BIOSCIENCES BIOTECHNOLOGY RESEARCH ASIA, April 2015. Vol. **12**(1), 287-293

Biokinetic Conception of Nitrogen Transformation in Harsh Climates of Cryogenic Soils in Central Asia

Lubsan Vladimirovich Budazhapov

Federal State Budgetary Scientific Institution, "Buryat Research Institute of Agriculture", Russia, Republic of Buryatia, 670045, Ulan-Ude, Str. Tretjyakov, 25z, Russia.

DOI: http://dx.doi.org/10.13005/bbra/1664

(Received: 06 February 2015; accepted: 01 March 2015)

This paper presents results of long-term model, greenhouse and microfield experiments on nitrogen transformation in soil-plant systems with application of stable nitrogen isotope (^{15}N) as renewed efforts to make a biokinetic conception of nitrogen status in harsh climates of the northern part of Central Asia, namely in Transbaikalia. It uses a theory to investigate velocity characteristics of nitrogen pool change in cryogenic soil environments. The goal of theoretical background of nitrogen pool velocity transformation is to reveal modern approach to assessment of inherent nature cycle. In nitrogen cycle of soil-plant systems kinetic parameters were evaluated as the main processes of nitrogen ^{15}N uptake and immobilization in terms of scaling with constant of growth velocity and microorganism performance being a key position in nitrogen transformation. The results show a new possibility to assess nitrogen cycle through calculated velocity constant and revealed dynamic pattern of the main processes. The ongoing assessment enables us to formulate a new original hypothesis for theoretical kinetical model.

Key words: Biokinetic conception, Nitrogen transformation, Constant of speed, Kinetic balance.

Nowadays the importance of improved soil fertility and crop productivity facilitates to find efficient solution to the problem by estimating velocity of nitrogen transformation under specific and harsh soil-climatic conditions. Accordingly, Transbaikalia found in the northern part of Central Asia is no exception. Soil fertility in this area is known to decline, and cryogenic soils considerably are in short of nitrogen (Gamzikov, 1981; Budazhapov, 2009). As crop productivity in these soils is very low, it cannot be achieved without the use of nitrogen fertilizers. Hence, this review first of all examines quantitative characteristics of nitrogen transformation in soil - plant systems because of few detailed characteristics of these processes in the scientific literature. Secondly, it looks into theoretical and experimental studies to build a modern approach in addressing nitrogen problems. Thirdly, it presents a detailed biokinetic evaluation of nitrogen that gives eventually a wide scope to statistical findings. Finally, the implications of mathematical modelling of nitrogen transformation are assessed to build a biokinetic conception, whilst a traditional assessment of approach cannot fully reveal the above-mentioned aspects.

METHOD

The research is based on nitrogen transformation results obtained during the last two decades (1991-2012) with the use of nitrogen stable

* To whom all correspondence should be addressed.

isotope ^{15}N and statistic analysis. Investigations were held near Baikal Lake, the Buryat Republic and Transbaikalia region including Aginsk district in the agro-soil-climatic zones, such as dry steppe, steppe, forest steppe and frozen cryogenic areas. The latter ones are characterized by diverse agro-climatic conditions in terms of soil fertility, climates and cryogenic levels. According to these special features, chestnut soil is formed in dry steppe with black soil in steppe, grey forest soil in forest steppe, and black meadow soil in frozen cryogenic environment. It follows that cryogenic soil fertility range from poorly resolved acid to alkali soil solution defined by low content of humus, common and mineral nitrogen, phosphorus and potassium with insufficient soil moisture, air humidity and rainfall with high cryogenic level common to the arid zones. As a result, microbiological status is very specific, where among soil microorganism groups Actinomicetes universally predominate. Our studies were carried out through model, greenhouse, microfield and field experiments using spring grain crops, such as wheat, barley and oats and stable isotope labeled ^{15}N. In model investigations under temperature and humidity conditions controlled we estimated changes of nitrogen fertilizer absorption in the first and next 10 days by assessing the differences between constant (k) of growth velocity. We eventually calculated a curve of nitrogen fertilizer uptake for each cryogenic soil. In greenhouse and microfield experiments with Vagner's vessels and bottomless vessels we studied nitrogen transformation by estimating its kinetic characteristics that followed a general scheme involving fertilizer free; application of phosphorus (P) and potassium (K) fertilizer (P40K40); application of both nitrogen, phosphorus and potassium(NPK) fertilizers with alternating frequency from 8 to 24. Field study revealed results obtained during yearly micro-field experiments, where among analytical methods the traditional chemical, agrochemical, soil science and microbiological analysis were used. In generalizing results such traditional statistical methods as variation, correlation and regression with mathematic modelling were intensively introduced in the experiments. The size of velocity constant (k) of the main nitrogen transformation process was determined by the use of data and modelling scheme, in particular exponent equation: $y = ae^{kt}$, where the k of velocity process is for any time, i.e. day, season, year.

RESULTS

Nitrogen nutrient and kinetic of nitrogen absorption

Many international and russian works on the assessment of nitrogen transformation under various soil-climatic conditions prove that sizes of nitrogen absorption and nitrogen plant nutrition is a key to understanding the process (Jansson, 1958, 1963, 1971; Azami, 1972; Stanford and Legg, 1968; Gamzikov, 1981; DeNeve and Hoffman, 1996; Bremer and Kuikman, 1997; Petersen *et al.* , 2005; Shen *et al.* , 2005; Oik, 2006; Kuzyakov and Bol, 2006). Given that a new assessment suggests revealing not only quantitative parameters of nitrogen uptake, but focusing specifically on kinetic characteristics then it is possible to consider that speed of nitrogen absorption namely and velocity constant occurrence is more important than the rate of nitrogen content. The current analysis indicates that we deal with biokinetic model here. According to the findings presented below, biological differences of grain crops are shown in absorption of nitrogen fertilizer and soil nitrogen. Among them oats is defined by the highest kinetic use independently of the soil fertility, and its velocity constant (k) reaches k = 0.735 per day and is higher than that of wheat and barley (table 1).

The data shows powerful root system and deep penetration into fertility layer of soil profile, and better absorption of nitrogen, water and other nutrients. Accordingly, different kinetics of grain crop absorption is represented here for the first time. It is known that higher immobilization of nitrogen fertilizer in soils is a positive factor in the cycle of nitrogen transformation (Jansson *et al*., 1982; Jenkinsson *et al*., 1985; Stenger *et al*.,1995; Whalen *et al*., 2000; Shen *et al*., 2005; Janzen, 2006). Due to this process the content of nitrogen respectively in soils increases. However, quantitative parameters of immobilization of nitrogen fertilizer in soils are defined as a basic feature excluding kinetic assessment of the process**.** After its last exposure we examined that kinetic parameters of soil microorganisms and their performance are a constituent part in the assessment of nitrogen transformation (Jenkinsson and Powlsen, 1976; Trinsoutrot *et al*., 2000; Li *et al*., 2003; Pansu and Thuries, 2003; Jones *et al*., 2004; Cookson *et al*., 2005; Petersen *et al*., 2005; Janzen, 2006).

Kinetics of microorganism activity in nitrogen immobilization

Therefore, we undertook an attempt to assess kinetic microorganism activity in cryogenic soils as a key approach to biokinetic conception. For the first time kinetic activity of soil microorganisms in immobilization of nitrogen fertilizer in cryogenic environments was assessed. Among groups of soil microorganisms Actinomicetes were identified for the highest kinetic activity than fungi, and their activity constant (k) in cryogenic soils was different and reached k = 0.129 in chestnut soil, k = 0.165 in grey forest soil and k = 0.434 per year in black meadow frozen soil (table 2). Immobilization of nitrogen fertilizer was the highest by its kinetic activity in black meadow frozen soil. Hence, higher quantity of soil microorganisms is not eventually followed by higher similar immobilization of nitrogen. The results of correlation analysis definitely justify the new hypothesis. Smaller kinetic (k) activity of Actinomicetes in chestnut soils (k = 0.129 per year) provide with higher correlation (r = 0.84 ± 0.21) and in contrast their highest kinetic (k) activity in grey forest soils (k = 0.165 per year) leads to a smaller degree correlation (r = 0.62 ± 0.29) in relation to immobilization of nitrogen fertilizer in cryogenic soils (table 2). Compared to Actinomicetes kinetic (k) activity of soil fungi is very low and slow, independently of its amounts and soil fertility, thereby it reaches only k = 0.001 per year (table 2).

The latter is driven by higher adaptation of Actinomicetes group to very harsh hydro-temperature regimes of cryogenic soils. Earlier similar conclusions were found in number of international and russian works (Jansson *et al*., 1982; Keeley and Strevenson, 1985; Kennedy and Smith, 1995; McCarty *et al*., 1995; Jensen, 1997; Peterson *et al*., 2005; Budazhapov, 2009). This almost certainly to emphasize that the attempts of assessing microorganism kinetic activity (k) may be fundamental for building a basis for biokinetic conception of nitrogen transformation in harsh environments of the northern part of Central Asia.

Potential and velocity constant in soil nitrogen mineralization

It is known that potential and velocity constant (k) of organic nitrogen mineralization in

Table 1. Velocity constant (k, day) of nitrogen fertilizer absorption in cryogenic soils

Type soils	Percent of N in soil	Soil moisture	Wheat	Barley	Oats
Chestnut	0.137 ± 0.04	60-70 percent of full moisture capacity	0.674	0.673	0.735
Black	0.220 ± 0.02		0.544	0.518	0.612
Grey forest	0.168 ± 0.08		0.679	0.701	0.723
Black meadow	0.433 ± 0.06		0.429	0.374	0.633

Table 2. Constant of microorganism activity and growth velocity in cryogenic soils

Assessment parameters	Chestnut soil,n = 9	Grey forest soil, n=10	Black meadow soil, n = 6
Fungi group of soil microorganisms			
Quantity, 10^3/ g soil	20.7 ± 1.9	9.17 ± 0.78	85.9 ± 4.82
Correlation, $r \pm s_r$	0.40 ± 0.35	0.32 ± 0.35	0.21 ± 0.49
k of growth velocity	0.0004 per year	0.003 per year	0.0004 per year
k of activity	0.011 per year	0.001 per year^{-1}	0.001 per year
Actinomicetes group of soil microorganisms			
Quantity, 10^6/ g soil	1.84 ± 0.49	2.11 ± 0.26	7.37 ± 0.31
Correlation, $r \pm s_r$	0.84 ± 0.21	0.62 ± 0.29	0.92 ± 0.12
k of growth velocity	0.0014 per year	0.002 per year^{-1}	0.0004 per year
k of activity	0.129 per year	0.165 per year^{-1}	0.434 per year

soils indicates diagnostics of soil nitrogen status (Stanford and Smith, 1972; Jenkinsson *et al*., 1985; Harmsen and Mogarhan, 1988; Jensen, 1994, 1997; Henriksen and Breland, 1999; Trinsoutrot *et al*., 2000; Dinesh *et al*., 2001; Kumar *et al*., 2002, Akasaka *et al*., 2003; Meirvenne *et al*., 2003; Kuzyakov and Bol, 2006). Due to the analysis, potential (No) and constant (k) rate of nitrogen mineralization are shown significantly smaller than in similar European, American and Australian soils. The data reports that they range from 0.08 to 2.19 percent in nitrogen soil content and 0.053 to 0.380 per year in decrease of nitrogen mineralization constant (k) in cryogenic soils (table 3).

Many international works show that potential (No) of nitrogen mineralization in European soils range from 7 to 20 percent and constant (k) rate of nitrogen mineralization is from 0.027 to 1.180 per year. This produces specific data of nitrogen mineralization for harsh cryogenic soil conditions that may be interpreted as low microorganism activity, lack of energy resources in cryogenic soils for developing nitrogen mineralization. Hence, a trend line of organic nitrogen mineralization approximates by exponent equation decreasing in time**.**

Kinetic balance of nitrogen transformation

The model shows that kinetics of organic nitrogen mineralization in cryogenic soils is very low and half-life decomposition is much longer, and is five times more than in European soils with nearly 15 years in duration. It is relevant to highlight in this regard that this model has never been assessed before. Neither a kinetic balance of nitrogen transformation that among cryogenic soils was predominantly formed in grey forest soils, whereas constants (k) of speed nitrogen fertilizer absorption and immobilization were higher than nonspecified losses (table 4).

Such state of kinetic nitrogen balance relates to the same low constant (k) of velocity losses (k = 0.067 per day $^{-1}$) and the same higher constant (k) of speed absorption (k =0.723 per day) in cryogenic soils (table 4). Kinetic balance of other soils is less positive and reaches its deficit. This can be seen from the comprehensive estimates mentioned above to make a final conclusion to biokinetic conception.

Table 3. Potential (No) and velocity constant (k) of nitrogen-organic mineralization of cryogenic soils in harsh climates

Assessment parameters		Chestnut soil, n = 11	Black soil n = 7	Grey forest soil, n=10	Black meadow soil, n = 6
		Fertilizer free			
No	mg / 100 g	2.98 ± 0.73	3.69 ± 0.82	3.69 ± 0.93	6.16 ± 1.28
	percent of soil N	2.17	1.15	2.19	1.42
	k, year $^{-1}$	0.355	0.380	0.344	0.291
		Use of fertilizer (NPK)			
No	mg / 100 g	1.14 ± 0.03	0.76 ± 0.08	0.54 ± 0.07	0.34 ± 0.10
	percent of soil N	0.83	0.24	0.31	0.08
	k, year $^{-1}$	0.148	0.121	0.148	0.053

Table 4. Kinetic (k) balance of nitrogen transformation in soil-plant systems

Type of soils	Constant (k) of nitrogen pool velocity, day / day $^{-1}$			
	Mineral	Absorption	Immobilization	Nonspecified
Chestnut	0.867 day $^{-1}$	0.673 per day	0.449 per day	0.255 per day
Black	0.665 day $^{-1}$	0.518 per day	0.383 per day	0.236 per day
Grey forest	0.759 day $^{-1}$	0.723 per day	0.103 per day	0.067 per day
Black meadow	0.865 day $^{-1}$	0.374 per day	0.105 per day	0.386 per day $^{-1}$

DISCUSSION

The theory of nitrogen transformation in harsh climates of cryogenic soils is one of the first verification models on the assessment of nitrogen circulation in soil-plant systems. Change of velocity nitrogen transformation is a modern attempt to form biodynamic concept as a more accurate reflection of nitrogen conversion cycle. The model represents mainly quantitative parameters being not able to reflect nitrogen conversion. Using mathematical calculation of these processes with exponent equation we obtained its kinetic features as the first stage. Calculation of velocity constant (k) in main nitrogen pools (table 4) and assessment of mathematic modelling of nitrogen transformation combined as a multiple assessment resulted in prediction model, since similar assessments are hardly possible in traditional quantitative parameters. The estimate reveals that velocity characteristics are possible to measure nitrogen transformation as a more dynamic component on the one hand, and forecast model on the other hand as a key solution to many urgent problems, as well as food and ecology safety. The conceptual model shows that velocity assessment of nitrogen status in soil-plant systems requires a proper mathematical calculation and accurate data interpretation. According to original hypothesis of nitrogen cycle, the most fundamental issue is rather quantitative assessment than kinetic composition of rotation of nitrogen pools (Campbell *et al*., 1984; Jenkinsson *et al*., 1985; Hart *et al*., 1986; Blackmer and Green, 1995; McCarty *et al.*, 1995; Stenger *et al*.,1995; Jensen 1997; Henriksen and Breland, 1999; Kuzyakov *et al.*, 2000; Trinsoutrot *et al.*, 2000; Whalen *et al*., 2000; Thuries *et al*., 2001; Li *et al*., 2003; Pansu and Thuries, 2003; Jones *et al.*, 2004; Gianello and Tedesco, 2004; Peterson *et al*., 2005; Shen *et al*., 2005; Janzen, 2006). The hypothesis indicates that the most considerable part in the assessment lies in the rapid rotation of nitrogen pools to indicate heavily the changes of soil nitrogen status. However, the study highlights that short time of nitrogen in mineral form and higher resistance slow rotation pools of organic nitrogen in cryogenic soils is one of the current challenging points. And yet, the systematic difficulties do not allow to predict changes in rapid and slow rotation of nitrogen pools with the help of traditional methods. The assessment of nitrogen cycle in soil - plant systems with priority calculation of velocity characteristics transformation is of immense importance. Therefore, in the current review we have managed to obtain quantitative parameters and predictive assessment of nitrogen pools on velocity parameters. We suggest to make assessment of nitrogen transformation in harsh environments of cryogenic soils as a biokinetic conception that lays theoretical foundation on velocity activity in nitrogen cycle. It has been first represented as a proof for these types of cryogenic soils. The most important aspect of the ongoing hypothesis is a mathematical model of nitrogen transformation. This mathematical extrapolation of results allows to build a basis for theoretical simulation of nitrogen cycle and a more dynamic pattern of nitrogen pool changes, in particular for short-lived forms of nitrogen. The conception for all that is not an ultimate goal, and this is precisely why it is necessary to make a further independent verification in various soil environments.

CONCLUSION

Long-term investigations with the application of nitrogen stable isotope (^{15}N) and modelling are the first to measure kinetic parameters of nitrogen cycle in harsh climates of cryogenic soils in the northern part of Central Asia. The biokinetic conception of nitrogen transformation is introduced as a key model for quantitative assessment. The study shows that the existing conception needs further attention of researchers and cooperative investigations to preserve unique natural resources and apply the findings in the future research.

ACKNOWLEDGMENTS

The biokinetic conception of nitrogen transformation would not have been possible without help of several people. First of all, I would like to thank professor Irina Lavrova (Moscow, Russia) and a researcher consultant professor Gennady Gamzikov (Novosibirsk, Russia) for support and help in the research. I would also like to thank other participants from Russian State Agrarian University - Moscow Agricultural

Academy named after K.A.Timiryazev (RSAU-MTAA) and Novosibirsk State Agricultural University (NSAU). A special thank is to Buryat State Academy of Agriculture named after V.R. Philippov (BSAA).

REFERENCES

1. Akasaka, K., Konno, T., Owa N., Assessment of nitrogen potential mineralization in soil Mekong river. *Bulletin Faculty Agricultural Niiagata University*, 2003; **55**(2): 151-160.
2. Azami, T., Immobilization and mineralization of nitrogen compounds in paddy soils. P2. On the remineralization of immobilized nitrogen and the difference in mineralization between immobilized and organic nitrogen. *Abstract Soil Science and Plant Nutrient*, 1972; **18**(3): 126-127.
3. Blackmer, A.M., & Green, C.J., Nitrogen turnover by sequential immobilization and mineralization during residue decomposition in soil. *Soil Science Society of America Journal*, 1995; **59**(4): 1052-1058.
4. Bremer, E., & Kuikman, P., Influence of competition for nitrogen in soil on net mineralization of nitrogen. *Plant and Soil*, 1997; **190**(1): 119-126.
5. Budazhapov, L.V., Biokinetic assessment of nitrogen transformation in soil - fertilizer - plant system in conditions of Transbaikalia (Doctoral dissertation). Research institute of agrochemistry, Moscow, Russia, 2009.
6. Campbell, C. A., Jame, Y.M., Winkleman G.E., Mineralization rate constants and their use estimating nitrogen mineralization on some Canadian prairie soils. *Canadian Journal Soil Science*, 1984; **64**(4): 333-343.
7. Cookson, W.R., Rowarts J.S., Cameron K.C., The effect of ammonium applied 15^N - labeled fertilizer leaching in a cultivated soil during winter. *Nutrient Cycle Agroecosystem*, 2005; **56**(2): 99-107.
8. Dinesh, R., Suryanarayana, M.A., Gloshal, S.C., Leguminous cover effect on nitrogen mineralization rates and kinetics in soils. *Journal Agronomy and Crop Science*, 2001; **187**(3): 161-167.
9. De Neve, S., & Hoffman, G., Modelling N mineralization of vegetable crop residues during laboratory incubations. *Soil Biology and Biochemistry*, 1996; **28**(10- 11), 1451-1457.
10. Gamzikov, G.P., Nitrogen in landscape of West Siberia. Novosibirsk: Science Publ, 1981.
11. Gianello, C., & Tedesco, M.J., Soil nitrogen availability evaluated by kinetic mineralization parameters. *Soil Science and Plant Analysis*, 2004; **35**(9): 1293-1307.
12. Harmsen, K.A., & Mogarhan, J.T., A comparison of the isotope and difference methods for determining nitrogen fertilizer efficiency. *Plant and Soil*.1988; **105**: 55-67.
13. Hart, P.B.S., Rayner, J.H., Jenkinson, D.S., Influence of pool substitution on the interpretation of fertilizer experiments with 15^N. *Soil Science Journal*, 1986; **37**(3): 389-403.
14. Henriksen, T.M., & Breland, T.A., Evaluation of criteria for describing crop residue degradability in a model of carbon and nitrogen turnover in soil. *Soil Biology and Biochemistry,* 1999; **31**(8): 1135-1149.
15. Janzen, H.H., The soil carbon dilemma: shall we hoard it or use it? *Soil Biology and Biochemistry,* 2006; **38**: 419-424.
16. Jansson, S.L., Trace studies on nitrogen transformations in soil with special attention to mineralization - immobilization relationships. *Annual of the Royal Agricultural college of Sweden*, 1958; **24**: 101-121.
17. Jansson, S.L., Balance sheet and residual effects of fertilizer nitrogen in 6-year study with 15^N. *Soil Science,* 1963; **95**(1): 31-37.
18. Jansson, S.L., Use of 15^N in studies of soil nitrogen. *Soil Biochemistry*, 1971; **2**: 129-166.
19. Jansson, S.L., Person, J., Stevenson, F.J., Mineralization and immobilization of soil nitrogen. *Agronomy*, 1982; **22**, 29-252.
20. Jenkinsson, D.S. & Powlsen D.S., The effect of biological treatments on metabolism in soils. II. A method for measuring soil biomass. *Soil Biology and Biochemistry,* 1976; **8**: 209-213.
21. Jenkinsson, D.S., Fox, R.X., Rayner, J.H., Interaction between fertilizer nitrogen and soil nitrogen: the so-called "priming effect". *Soil Science*, 1985; **36**(3), 425-444.
22. Jensen, E.S., Mineralization - immobilization of nitrogen in soil amended with low C: N ratio plant residues with different particle sizes. *Soil Biology and Biochemistry,* 1994; **26**(3): 519-521.
23. Jensen, E.S., N immobilization and mineralization during initial decomposition of 15^N - labeled pea and barley residues. *Biology Fertility Soils*, 1997; **24**(1): 39-44.
24. Jones, D.L., Shannon, D., Murphy, D.V., Role of dissolved organic nitrogen (DON) in soil N cycling in grassland soils. *Soil Biology and Biochemistry*, 2004; **36**: 749-756.
25. Keeley, K.R., & Strevenson, F.J., Characterization and immobilized 15^N from the soil microbial biomass. *Soil Science and Biochemistry*, 1985; **4**(17): 517-523.

26. Kennedy, A.C., & Smith, K.L., Soil microbial diversity and the sustainability of agricultural soils. *Plant and Soil*, 1995; **170**(1): 75-86.
27. Kumar, K., Rosen, C., Cuipta, S.C., Kinetics of nitrogen mineralization in soils amended with sugar heel processing by - products. *Soil Science and Plant Analysis*, 2002; **35**(19-21): 3635-3651.
28. Kuzyakov, Ya.V., Friedel, J.K., Stahr K., Review of mechanisms and quantification of priming effects. *Soil Biology and Biochemistry*, 2000; **32**: 1485-1498.
29. Kuzyakov, Ya.V., & Bol, R., Sources and mechanisms of priming effect induced in two grassland soils amended with slurry and sugar. *Soil Biology and Biochemistry*, 2006; **38**: 747-758.
30. Li, H., Han,Y., Cai, Z., Nitrogen mineralization in paddy soils of the Taihy region of China under anaerobic conditions: dynamics modeling. *Geoderma*, 2003; **115**(3-4): 161-165.
31. McCarty, G.W., Meisinger, J.J., Jenninskens, F.M.M., Relationships between total - N, biomass - N and active - N in soil under different tillage and treatments. *Soil Biology and Biochemistry*, 1995; **27**(10): 1245-1250.
32. Meirvenne, M.V., Maes, K., Hofman, G., Three - dimensional variability of soil nitrate - nitrogen in an agricultural field. *Biology and Fertility Soils*, 2003; **37**(3): 147-153.
33. Oik, D.C., A chemical fractionation for structure – function relations of soil organic matter in nutrient cycling. *Soil Science Society of America Journal*, 2006; **70**: 1013-1022.
34. Pansu, M., & Thuries, L., Kinetics of C and N mineralization, N immobilization and N volatilization of organic inputs in soil. *Soil Biology and Biochemistry*, 2003; **35**(1): 37-48.
35. Petersen, B.M., Jensen, L.S., Hansen, S., CN - SIM: a model for the turnover of soil organic matter. II. Short - term carbon and nitrogen development. *Soil Biology and Biochemistry*, 2005; **37**(5): 375-393.
36. Shen, R.-P., Sun, B., Zhao, Qi-G., Spatial and temporal variability of N, P and K balance for agroecosystems in China. *Pedosphere*, 2005; **15**(3): 347-355.
37. Stanford, G., & Legg, L.O., Correlation of soil N availability indexes with N uptake by plants. *Soil Science Society of America Journal*, 1968; **105**(5): 320-326.
38. Stanford,G., & Smith, S.L., Nitrogen mineralization potentials of soils. *Soil Science Society of America Journal*, 1972; **36**(3): 465-472.
39. Stenger, R., Priesack, P., Beese, P., Rates of net nitrogen mineralization in disturbed and undisturbed soils. *Plant and Soil*, 1995; **171**(2): 323-332.
40. Thuries, L., Pansu, M., Feller, C., Kinetics of added organic matter decomposition in a Mediterranean sandy soil. *Soil Biology and Biochemistry*, 2001; **33**(7): 997-1010.
41. Trinsoutrot, I., Recous, S., Bentz, B., Biochemical quality of crop residues and carbon and nitrogen mineralization kinetics under non - limiting nitrogen conditions. *Soil Science Society of America Journal*, 2000; **3**(64): 918-926.
42. Whalen, J.K., Bottomley, P.J., Myrold, D.D., Carbon and nitrogen mineralization from light- and heavy- fraction additions to soil. *Soil Biology and Biochemistry*, 2000; **32**: 1354-1352.