Changes in soil arthropod functional group in a wheat crop under conventional and no tillage systems in Argentina

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Abstract

Different functional groups of soil arthropodofauna present in the agro-ecosystem can be severely modified by tillage practices. The abundance of different trophic groups subject to conventional tillage (CT) and no tillage (NT) practices were evaluated compared to a natural field boundary (FB) in a wheat crop. Arthropods were captured using pitfall traps and collected every 20 days during 10 months, and grouped according to their habits in predators, phytophagous and detritivorous. Tillage systems affected the abundance of arthropod fauna and the proportion between different functional groups as regards a FB. Predators constituted the most abundant group of all arthropods captured, and their number was higher under NT than under CT. In CT, an increase in predators was observed only in spring, probably associated with a recolonisation from the adjacent plots of NT. Phytophagous was the least representative group in the three evaluated systems, it was higher under cropped plots (NT and CT) than in the FB, and was not affected by tillage practices.

Under NT, the number of predators, remained higher along the crop development. Phytophagous activity in no till plots remains constant. In FB, the number of captured individuals was lower and relatively stable along the whole sampling period than in the cultivated plots.

Ploughing action (CT plots) provoked a decrease in the relative importance of predators and an increase in phytophagous as regards those in NT and FB. Total biomass of captured arthropod fauna showed significant differences between treatments, being higher in NT and lower in CT plots.

It is concluded that tillage systems affect not only the abundance of arthropod fauna but also the proportion between different functional groups. The consequences of these changes for soil quality are discussed later on.

Keywords: Soil ecology; Tillage practices; Arthropod fauna; Pitfall traps; Arthropod biomass

1. Introduction

Intensive agricultural practices in the last decades have been associated with a decrease in the abundance and diversity of several animal and plant species (Paoletti, 1988; Alderweireldt et al., 1991; Pfiffner and Niggli, 1996; Marasas et al., 1997). In recent years, sustainable agriculture has appeared as a way of maintaining agro-ecosystem productivity while avoiding natural resource degradation. Since soil is one of the main natural resources of agro-ecosystems, those species constituting soil biota are important because of their role in enhancing and maintaining soil quality

(Beare, 1997). Likewise, an appropriate balance in arthropodofauna between predators and phytophagous is necessary in a sustainable agricultural system in order to prevent the increase of harmful pests.

Many of the arthropod fauna act as specific or non-specific predators and others as strictly phytophagous, detritivorous or opportunist polyphagous. In spite of the different roles they play in the food web, they also take a significant part in organic matter incorporation improving the soil structure, due to mechanical activity by digging and burrowing for resting and/or food relocation (Zunino, 1991). The latter is especially important in those groups with fossorial habits in adult and larval stages (Alderweireldt et al., 1991; Primavesi, 1990; Stinner and House, 1990). Likewise, Kajak (1997) found that macroarthropods produced a higher proportion of detritus and faeces, and that this was associated with an increase in total organic carbon, humic and fulvic acids.

Tillage practices exert a great pressure in agro-ecosystems, modifying the habitat of important functional groups of edaphic arthropods (Robertson et al., 1994; Jones, 1979). Robertson et al. (1994) in semiarid regions and Stinner and House (1990) in temperate conditions studied the effect of different tillage practices on edaphic taxa with different feeding habits, reporting an increase in biodiversity in those agro-ecosystems under no tillage (NT), where predators were the best represented group.

Generally, comparative studies of arthropod fauna under different tillage systems have been in degraded soils after many years of intensive agricultural practices, where NT was incorporated as an alternative to conventional practices in order to protect and recover soil quality (Beviacqua et al., 1984; Robertson et al., 1994; Cárcamo, 1995). However, little is known about the effect of different tillage systems when applied in a no agricultural soil for first time as compared with field boundary (FB).

In Argentina, the area cultivated under the NT system has markedly increased in the last 5 years as more environmentally sound technology to avoid soil erosion. In a wheat crop cultivated under NT system in a temperate zone of Argentina an increase in abundance and diversity of ground beetles was reported as compared with those under conventional tillage (CT) (Marasas et al., 1997). However, little information is available about the effect of tillage systems on the balance between arthtropod fauna of different feeding habits.

It is considered that no soil turn over favours an equilibrium between different functional groups of the arthropod fauna similar to those of natural non disturbed systems.

The aim of this paper was to evaluate the changes taking place among different groups or arthropod fauna in a wheat agro-ecosystem in a temperate climate when a soil uncultivated for a long time is disturbed by different tillage practices.

2. Materials and methods

2.1. Site description

The study was carried out at the Faculty of Agricultural Sciences Experimental Station, La Plata, Argentina (35° SL), during 1995. The climate is temperate with a mean annual temperature varying between 22°C for the hottest month (January) and 8°C for the coldest one (July). Mean annual rainfall is 1000 mm, without dry season. The field has a typical argiudol soil with some internal drainage deficiencies and the following values at sowing time (0–20 cm deep): organic matter 4.2 and 4.4%, pH 6.1 and 5.7 and a C/N ratio 11.5 and 12.1 for plots under CT and NT, respectively. The field remained 25 years uncropped untill 1993, when a wheat crop was sown. During 1994, although no crops were sown, the strips were maintained with or without till as in previous years.

2.2. Experimental design

On 26 June 1995, two commercial wheat (*Triticum aestivum* L.) cultivars were sown at a density of $120\,kg\,ha^{-1}$ on alternative strips of 70 m long and 10 m wide each one under CT with moldboard plow and NT strips in a randomised block design with four repetitions. The size of each plot was $100\,m^2$ and all were fertilised with $100\,kg\,ha^{-1}$ of superphosphate (00-46-00) at sowing. The plots under NT were kept weed free, before sowing by glyphosate applications ($3.5\,l\,ha^{-1}$). After crop emergence weed was controlled by applications of 2-4D plus Picloram at $400\,cm^3\,ha^{-1} + 100\,cm^3\,ha^{-1}$, respectively, in all plots.

Table 1
Orders, families, tribes and species of arthropod captured during 1995–1996 period grouped, according to its feeding habits

Predators	Phytophagous	Detritivorous
Insecta	Insecta	Insecta
Coleoptera	Coleoptera	Coleoptera
Carabidae	Carabidae	Cucujidae
Tribu Carabini	Tribu Harpalini	Aphodiidae
Calosoma (*Castrida*) *retusum* (Fabricius, 1775)	*Selenophorus* (*Selenophorus*) *alternans* (Dejean, 1829)	Trogidae
Tribu Scaritini	*Selenophorus* (*Selenophorus*) *anceps* (Putzeys, 1878)	Tenebrionidae
Sacarites (*Scarites*) *anthracinus* (Dejean, 1831)	*Selenophorus* (*Selenophorus*) *punctulatus* (Dejean, 1826)	Lathrididae
Scarites (*Scarites*) *m. melanarius* (Dejean, 1831)	*Selenophorus* (*Selenophorus*) sp.	Leiodidae
Tribu Clivinini	*Notiobia* (*Anisotarsus*) *cupripennis* (Germar, 1824)	Diplopoda
Clivina (*Paraclivina*) *breviuscula* (Putzeys, 1866)	*Polpochila* (*Polpochila*) *pueli* (Négre, 1963)	
Clivina (*Semiclivina*) *platensis* (Putzeys, 1866)	*Bradycellus viduus* (Dejean, 1829)	
Clivina (*Semiclivina*) *urophthalmoides* Kult, 1947	*Bradycellus debilis* (Erichson, 1847)	
Aspidoglossa intermedia (Putzeys, 1866)	Chrysomelidae	
Tribu Brachinini	Apionidae	
Brachinus (*Neobrachinus*) *pallipes* (Dejean, 1826)	Curculionidae	
Tribu Bembidiini	Elateridae	
Notaphus (*Notaphus*) *laticollis* (Brullé, 1838)	Dynastidae	
Notaphiellus solieri (Germain, 1906)	Chrysomelidae	
Pericompsus (*Eidocompsus*) *metallicus* (Bates, 1861)	Hydrophilidae	
Micratopus sp. Nov.	Heteroptera	
Tribu Pterostichini	Pentatomidae	
Trirammatus (*Feroniomorpha*) sp.		
Trirammatus (*F.*) *striatulus* (Fabricius, 1792)		
Parhypates (*Paranortes*) *cordicollis* (Dejean, 1828)		
Argutoridius chilensis ardens (Dejean, 1828)		
Loxandrus simplex (Dejean, 1828)		
Loxandrus cfr. *Confusus* (Dejean, 1831)		
Loxandrus sp. no. 1		
Loxandrus sp. no. 2		
Loxandrus sp. no. 3		
Tribu Lebiini		
Lebia (*Lebia*) *venustula* (Dejean, 1831)		
Apenes (*Malisus*) cfr. *Erythrodera* (Chaudoir 1875)		
Coccinellidae		
Staphylinidae		
Dytiscidae		
Histeridae		
Lampyridae		
Scorpiones		
Chilopoda		
Hemiptera		

In all plots, five pitfall traps were located 2 m apart resulting in total 20 traps per treatment. The same number of traps were also located in four plots of 40 m^2 each, on the only side with a FB uniform in structure and vegetation (constituted mainly by gramineae species), and never disturbated by agricultural practices. This strip was parallel to field crop and 20 m apart. Each pitfall trap consisted of plastic pots 150 mm deep, with a diameter of 100 mm, filled with 4% formaldehyde in water and some drops of detergent. The traps were protected by a roof of 15 cm^2 located 10 cm over the trap surface. Pitfall traps were collected every 20 days during 10 months since 25 June (12 samples).

The number of total individuals captured in pitfall traps was evaluated as a measure of the activity of the surface living-invertebrates (Thiele, 1977; Baars, 1979). Total biomass (wet) was estimated for 10 individuals of each species weighed in a digital balance with 0.01 g of precision. For each species, the mean value, represented by every frequency of size was chosen.

All captured individuals were determined at family level. In the phytophagous group, only those which feed roots, seeds and/or sprouts, typically edaphic crawlers were included, discarding the epiphytic fauna, as they are rarely captured by pitfall traps and the wheat crop has not important aerial pests in this area. Carabids, considered the most abundant family (Marasas et al., 1997), were identified at species level consulting the current literature as well as the collections of La Plata Museum of Natural Sciences and Bernardino Rivadavia, Argentine Museum of Natural Sciences.

Data were analysed by ANOVA, considering the mean value of the five traps of each plot. The values were previously transformed by log function. To facilitate interpretation of the data, figures were presented untransformed. Means differences were determined by LSD test at $P < 0.05$.

3. Results

During the whole sampling period a total of 4280 individuals was captured, grouped according to feeding habits in predators, phytophagous and detritivorous (Table 1). The edaphic community was represented by different arthropod groups. Coleoptera showed higher abundance and diversity and was together with chilopods, diplopods and opiliones the best represented of all captured arthropod fauna. In Table 1, the most important orders and families are represented, and also Coleoptera at tribe and specie levels.

Predators constituted the most abundant group of all captured arthropods. A higher number of individuals were captured under NT than CT or FB (Table 2). Phytophagous arthropods were present in lower numbers in the three evaluated systems and were higher under cropped plots (NT and CT) than in the FB. A higher number of detritivorous individuals was captured in NT plots, though they were only statistically different when compared with FB (Table 2).

Table 2
Total of individuals per plot captured over the whole sampling period grouped according to its feeding habits[a,b]

	Predators	Phytophagous	Detritivorous	Total
NT	272 a	83 a	131 a	485
CT	136 b	82 a	101 ab	319
FB	147 b	41 b	78 b	266
Total	554	206	310	1070

[a] No tillage: NT; conventional tiller: CT; field boundary: FB. Values presented are average of four repetitions.

[b] Values within each column followed by the same letter do not differ statistically for $P > 0.05$, according to LSD test.

The activity of different arthropod groups along the time varied between tillage systems (Fig. 1a–c). Under NT, the number of predators, mainly represented by Carabidae and Staphylinidae, remained higher during the crop development. On the contrary, Scorpions and Chilopoda were more abundant in summer when a decrease in the number of predators was observed.

Phytophagous abundance was very low under no till plots and remained constant showing a little increase only at the end of the crop season (sampling 10, Fig. 1a). None of the captured arthropods of the mentioned families in Table 1 has been described as an aerial crop pest. Diplopods and Coleoptera detritivorous species mainly those of the Scarabeidae, Trogidae and Tenebrionidae families showed an increase in samplings 4–6 in no till plots, which corresponding to the beginning and development of the spring season.

In conventional tiller plots (Fig. 1b), a low number of predators was collected in the first samplings. Then the number increased towards spring (samplings 5, 6 and 7), and decreased towards the end of the crop development. The number of phytophagous and detritivorous captured remained low and relatively stable during the whole sampling period.

The behaviour of the individuals from the three groups in FB was different from those of the cultivated systems. The number of captured individuals was lower and relatively stable along the whole sampling period. No statistically significant differences

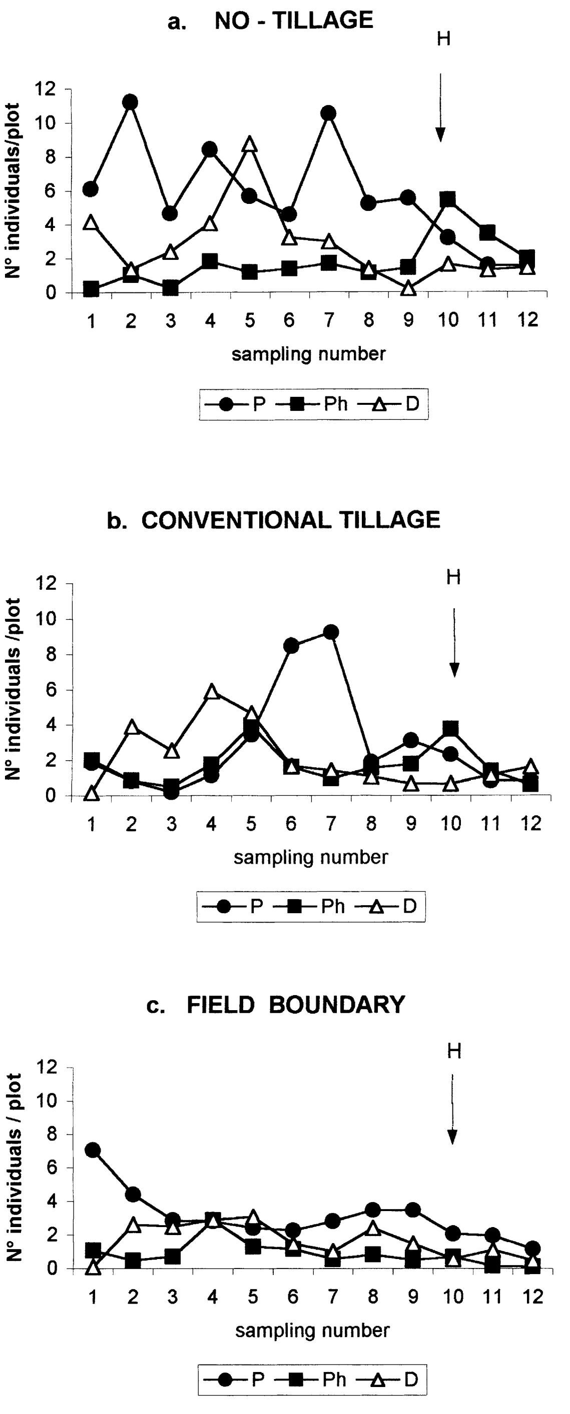

Fig. 1. Variations among functionals groups of artrhopod fauna along time (P: predators, Ph: phytophagous and D: detritivorous) for each tillage system. H: wheat harvest.

were observed between groups (Fig. 1c), though a higher number of predators were recorded.

When the proportion of each group over the total of captured individuals was calculated for each treatment, significant differences between CT and the other two systems (NT and FB), mainly in predators and phytophagous groups (Fig. 2), were observed. Ploughing action (CT plots) provoked an important decrease in predators:phytophagous relationship ($P/Ph = 1.6$) compared with NT ($P/Ph = 3.3$) and FB ($P/Ph = 3.5$) treatments (Fig. 2).

The total biomass of captured arthropod fauna during this experiment were significantly higher in NT and lower in CT plots (Fig. 3).

4. Discussion

The results presented here showed that, under the weather conditions of this year (similar to the historical mean) tillage practices exert a great influence on the activity of the groups of the studied arthropod fauna. A higher activity of predators was observed under NT indicating that these plots presented the best environmental conditions for predator's activity, probably due to the absence of the mechanical action of the plough, and a permanent soil cover that offers several habitats for shelter or feeding. This cover guarantees their activity, permanence and abundance in this system (Krooss and Schaefer, 1998). Although this group has been frequently related to its function as biological control of harmful pests, the species with digging or burrowing habits may also play an important role in the improvement of the physical soil conditions enhancing the aeration and water movement. These species were represented by Carabidae family, tribe Scaritini (*Scarites* (*Scarites*) *anthracinus*, *S.* (*Scarites*) *melanarius*), Clivinini (*Aspidoglossa intermedia*, *Clivina* sp.) and Harpalini (species of the genus *Notiobia, Selenophorus, Polpochila,* and *Bradycellus*). In addition, other species of large and medium size, which remove the soil anfractuosities or modify the more superficial existing galleries, (Pterostichini with species of the genus *Trirammatus, Loxandrus, Parhypates* (*Paranortes*), and *Argutoridius*) were captured. These groups showed a decrease in summer, because these species look for shelter to protect themselves from the effect of hot and direct sunrays.

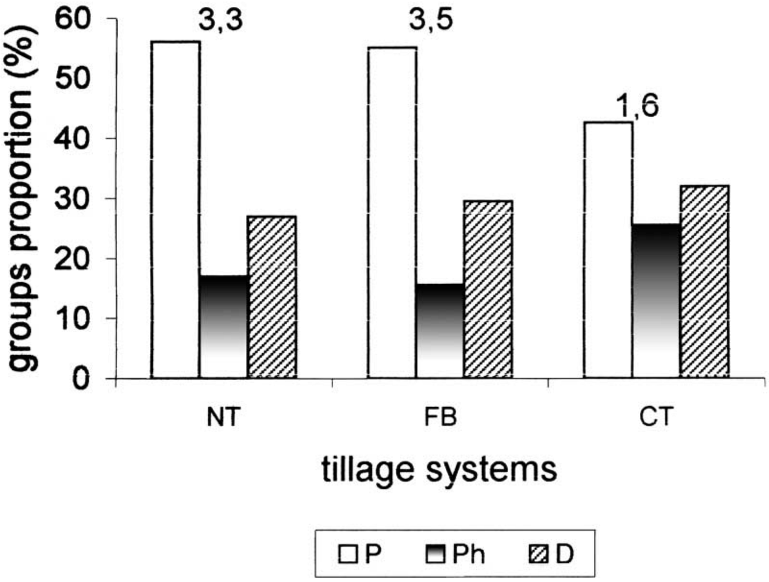

Fig. 2. Proportion of the different functional groups over the total captured individuals for each tratment. P: predators, Ph: phytophagous and D: detritivorous. NT: no tillage, CT: conventional tillage and FB: field boundary. Numbers over the column represent the predators/phytophagous relationship.

The notorious decrease of predator's activity in plots under CT would reflect the impact of the ploughing action on the species of this family, even though this effect seems to depend on several factors (Baguette and Hance, 1997). The turn over of the soil in winter months affected those species of Carabidae best represented such as *Parhypates* (*Paranortes*) *cordicollis*, because, either the adults or their larvae remained active along the year, although more active mainly in winter and spring. So do *Scarites* (*Scarites*) *anthracinus* and *S.* (*Scarites*) *melanarius*, both with adults and larvae with digging habits that hibernate in their self-made galleries.

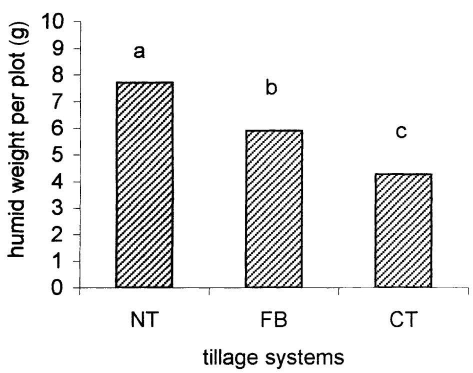

Fig. 3. Arthropod total biomass for each treatment. NT: no tillage, CT: conventional tillage and FB: field boundary, during all sampling period.

In spite of their effect on predators, tillage practices did not affect abundance of those groups with phytophagous habits, agreeing with Robertson et al. (1994) results. Captured phytophagous were mainly crowling beetles, which found an additional source of food in the crop system and probably came from the adjacent plots of FB, their probable shelter sites (Sotherton, 1984; Thomas, 1997; Coombes and Sotherton, 1986). In spite of this, *Selenophorus* (*Selenophorus*) *anceps*, a carabid species with predominant phytophagous and digging habits either as an adult or in larval stage was affected by CT drastically decreasing its abundance. This suggests that the effect of tillage practices on the different species is related not only to their feeding habits but also to their seasonal phenology.

In spring, the activity of predators in CT rose to similar values of those in NT. Because no posterior mechanical labour was done in these plots, soil tends to be covered by weeds and crop growth. This would facilitate the system recovery and a probable recolonisation of these plots from adjacent ones as was suggested in previous works (Marasas et al., 1997). This can be supported by the flying ability of a great number of individuals of Carabidae species and in the particular case of *Parhypates* (*Paranortes*) *cordicollis,* on its cursorial abilities.

Little fluctuation of the different functional groups along time was observed in the FB plots, which is a typical behaviour that can be found in natural habitats or in those slightly modified by human activities (Lasinio and Zapparoli, 1993).

Our results suggest that when an uncropped field is cultivated with low aggressive tillage practices (no soil turn over) a proportional relationships between arthropod fauna groups, similar to those under natural fields (FB), can be maintained in spite of the presence of wheat crop. Blumberg and Crossley (1983) remarked on the advantages of no till practices over conventional systems in promoting system stability. On the contrary, when agro-ecosystems are altered by CT practices the balance between different functional groups could be affected by a decrease in predators/phytophagous relationship in just the first year of crop growth.

Even though the captured individuals in our experiment represent just a part of the existing soil arthropod fauna, our results agree with those of Kajak (1997), who observed that a decrease in predators patrolling soil surface was associated with an increase in phytophagous number. Probably, if this CT practice continues in the future the differences could increase and the system ability for self-regulation could be altered, and some phytophagous species could become important crop pests. This idea is in agreement with Robertson et al. (1994), who found that a decrease in predator numbers, after many years of CT practices, would lead to an increase of those crop pests which live in the soil.

The detritivorous activity was also affected by tillage treatments. A higher activity was observed under agricultural plots than under FB. Probably crop systems presented better conditions regarding quantity and quality of available organic matter. The most abundant captured individuals were those of Diplopoda, especially during the spring period. It is not clear, if the low number of detritivorous species captured was due to the sampling method used (pitfall traps), which only capture species with active surface movements, or if it represents the true fact that took place preferably in this crop.

The arthropod biomass was higher in NT than in the other treatments. The qualitative and quantitative incorporation of organic matter as a consequence of the total biomass that is present in some agro-ecosystems has been little studied, though its importance has been remarked by Primavesi (1982). It is clear that no till practices enhance the diversity in organic matter incorporation. The higher arthropod fauna biomass in NT and the incorporation of crop residues will enhance the activity of such organisms that play a role in organic matter incorporation and nutrients cycling. According to Kajak (1997), the intensity of macroarthopod patrolling influences biotic structure (micro and mesofauna) and carbon transference. This suggests that labile organic matter incorporation (dead organisms or at the beginning of their decomposition stage) would be higher under NT than under CT. This would lead to an increase of the edaphic biodiversity which, in turn, will favours organic matter degradation or decomposition, thus, improving physical properties and the nutrient cycling, all of them relevant to the agro-ecosystem sustainability.

The higher organic matter incorporation in the no till treatment means a greater diversity and quantity of organic matter, which plays an important role in improvement of soil quality.

5. Conclusions

Under the prevailing weather conditions of this particular year, tillage systems had an important effect on the abundance of arthropod fauna and in the different functional groups proportion.

No till practices could promote a higher predator activity probably associated to a no soil plow and a permanent soil cover. Ploughing action could change the proportion between groups provoking an important decrease of the relative importance of predators and an increase of phytophagous respect to those in no till and undisturbed conditions.

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