deer (Cervus elaphus L.), and roe deer (Capreolus capreolus L.) (Jerina, 2006; Trdan and Vidrih, 2008). The wild boar Sus scrofa (L.) is currently increasing in abundance across Europe and other parts of the world (Schley and Roper, 2003; Barrios-Garcia and Ballari, 2012; Schlager and Haag-Wackernagel, 2012). Rapidly increasing wild boar populations cause extensive agricultural damage (consumption of agricultural crops and rooting of grassland) (Laznik et al., 2012; Bueno et al., 2013). They are an omnivorous species whose diet consists primarily of plant material and only partly of animal materials. Any locally abundant food source is often exploited, leading to conflicts with human activities (Barrios-Garcia and Ballari, 2012).

R-selected species typically reach high population densities within a very short time period (Geisser and Reyner, 2005). Compared to other ungulate species, wild boars show several attributes that are typical for r-strategists. They have high ecological plasticity, an opportunistic feeding behaviour and by far the highest reproductive potential in relation to body mass (Geisser and Reyner, 2005).

The recent increase in wild boar populations in many European countries is thought to be a consequence of, among other reasons, socioeconomic changes (Gortazar et al., 2000), favourable changes in climatic conditions (Geisser and Reyner, 2005), migration processes (Hahn and Eifeld, 1998), changes in common crops and the productivity of deciduous trees (Geisser and Reyner, 2005), artificial feeding and management practices (Geisser and Reyner, 2005), and lack of predators (Genov, 1981).

Among wildlife species in Slovenia, wild boars cause the most damage, which in some areas is responsible for more than 50% of estimated damage to plants (Vidrih and Trdan, 2008). Such damages often prompt disagreements between representatives of the local hunting association and farmers. The state is held responsible for damage if it is spread over more than 50% of agricultural land. For damage that does not exceed this share, the regional hunting association, which manages the hunting grounds where damage is noticed, is obliged to pay compensation (Vidrih and Trdan, 2008).

The total damage caused by wild boars in Slovenia in the period 1998-2000 was approximately 460,000 EUR, which represented approximately 60% of the total damage caused by game in this period (Jerina, 2006). In the period 2000 to 2010, damage represented from 30 to 50% of the total damage caused by wildlife species. In 2008 alone, the damage amounted to 480,000 EUR or 85% of the total damage caused by wildlife species. The damage to grasslands caused by wild boars exceeded 50% for the first time and amounted to 259,500 EUR or 56% of total damage caused by wild boars (Vidrih and Trdan, 2008). Currently, wild boars have colonised 55% of Slovenia, and its potential habitat comprises 67% of the country. The distribution and number of wild boars will likely increase, particularly if present trends of environmental changes continue (e.g., increasing temperature, woodiness, and reduction of coniferous trees) (Jerina, 2006; Barrios-Garcia and Ballari, 2012).

According to the literature, the main factors affecting the level of damage to crops are species cultivated (Genov et al., 1995; Geisser, 1998), distance of crops from the woods (Thurfjell et al., 2009), ripening period of crops (Thurfjell et al., 2009), density of wild-boar populations (Geisser, 1998), and availability of natural food in the woods (Genov et al., 1995).

This paper focuses on the correlations between different soil parameters [presence of grubs, earthworms, soil pH, content of P₂O₅, K₂O and organic matter (OM)] and wild boar damage to grasslands. The aim of the study is to identify which soil parameters affect wild boar rooting percentage across a wide range of habitats in South East Slovenia.
Materials and methods

The experiment took place at six locations in Kočevje region (densely wooded part of South-East Slovenia): Stari Log (SL) [99 m above the sea level (asl), 45°43'31.6 N, 14°55'20.13 E], Gotenica (G) (659 m asl; 45°36'42.53 N, 14°44'49.72 E), Kačji Potok (KP) (527 m asl; 45°34'41.06 N, 14°57'57.23 E), Dolnja Briga (DB) (611 m asl, 45°31'20.05 N 14°49'8.3 E), Stari Breg (SB) (527 m asl, 45°41'7.12 N, 14°55'16.63 E), and Novi Lazi (NL) (546 m asl, 45°34'18.7 N, 14°50'56.12 E) (Figure 1). The experimental area was selected based on official results (Slovenian Forest Service, 2013) on grassland damage caused by wild boar rooting and scientific paper (Adamič and Jerina, 2009). The majority of the reports of rooting were followed up by inspection in the field to confirm if they had been caused by wild boar and to assess the extent of the damage. Boar damage was distinguished from damage caused by badgers Meles meles on the basis of a combination of field characters (Wilson, 2004). Damages in the experimental areas were due to rooting activities of wild boars, which feed on white grubs and other members of soil fauna (earthworms, etc.) and flora that provide protein-rich food (Baubet et al., 2003; Bueno et al., 2009). On 16 April 2013, each location was assessed visually (Wilson, 2004) (in % of damaged area), and samples of white grubs and earthworms were taken from 2 to 3 randomly chosen sub-locations (including control areas) in the experimental area (area damaged by wild boar feeding and undamaged, i.e. control samples). Ten holes (0.5×0.5 m; 0.5 m deep) were made at every sub-location (50×50 m). Quantification of white grubs and earthworms was completed according to Laznik et al. (2012). The soil organisms from all sub-locations were kept in plastic bags and weighed at the Laboratory of Entomology (University of Ljubljana, Slovenia) within 8 h after excavation at the latest.

To determine the linkage between grass area damaged by wild boars and the presence of white grubs and earthworms in the soils, soils were sampled and analysed to determine their fertility. At each sub-location, 3 soil samples were taken (Laznik et al., 2012). Soil analysis was completed in a chemical laboratory at the Agricultural Institute of Slovenia (Ljubljana). The goals of soil analysis were to determine pH value (ISO 10390:2005; ISO, 2005) of P2O5 and K2O (through soil extraction by ammonium-lactate (AL) solution method) accessible to plants and to determine OM in soil (ISO 14235:1998; ISO, 1998). Soil samples were taken from the upper layer of soil (from 0 to 6 cm deep) during the spring.

Statistical analyses were performed using Statgraphics Centurion XVI (Statpoint Technologies Inc., Warrenton, VA, USA). Prior to analysis, each variable was tested for homogeneity of variance, and the data that showed to be non-homogenous were transformed to log(Y) before ANOVA. Correlations between damage ratio and biotic and abiotical factors were calculated based on average values of different parameters in our observation (Bohinc and Trdan, 2012). The Duncan’s multiple range test was used to determine any significant correlation. The best fitting model was selected according to significant F values. The level of significance was set at 95%.

Results

Soil analysis

Analysis of the soil excavation showed that larvae of margined vine chafer (Anomala dubia [Scopoli]) (L1 [first larval stage] and L2 [third larval stage]), June beetle (Amphimallon solstitialis [L.]) (L1) and garden chafer (Phyllopertha horticola [L.]) (L2) were present in April 2013. Earthworms found during soil excavation belonged to the species Lumbricus rubellus Hoffmeister, Lumbricus terrestris L., and Eisenia fetida (Savigny). On average, 104 earthworms/m² were found, while their number/m² ranged between 13 in Stari Breg (SB1) to 289 in SL (Table 1). Using the excavation method, we also determined the average number of grubs in soil. Huiting et al. (2006) stated that the critical threshold of grubs (number of grubs which can cause an economic damage) on grassland is between 10 to 20 grubs/m². On average, 11 grubs/m² were found, while their number/m² varied from 2 in Stari Breg (SB2) to 35 in G (Table 1).

The average pH in all analysed samples was 5.5, the lowest pH (4.7) was in the soil sample in SL, and the highest pH (7.1) was measured in the experimental soil in G (Table 1). The recorded pH values of soil belong to the central three in regard to the degree of acidity, namely: acidic soil (from 4.5 to 5.5), moderately acidic soil (from 5.6 to 6.7), and neutral soil (from 6.8 to 7.2). The soils sampled and analysed for phosphorus were categorised into four ranges (A, B, C and E) according to the AL method (Table 1). The soil with the least amount of phosphorus (range A: <6 mg P2O5/100 g of soil) was found at Stari Log (SL1), Kačji Potok (KP2, KP3), Stari Breg (SB1, SB2) and Novi Lazi (NL1, NL2). Range B (from 6 to 12 mg P2O5/100 g of soil) comprises the soil from DB, while range C (from 13 to 25 mg P2O5/100 g of soil) was the soil from Stari Log (SL2). The sampled soil at G contained 57 mg P2O5/100 g of soil (range E), which was caused by the application of chicken manure from a nearby farm in the year prior to sampling. The goal – ensuring the proper amount of phosphorus in soil (Pautler and Sims, 2000) – is represented by range C, which was achieved only in a few cases. The soil samples had more potassium than phosphorus, as they

Figure 1. Location of the study area in Slovenia (in black).
mostly belonged to range B (10 to 19 mg K₂O/100 g of soil) (Table 1). In the desired range (C: 20 to 39 mg K₂O/100 g of soil) were the soils in Stari Log (SL2), Kačji Potok (KP1) and Stari Breg (SB1, SB2), where we established the highest value of K₂O/100 g of soil among the studied locations. Since all soil samples were collected on grassland, the percentage of OM was high as expected. The average percentage of OM was 8.4; the lowest value was recorded in Kačji Potok (KP2) (6.6%), while the highest was found in G (12.4%).

**Influence of grubs and earthworms on wild boar grassland damage**

Results showed a strong correlation of wild boar grassland damage to the average number of grubs in soil per m² (P=0.0093; r=0.73). On the other hand, the average number of earthworms in soil per m² did not have a significant influence (P=0.1344) on wild boar damage. Moreover, the analysis showed that average weight of grubs per m² had a significant influence (P=0.0172) on wild boar damage in grassland, indicating a strong positive relationship (r=0.69) between the variables. The average weight of earthworms per m² did not have a significant influence (P=0.0687) on wild boar damage. Furthermore, when the average number and weight of grubs and earthworm per ha were calculated, the results confirmed previous observations (Table 2).

**Influence of soil elements and pH on wild boar grassland damage**

Soil analysis showed that values of P₂O₅ had a significant influence (P=0.0004) on wild boar damage, indicating that the model as fitted explained 76.67% of the variability. However, pH (P=0.0907) and K₂O (P=0.2107) values in soil did not have a significant influence on wild boar damage and indicated a moderate (r=0.53) and a relatively weak correlation (r=0.41) between the variables, respectively. Similar conclusions were made concerning values of OM (P=0.1646; r=0.51) in soil (Table 3).

### Table 1. Average number and weight of earthworms and grubs per m² (mean of ten replicates±standard error), wild boar damage and soil parameters (mean of three replicates±standard error) at different locations in Kočevo Region.

| Location   | Earthworms, no./m² | Grubs, no./m² | Earthworms, g/m² | Grubs, g/m² | Wild boar damage, % | pH in CaCl₂ | P₂O₅ mg/100 g | K₂O mg/100 g | OM (f=1.724), % |
|------------|---------------------|---------------|------------------|-------------|---------------------|------------|---------------|--------------|-----------------|
| SL1        | 281±11              | 19±3          | 77±8             | 2±2         | 5.4±0.3             | 17±2       | 13±2          | 6.8±0.3       |
| SL2        | 24±3²               | 8±2           | 3±2              | 7±1¹        | 44±3              | 4.7±0.2   | 22±2         | 7.6±0.2       |
| KP1        | 228±13²             | 5±2           | 44±4             | 4±1         | 35±3              | 6.4±0.5   | 6±1¹         | 7.6±0.2       |
| KP2        | 120±11              | 3±1           | 30±8             | 3±1         | 34±3              | 4.8±0.4   | 3±1          | 6.6±0.4       |
| KP3        | 128±6               | 23±3          | 62±5             | 22±2        | 56±4              | 5.5±0.3   | 4±1²         | 6.9±0.2       |
| G          | 56±4                | 35±4          | 39±4             | 34±2        | 2±2               | 7.1±0.3   | 57±6         | 12.4±0.2      |
| DB         | 63±6               | 3±1           | 30±3             | 3±1         | 93±7              | 5.4±0.4   | 7±1          | 9.4±0.3       |
| SB1        | 13±5               | 4±1           | 3±1              | 3±1         | 15±2              | 5.0±0.6   | 3±1          | 7.6±0.2       |
| SB2        | 47±3              | 2±1           | 11±2             | 3±1         | 84±5              | 5.5±0.7   | 3±1          | 7.3±0.2       |
| NL1        | 73±4²              | 12±3          | 28±2             | 12±1        | 73±6              | 4.9±0.3   | 3±1          | 7.6±0.5       |
| NL2        | 109±3              | 11±2          | 42±3             | 9±2         | 83±6              | 5.6±0.3   | 15±2         | 8.3±0.3       |

OM, organic matter; SL1, Stari Log 1; SL2, Stari Log 2; KP1, Kačji Potok 1; KP2, Kačji Potok 2; KP3, Kačji Potok 3; G, Gotenica; DB, Dolnja Briga; SB1, Stari Breg 1; SB2, Stari Breg 2; NL1, Novi Lazi 1; NL2, Novi Lazi 2. Different letters within the same column indicate statistically significant differences.

### Table 2. Effect of correlations between grub and earthworm presence on wild boar grassland damage (P<0.05 Duncan’s multiple range test).

| Wild boar damage, % | Earthworms, no./m² | Grubs, no./m² | Earthworms, g/m² | Grubs, g/m² |
|---------------------|---------------------|---------------|------------------|-------------|
| Wild boar damage, % | r=0.48              | r=0.73*       | r=0.56           | r=0.69*     |
| P=0.1344            | P=0.0093            | P=0.0687      | P=0.0172         |
|                      | y=1/(0.021+0.0004*x²) | y=1/(0.033+0.0004*x²) |
| Earthworms, no./m²  | r=0.27              | r=0.94*       | r=0.27           | r=0.27      |
| P=0.4096            | P<0.0001            | P=0.4080      |                  |
|                      | y=1/(0.005+0.1737*x) |                  |
| Grubs, no./m²       | r=0.59              | r=0.99*       | r=0.59           | r=0.59      |
| P=0.0558            | P<0.0001            | P=0.0676      |                  |
|                      | y=sqrt (18.42+11*x²) |
| Grubs, g/m²         | r=0.56              | r=0.56        | r=0.56           | r=0.56      |
| P=0.0676            | P=0.0676            | P=0.0676      |                  |

First row parameters refer to x, while first column ones refer to y.
Interaction between soil elements and pH

Results showed that content of P$_2$O$_5$ and OM in soil has a significant influence (P=0.0096 and P=0.0070, respectively) on pH ratio in soil, indicating that the model as fitted explained 54.35 and 57.33% of the variability, respectively. However, the content of K$_2$O in soil did not have a statistically significant influence (P=0.0096) on pH ratio in soil. The correlation coefficient equals 0.17, indicating a relatively weak relationship between the variables. Further analysis revealed that OM in soil significantly influenced the content of P$_2$O$_5$ (P=0.0001; r=0.91). The model as fitted explained 83% of the variability between the observed parameters (Table 5).

Table 3. Effect of correlations between soil elements and pH on wild boar grassland damage (P<0.05 Duncan’s multiple range test).

| Wild boar damage, % | pH in CaCl$_2$ | P$_2$O$_5$, mg/100 g | K$_2$O, mg/100 g | OM (f=1.724), % |
|---------------------|----------------|----------------------|------------------|-----------------|
| Wild boar damage, % | r=0.53         | r=0.87*              | r=0.41           | r=0.51          |
|                      | P=0.0007       | P=0.0004             | P=0.2107         | P=0.1046        |
| pH in CaCl$_2$       |                |                      |                  |                 |
| r=0.73*             |                | r=0.75*              | r=0.017          | r=0.91*         |
| P=0.0096            |                | P=0.0070             | P=0.0001         |                 |
| y=(2.3+0.0001*x)$^2$|                |                      |                  |                 |
| P$_2$O$_5$, mg/100 g|                |                      |                  |                 |
| r=0.35              |                | r=0.91*              |                  |                 |
| P=0.2820            |                | P=0.0001             |                  |                 |
| K$_2$O, mg/100 g    |                |                      |                  |                 |
| y=sqrt(-1536.6+28.1*$x^2$) |           |                      |                  |                 |
| OM (f=1.724), %     |                |                      |                  |                 |

Table 4. Effect of correlations between soil elements and pH on grubs in soil (P<0.05 Duncan’s multiple range test).

| Grubs, no./m$^2$ | Grubs, g/m$^2$ | pH in CaCl$_2$ | P$_2$O$_5$, mg/100 g | K$_2$O, mg/100 g | OM (f=1.724), % |
|-----------------|----------------|----------------|----------------------|------------------|-----------------|
| Grubs, no./m$^2$ |                |                |                      |                  |                 |
| r=0.99*         |                | r=0.71*        | r=0.90*              | r=0.47           | r=0.74*         |
| P=0.0001        |                | P=0.0136       | P=0.0001             | P=0.1417         | P=0.0082        |
| y=sqrt(18.42+1.1*$x^2$) |            | y=sqrt(-728.8+31.4*$x^2$) | y=sqrt(19.1+20.9*$x^2$) |                  |                 |
| Grubs, g/m$^2$  |                |                |                      |                  |                 |
| r=0.72*         |                | r=0.91*        | r=0.77*              | r=0.017          | r=0.75*         |
| P=0.0011        |                | P=0.0001       | P=0.0049             | P=0.0070         | P=0.0049        |
| y=sqrt(-713.8+29.9*$x^2$) |            | y=sqrt(88.6+0.33*$x^2$) | y=sqrt(-371.1+8.5*$x^2$) |                  |                 |
| pH in CaCl$_2$  |                |                |                      |                  |                 |
| r=0.73*         |                | r=0.35         | r=0.80               | r=0.51           |                 |
| P=0.0096        |                | P=0.2820       | P=0.0001             |                  |                 |
| y=(2.3+0.0001*$x^2$) |            |                  |                      |                 |                 |
| P$_2$O$_5$, mg/100 g |                |                |                      |                  |                 |
| K$_2$O, mg/100 g |                |                |                      |                  |                 |
| y=sqrt(-1536.6+28.1*$x^2$) |            |                  |                      |                 |                 |
| OM (f=1.724), % |                |                |                      |                  |                 |

Discussion

The literature provides many specific examples of seasonal differences in wild boar diet (Barrios-Garcia and Ballari, 2012). Vegetable options occurred more frequently in the diet of wild boars than animal options (Dardaillon,
Schley and Roper (2003) and Schley and Roper (2003) reported that among animal options, insects, earthworms, birds and mammals were eaten most consistently. Briedermann (1976) and Tučak (1996) reported that animal consumption is seasonal and can constitute up to 30% of wild boar diet (Challies, 1975; Chimera et al., 1995). Wilcox and Van Vuren (2009) hypothesised that protein deficiency through the season might be an important factor influencing animal predation rates.

The results of our research indicate that the number of earthworms in soil does not affect the extent of damaged grass cover. The results are in agreement with those of Baubet et al. (2003), who suggested that earthworm consumption is mainly opportunistic and that wild boar forage for earthworms during weather conditions suitable for earthworms. In this case damage does not occur on grass cover, as established in our research. The results by Baubet et al. (2003) confirm our findings, as the period between March and April, when we performed the analysis, was rainy (the average precipitation in experimental locations was 213 mm) (ARSO, 2013), which made the earthworms come to the soil surface, thereby enhancing their capture rate. In this case damage does not occur on grass cover, as established in our research. The results by Baubet et al. (2003) confirm our findings, as the period between March and April, when we performed the analysis, was rainy (the average precipitation in experimental locations was 213 mm) (ARSO, 2013), which made the earthworms come to the soil surface, thereby enhancing their capture rate. In this case damage does not occur on grass cover, as established in our research.

The results of our research indicate that the number of earthworms in soil influences the extent of grassland damage. Vertical movement of grubs in soil is conditioned by the development stage of an organism and the season (Hawley, 1949; Laznik et al., 2012); larvae stay in the soil, and wild boars must reach them by rooting (Herrero et al., 2006). In this case, damage occurs on grass cover, as established in our research.

Several studies showed that earthworm and grub distribution in soil is affected by the physical and chemical characteristics of the soil, such as temperature, pH, moisture, OM and soil texture (Polivka, 1966; Edwards and Bohlen, 1996; Chalasani et al., 1998; Brandhorst-Hubbard et al., 2001; Ismail, 2005). Results of our research showed that the average number of earthworms in soil is estimated by K2O. Furthermore, results of our investigation showed a negative correlation of earthworm weight and K2O soil content. Indeed, we found a lot of small earthworms (mainly E. foetida) in soils with high values of K2O, while in other cases much bigger earthworms (L. rubellus and L. terrestris) were found. Conversely, the content of K2O indicated a relatively weak relationship with the number of grubs in soil, while other factors (pH, P2O5 content, OM content) showed positive correlations with the density of grubs. The obtained results do not confirm the results of some previous studies (Edwards and Bohlen, 1996; Chalasani et al., 1998; Ismail, 2005) in which the researchers established strong correlations between the number of earthworms in soil and the content of pH and OM.

Edwards and Bohlen (1996) reported that pH is a vital factor that determines the distribution of earthworms, as they are sensitive to hydrogen ion concentration. Several researchers have stated that most earthworms prefer a pH of about 7.0 (Pagaria and Totwat, 2007; Suthar, 2008). An average value of pH was in our experiment 5.5. Among the species, L. rubellus, L. terrestris, and E. foetida were dominant. Up to now these species were investigated in Slovenia above all in the context of soil pollution (Udovič and Leštan, 2010a, 2010b). Olson (1928) reported that L. terrestris occurs in soils with pH 5.4. Guild (1951) and Satchel (1983) reported that L. terrestris was not very sensitive to pH. Their results are in agreement with ours since our investigation showed a weak correlation (not significant) between earthworm distribution and pH values. Our results showed a weak correlation (not significant) between earthworm distribution and values of OM. Several other studies showed that the distribution of earthworms is greatly influenced by the distribution of OM. Soils that are poor in OM do not usually support large numbers of earthworms (Edwards and Bohlen, 1996; Ismail, 2005). Furthermore, several studies showed a strong positive correlation between earthworm quantity and biomass and the OM content of the soil (Doube et al., 1997; Ismail, 2005). Our investigation does not support the results of previous mentioned authors. Only one location in our experiment (G) was rich in OM. Soils from other locations were relatively poor in OM. This could explain not significant correlation between the vari-

**Table 5. Effect of correlations between soil elements and pH on earthworms in soil (P<0.05 Duncan’s multiple range test).**

| Earthworms, no./m² | Earthworms, g/m² | pH in CaCl₂ | P₂O₅, mg/100 g | K₂O, mg/100 g | OM (f=1.724), % |
|------------------|-----------------|-------------|---------------|---------------|-----------------|
| Earthworms, no./m² | r=0.94*         | r=0.27      | r=0.44        | r=0.81*       | r=0.38          |
|                  | P<0.0001        | P=0.361     | P=0.174       | P=0.0024      | P=0.2453        |
|                  | y=1/(0.005+0.1737/x) |           |               |               |                 |
| Earthworms, g/m² | r=0.50          | r=0.52      | r=0.84*       | r=0.26        |
|                  | P=0.1150        | P=0.0966    | P=0.0010      | P=0.4400      |
|                  | y=exp(4.9-0.005*x²) |           |               |               |                 |
| pH in CaCl₂      | r=0.73*         | r=0.17      | r=0.75*       |
|                  | P=0.0006        | P=0.6107    | P=0.0070      |
|                  | y=(2.3+0.0001*x²) |           |               |               |                 |
| P₂O₅, mg/100 g   | r=0.35          | r=0.91*     |
|                  | P=0.2820        | P=0.0001    |
|                  | y=sqrt(-1536.6+28.1*x²) |     |               |               |                 |
| K₂O, mg/100 g    | r=-0.13         |
|                  | P=0.6818        |
| OM (f=1.724), %  | -               |

OM, organic matter. First row parameters refer to x, while first column ones refer to y.
ables. Brandhorst-Hubbard et al. (2001) showed that grubs prefer to migrate to areas that have a high OM content, and our investigation confirms these results. Polivka (1960) studied the relationship of soil pH and the population of grubs (Papilio jasonicola Newman, Cyclocephala borealis Arrow and Phyllophaga spp.). Their study indicated that grubs increase more rapidly in a low soil pH and that a high grub population continues to exist in these soils year after year as long as favourable weather prevails during the egg and young larval stages. This investigation concluded that it is possible to reduce grub population by simply applying lime to soil. As the pH values of our investigated soils were classified from acid to neutral (from 4.7 to 7.1) we can conditionally confirm those results, since the grub species in our investigation were not the same (A. dubia, A. solstitialis, and P. horticola).

On the basis of the results we conclude that grubs in the territory of South East Slovenia represent a more important source of protein than earthworms for wild boars, although the mass of grubs (105 kg/ha) on the area represents a smaller percentage of soil biota than earthworms (335 kg/ha). By systematically reducing the number of grubs in soil – as the number of synthetic soil insecticides is constantly decreasing, we ought to apply primarily entomopathogenic nematodes, bacteria, and fungi (Laznik et al., 2012) – we can reduce rooting of grasslands by the studied mammal and consequently improve the cost-effectiveness of the production of voluminous fodder in the territory of South East Slovenia and other areas facing the damaging effects of the wild boar on grassland.

Conclusions

The results of our research indicate that the number of earthworms in soil does not affect the extent of damaged grass cover, since earthworm consumption is mainly opportunistic and that wild boar forage for earthworms during weather conditions suitable for earthworms is on the soil surface, thereby enhancing their capture rate. In this case damage does not occur on grass cover, as established in our research. On the other hand, the results of our research indicate that the number of grubs in soil influences the extent of grassland damage, since wild boars must reach them only by rooting. Results of our research showed that the average number of earthworms in soil is affected by K2O values of the soil. Furthermore, they also showed a negative correlation of earthworm weight and K2O soil content. Our results showed a weak correlation (not significant) between earthworm distribution and values of OM and pH.

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