EFFECT OF NO-TILL AND MINIMUM TILL TECHNOLOGIES OF CULTIVATION ON THE COMPOSITION AND AMOUNT OF SOIL NEMATODES

Dzhalankuzov T.D., Savkina E.,

Institute for Soil Science and Agrochemistry, Al-Farabi 75v, 050060 Almaty, Kazakhstan

Abstract

Reduced mechanical processing of soils is being tested in Kazakhstan, on chernozem soil of Kostanai Institute of Agriculture. The study region is characterized with sharp-continental climate that is subject to wind and water erosions. The area is experiencing lack of precipitation what is a serious problem for agricultural production, considering that the region belongs to the main grain production area in the Republic. In the conditions of non-irrigated monoculture of wheat, no-till and minimum till technologies can significantly improve soil fertility through better control of wind and water erosions, through improve of soil physical properties, and soil organic matter content. Soil organisms play important role in soil fertility formation. Soil microorganisms and nematodes serve as bioindicators of changes in soil management both in their qualitative and quantitative values, because they quickly response on the changes in soil physical characteristics. Therefore, the research was aimed to study composition and amount and microbiological properties of soil under no-till and minimum till technologies of soil cultivation in chernozem region of Northern Kazakhstan. The results of this work showed that under reduced soil cultivation (no-till and minimum till) the composition and number of soil nematodes as well as microorganisms were well presented and the differences between the two technologies of cultivation were insignificant or slight.

Keywords: nematode; no-till; minimum till; bioindication; density

INTRODUCTION

Lately a wide attention is drawn to the different technologies of soil cultivation without disturbance of soil plough horizon. According to many authors, yearly ploughing of soil with overturn of the upper layer deteriorate its structure. Resource and energy saving technologies such as no-till or minimum till were widely introduced in many countries (Baker et al., 1996; Derpsch and Friedrich, 2009; Baccouri, S. 2008; Antonio C.A. Carmeis Filho, 2016) mostly because of availability of corresponding herbicides and seeding machinery, knowledge of the peculiarities of no-till technology.

One of the important directions in studying reduced soil cultivation technologies is soil nematodes as bioindicators of soil ecosystem. Nematodes can change their composition in response to soil contamination and other deteriorations (Neher, 1999). Especially sensitive to the deterioration of ecosystem are *Dorylaimida* (L.) who belong to the strategists in the sub-class *Adenophorea* (Neher, 1999; Ferris et al., 2001).

Other nematodes, such as *Cephalobides* (L.), *Rhabditida* (L.) and *Monchisterides* (L.) having high reproductive ability belonging to the sub-class *Secernentea* (L.), are usually non- or less sensitive to the contaminants and tolerant to the xenobiotics.

The study of the faunal composition of nematodes, the prevalence of certain taxonomic groups, can reveal the disturbances in soil ecosystems caused by the use of mineral and organic fertilizers, treatment with chemical agents, various types of soil cultivation (Nahar et al., 2006).

Soil is the main reservoir and natural habitat for microorganisms that take an important part in the processes of soil formation and purification, as well as the cycle of substances in nature. Microorganisms not only decompose organic residues into simpler mineral and organic compounds, but also actively participate in the synthesis of high-molecular compounds that form a stockpile of nutrition in soil. Therefore, in solving the soil fertility problems and increasing the crop yield it is important to create favourable conditions for active development of microbiological processes and growth of microbiological population in soil.

Reduced till technologies is being tested in Kazakhstan, on chernozem soil of Kostanai Institute of Agriculture. The study region of northern Kazakhstan is characterized with sharp-continental climate that is subject to wind and water erosions. The area is experiencing lack of precipitation what is a serious problem for agricultural production, considering that the region belongs to the main grain production area in the Republic (Saljnikov, 2004). In the conditions of non-irrigated monoculture of wheat, no-till and minimum till technologies can significantly improve soil fertility through better control of wind and water erosions, through improve of soil physical properties, and soil organic matter content. Soil organisms play important role in soil fertility formation. Soil microorganisms and nematodes serve as bioindicators of changes in soil management both in their qualitative and quantitative values, because they quickly response on the changes in soil physical characteristics.

Therefore, the research was aimed to study composition and amount and microbiological properties of soil under no-till and minimum till technologies of soil cultivation in chernozem region of Northern Kazakhstan.

MATERIALS AND METHODS

The research was done based on Kostanai Research Institute of Agriculture. The soil samples were taken from the key soil profiles on chernozems on no-till and minimum till plots. The soil profiles were set up on a hollow sloping plain of the upper floodplain terrace on the right bank of the Tobol River, which is composed of Quaternary alluvial deposits, sandy loams, sands, clayey sands, loams and clays. The climatic data of the studied area in the studied period is presented in Table 1.

Table 1. Distribution of precipitation in vegetation season in studied years for studied region, mm

Years	May	June	July	August	SUM
Many-year average	31.0	45.0	50.0	30.0	156
2012	28.1	26.8	23.0	101.1	179
2013	20.6	9.7	106.6	-	146.9

On the no-till and minimum till treatments the depth of carbonates, structure, density, moisture characteristics were determined. Content of humus was determined by Tyurin methods; total nitrogen was determined by Kjheldal methods; carbonates by gas-volumetric method; Soil pH -potentiometrically in water solution; specific gravity – by pycnometer; soil moisture -by thermal drying; wilting point – by calculation from maximum hygroscopic value (using coefficient 1.34) (Mineev, 2001).

Soils samples for nematodes were taken from the depth 0-10, 10-20 and 20-30 cm in four field replications. Nematodes were isolated by the Berman funnel method using funnels and cotton filters from a soil volume of 50 cm^3 with an exposure of 24 hours, followed by fixing with 4% formalin. Isolated nematodes were harvested from each sample in 4 replications. Nematodes were counted under the binocular MBS-9. The determination of the quantitative and faunal composition of nematodes was carried out according to the generally accepted methods of faunistic analysis.

The total number of microorganisms was determined by seeding the soil suspension on solid nutrient media MPA (meat-peptone agar) for bacteria, SAA (starch-ammonia agar) for actinomycetes and Czapek's medium for fungi (Sohlenius and Bostrom, 1999).

RESULTS AND DISCUSSION

Soil microorganisms

As can be seen from Table 2, both minimum and no till technologies were favourable for the development of vital activity of microorganisms, but still more vigorous microbiological processes were observed with minimum soil treatment. The data obtained show that in all treatments of the experiment the bulk of the microorganisms were bacteria that grow on meat-peptide agar. For example, in the minimum till in the 0-10 cm layer they were 4.8; 10-20 cm - 4.2; and in 20-30 cm 2.2 million per gram of soil. And at no-till in a layer 0-10 cm - 4,0; 10-20 - 3.3; 20-30 - 2.0 million per gram of soil.

The studied bacteria are one of the most richly represented groups of the soil population. They along with actinomycetes and fungi cause a variety of processes associated with the transformation of organic and mineral compounds in the soil. The bacterial flora is represented mainly by bacteria forming spores such as *Bacteria Megaterium* and *Bacmesenterucus* (L.) as well as other microorganisms.

The second place by the amount belongs to actinomycetes. Same as bacteria, actinomycetes well represented in studied soils. Actinomycetes greatly contribute to decomposition of soil organic matter, decompose cellulose and form antibiotic compounds. Higher amount of actinomycetes was observed at no-till technology, especially at 0-10 cm of soil, because the upper layer of soil is most important for growth and development of these microorganism. In the deeper soil layers, the aeration and the content of organic matter are less and therefore the biological activity of soil is depressed.

The third place by quantity occupies the soil fungi. The functions of microscopic fungi in soil is various and important, because they participate in formation of humus and the products of cellulose decomposition. Results show that fungi were present mainly in upper soil layer (Table 2).

Thus, both technologies of soil cultivation (minimum and no-till) were suitable at favourable combination of temperature and humidity. The actively growing microflora positively influences on root system of plant, especially in aridic regions that are susceptible to wind erosion. At minimum and no-till technologies the plant residues remain on the soil surface what reduces erosion and increases moisture content in arable and sub-arable soil horizons. All these promotes intensive propagation of aerobic microorganisms and stimulates mineralization of crop residues in upper soil horizons, therefore improving root nutrition and increasing crop yield.

Table 2. Number of microorganisms under minimum and zero tillage systems

Tillage system	Depth, cm	million/g soil		thousand/g soil
		bacteria	actinomycetes	fungus
Minimum tillage	0-10	4.8	2.6	3.7
	10-20	4.2	2.5	2.9
	20-30	2.2	2.3	2.0
Zero tillage	0-10	4.0	2.9	3.9
	10-20	3.3	2.6	3.0
	20-30	2.0	2.0	2.1

Soil nematodes

Quantitative composition of nematodes

The average density of nematodes was 520 units in 50 cm^3. At no-till technology the density of nematodes was 3.4-6.1 times higher than at minimum till at a depth of 0-20 cm (Table 3). This probably occurred because of the large amount of root mass left by the plants-the food base for nematodes.

From spring to summer at less moisture the density of nematodes decreased at no-till for 2.5-4.8 times, and at minimum till for 1.5-1.9 times in 0-20 cm soil layer. At 20-30 cm soil layer the fluctuations in the number of nematodes were insignificant.

In spring there is a mass yield of nematode larvae occurs. The density index of nematodes and their individual families depends on the abundance of root mass and organic remains in the soil. The most numerous and frequently occurring families were - *Cephalobidae, Dorylaimidae*, *Qadsianematidae* (L.), and less numerous and rarely found were – *Aphelenchoididae*, *Alaimidae*, *Lontgidoridae* (L.) (Table 3).

Qualitative composition of nematodes

The faunal composition of nematodes on the investigated soils was represented by 15 families of 5 orders. The largest faunal diversity of the genera and families of nematodes was observed in the spring, during the period of mass release of nematode larvae. Differences in the faunistic diversity of soil nematodes at no-till and minimum till were insignificant. The largest faunal diversity of the genera and families of nematodes was observed in the 10-20 cm layer, both with no-till and minimum till treatments.

The first place belonged mainly to the family *Cephalobidae* (L.) at both minimum and no till treatments, which was 20-37.5% from the total amount of nematodes (Table 3). Family *Cephalobidae* was represented by the genera *Cephalobus, Eucephalobus, Acrobeles* and *Wilsonema* (L.).

The second and third places belong to different families: *Panogrolaimidae*, *Dorylaimidae* and *Qadsianematidae* (L.), that was 16%.

Nematodes of *Aphelenchidae* and *Aphelenchoididae* (L.) were 12%. The rarely found nematodes were *Plectidae* and *Alaimida* (L.) (6.7%).

There also was found parasitic nematodes of *Paratylenchidae, Pratylenchidae* and *Longidoridae* (L.) families, that was found at minimum and no till technologies on 10-30 cm soil layer. Endoparasites of the family *Pratilenchidae* are especially dangerous for agricultural crops. The dangerous root ectoparasites are also the *Longidodidae* nematodes, which are carriers of many dangerous viral plant diseases. In addition, they cause a general decrease in the volume of the roots and their darkening, as well as a delay in the growth of the entire plant, and the extension of the root tips.

Bioindication

The indices characterizing the fauna of nematodes, reflect real changes in communities with variations in environmental conditions. The index of ripeness (MI), proposed by Bongres (1990), is an indicator of the conditions of the soil ecosystem based on the faunistic and quantitative composition of nematodes. It is calculated based on the composition of nematode communities, which include organisms with different life cycles and types of nutrition. To determine the maturity index, a scale c-p is proposed for different families and a formula for determining the index, including the values of the density of taxa (Bongers, 1990; Bongers and Korthals, 1995). The index of maturity with its highest value shows a more stable ecosystem. Using the c-p scale and the index formula (MI), taken from the literature data, as well as the data obtained, we calculated the maturity index (MI), which shows the best living conditions for nematodes and ecosystem status in general (Table 4). The MI index shows that the best conditions for the nematodes were in spring at no-till technology in 0-10 cm soil layer, and in summer at no-till and minimum till on 0-10 cm layer. The differences between no-till and minimum till were insignificant.

Table 3. Density of nematode’s families under no-till and minimum till technologies in southern chernozem of northern Kazakhstan

Nematode’s family	Spring						Summer					
	No-till			Minimum till			No-till			Minimum till		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Rhabditidae	17.6	18.5		8.2	1.4		20.5	7.8	2.0	8.0	2.0	1.0
Plectidae	17.6	9.3	2.0	8.2	2.7	2.0	8.2	1.9	2.0	4.8	1.0	1.0
Cephalobidae	149.8	129.7	15.0	49.1	20.5	8.0	41.0	23.3	8.0	24.0	14.0	9.0
Panogrolaimidae	35.3	37.1		21.8	6.8		4.1	5.8	2.0	3.2	2.0	2.0
Aphelenchidae	26.4	55.6	1.0	5.5	2.7	3.0	8.2	3.9	2.0	1.6	1.0	1.0
Aphelenchiodidae	8.8	9.3		5.5	2.7	1.0	4.1		1.0	1.6	1.0	
Tylenchidae	44.2	18.5	2.0	8.2	4.1		12.3	7.8		4.8	2.0	
Nothotylenchidae	79.3	27.8	5.0	10.9	4.1		20.5	7.8		3.2	2.0	
Paratylenchidae		9.3	2.0		8.2	5.0	20.5	5.8	2.0		3.0	2.0
Hoplolaimidae		9.3			4.1			3.9			1.0	1.0
Pratylenchidae		9.3	2.0		1.4	2.0		5.8	4.0		2.0	3.0
Dorylaimidae	79.3	55.6	5.0	10.9	5.1	3.0	28.7	9.7	2.0	12.8	8.0	3.0
Qadsianematidae	61.7	37.1	3.0	10.9	4.1	3.0	32.8	7.8	2.0	12.8	6.0	4.0
Alaimidae		9.3		5.4	2.7	1.0	4.1			3.2	2.0	
Longidoridae		27.6	3.0	5.4	5.0	2.0		5.8	5.0		3.0	3.0
Total	520.0	463.3	40	150.0	75.3	30.0	205.0	97.1	32.0	80.0	50.0	30.0

Table 4. Percent of nematode families at no-till and minimum till treatments in southern chernozem of Northern Kazakhstan

Nematode's family	C-P	Spring						Summer					
		0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Rhabditidae	2	3.4	4.0		5.5	1.0		10.0	8.0	6.3	10.0	4.0	3.3
Plectidae	1	3.4	2.0	5.0	5.5	2.6	6.6	4.0	2.0	6.3	6.0	2.0	3.3
Cephalobidae	2	28.8	28.0	37.5	32.7	27.3	26.7	20.0	24.0	25.0	30.0	28.0	30.1
Panogrolaimidae	2	6.8	8.0		14.5	9.1		2.0	6.0	6.3	4.0	4.0	6.7
Aphelenchidae	1	5.1	12.0	2.5	3.6	3.6	10.0	4.0	4.0	6.3	2.0	2.0	3.3
Aphelenchiodidae	2	1.7	2.0		3.6	3.7	3.3	2.0		3.1	2.0	2.0	
Tylenchidae	2	8.5	4.0	5.0	5.5	5.4		6.0	8.0		6.0	6.0	
Nothotylenchidae	2	15.2	6.0	12.5	7.3	5.4		10.0	8.0		4.0	4.0	
Paratylenchidae	2		2.0	5.0		10.9	16.7	10.0	6.0	6.3		6.0	6.7
Hoplolaimidae	2		2.0			5.4			4.0	12.5		2.0	3.3
Pratylenchidae	2		2.0	5.0		1.0	6.7		6.0	6.3		4.0	10.0
Longidoridae	4		6.0	7.5	3.6	5.4	6.7		6.0			6.0	10.0
Dorylaimidae	3	15.2	12.0	12.5	7.3	7.2	10.0	14.0	10.0	6.3	16.0	16.0	13.3
Qadsianematidae	4	11.9	8.0	7.5	7.3	5.4	10.0	16.0	8.0	15.3	16.0	12.0	10.0
Alaimidae	5		2.0		3.6	3.6	3.3	2.0			4.0	4.0	
Total		10	15	10	12	15	10	12	13	11	11	15	11
MI		1.9	1.7	1.05	1.63	1.5	1.63	1.88	1.3	1.68	1.87	1.97	1.86
PPI		0.46	0.56	0.92	0.33	0.78	0.74	0.41	0.64	0.93	0.4	0.64	0.83

Trophic structure

For studying the trophic structure, the classification of Yeates (1993), that is the base for determination of the indices characterizing the Nematodes community was used. According to this classification the nematodes feeding on bacteria are bacteriotrophs, on fungi – mycotrophs, plant parasites – phytotrophs and omnivores – polytrophs.

Our studies confirmed the known fact that bacteriotrophs are the most abundant group in agricultural systems. Their number depends on the bacteria population, that changes depending on the type of soil treatments. Mineralization rate of nitrogen is greater when the number of bacteriotrophs is higher (Table 5).

The bacteriotrophs at no-till and minimum till treatments were presented with *Phabditidae*, *Plectidae*, *Cephalobidae* and *Panogrolaimidae* (L.).

The second place belonged to polytrophs. The polytrophs are omnivores of the *Dorilaimidae* and *Qadsianematidae* (L.). These nematodes were more presented at minimum till treatment.

Phytotrophs feeding on plant roots were presented with 6 families in both no-till and minimum till treatments:*Tylenchidae, Nothotylenchidae, Partatylenchidae, Hoplolaimidae, Pratylenchidae* and *Longidoridae* (L.).

At both treatments the bacteriotrophs were dominant (33.3-50%), and at minimum till their percent were higher than at no-till.

At 0-10 cm soil layer at both treatments the polytrophs were on the second place (16.2-36%), while on 20-30 cm – phytotrophs.

Table 5. Density of trophic groups of nematodes at no-till and minimum till soil cultivation

Nematode's family	Spring						Summer					
	No-till			Minimum till			No-till			Minimum till		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Bacteriotrophs	220.3	194.6	17.0	87.3	31.4	10.0	73.8	38.8	14.0	40.0	19.0	13.0
Mycotrophs	35.2	64.9	1.0	11.0	5.4	4.0	12.3	3.9	3..0	3.2	2.0	1.0
Polytrophs	141.0	102.0	8.0	23.2	11.9	9.0	65.6	17.5	4.0	28.8	16.0	7.0
Phytotrophs	123.5	101.8	14.0	24.5	26.9	7.0	53.3	36.9	11.0	8.0	13.0	9.0
Total	520.0	463.3	40.0	150.0	75.3	30.0	205.0	97.1	32.0	80.0	50.0	30.0

The results of this work showed that under reduced soil cultivation (no-till and minimum till) the composition and number of soil nematodes as well as microorganisms were well managed. The differences between the two technologies of cultivation were insignificant or slight in terms of composition and number of soil nematodes and microorganisms.

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