UDC 546.273

M.R. Tanasheva, O.I. Ponomarenko*, L.K. Beisembaeva, M.K. Kalabaeva
Al-Faraby Kazakh National University, Kazakhstan, Almaty
*E-mail: ponomarenko_o@mail.ru

The development of effective methods for determining boron in soils and soil solutions

Abstract. This paper is related to serious ecological problem in agriculture: soil degradation in rice fields in South Kazakhstan and in particular, to boron toxicity in rice, which resulted in reduced crop yields. The following abiotic factors were studied to determine the ability of boron to accumulate in rice fields: soil type, soil properties like salinity and acidity', season (level of precipitation), water logging /water shortage. The results shows that the severity of boron excess for fertility of rice crop which depends on boron ionic composition in soil. Adverse impact of both boron deficiency and boron excess are discussed. The necessity of boron fertilizers is shown for soils with high boron mobility.
Keywords: boron, toxicity, boron deficiency, micronutnent, boron fertilizers.

Introduction

Rice is mainly grown on meadow soils in the territory of Kazakhstan [1-7]. Meadow soil types are the main land suitable for rice cultivation in Kazakhstan; they include many subtypes that differ in extent and depth of salinity and alkalinity. The high level of alkalinity is one of the crucial genetic features, and therefore, its purposeful regulation defines fertility and effectiveness of soil and crop productivity. Over the past decade, the soils of Kazakhstan have changed dramatically: the upper soil horizons were dehumifiying, decalcifying, alkalinity of the soil has increased. In the rice fields of Kazakhstan the high content of mobile boron was stated and as a consequence - boric toxemia has taken place [8].

Among biochemical indicators of activity in the soil the most important element is the chemical factor in the accumulation of boron in the rice fields, especially the negative impact of boron during germination of rice.

For a number of years, in takyr flooded soils of Kazakhstan were recorded the high content of mobile boron, more than 10 mg\kg of soil [7]. With a moderate excess of boron in the soil plant growth is delayed and yield is reduced, but with a substantial surplus - boron acts as an herbicide of general operation and all the plants die.

Therefore the study of the causes of boron toxicity in takyr soils of rice fields and the development of methods of its regulation has a definite practical interest. The objects of current research are soils sampled from rice fields located in the lower reaches of the rivers Syr Darya [9], Hi and Amu Darya (Kyzylorda province) [10]. Stationary research was conducted on Akdalinsky and Karalinsky irrigation systems in order to develop methods of boron management in rice production in these regions.

Methodology

Boron belongs to seven main micronutrients (Fe, Mo, Zn, Cl, Cu, Mn, B) necessary for productive crop growth and is important in sugar transport, cell division, and synthesis of certain enzymes. Although boron is needed by plants in relatively higher quantities versus other microelements, the range between boron deficiency and toxicity is very narrow. Exceeding the recommended application rate or applying boron too frequently can result in toxic concentrations of boron in soils and plants, and as the result, reduction in crop yield, and in case of rice even termination of vegetation. Boron demand is estimated to be equal 12-50 mg/kg of dry matter.

Results and discussion

If Boron existing in soluble form, it is easily to be leached out and can be absorbed by plants,

and therefore, is subject to fluctuations in soil concentration. Keeping boron concentration at optimal level helps to maintain carbohydrate metabolic processes in plants, perform protein synthesis, seed and cell wall formation. Boron deficiency is a plant disorder characterized by fall of flowers and low yield of seeds and fruits at normal development of vegetative mass. Boron does not move from old organs into the young, growing ones. Acute boron deficiency leads to death of growth points of the roots and upper organs, chlorosis of the apical growing point, followed by its necrosis. The plant bushes, but new formed sprouts soon stop growing. The absence or deficiency of boron infringes the normal flow of carbohydrate, and therefore starch and sugar are accumulated in potato laves.

The plants require boron throughout the entire vegetative period. Boron content is different in crops (in mg/kg of dry matter): 4.7-8.1 in grains; 10-13 in potatoes: 22-23 in sugar beets. 30 to 270 g/ha of boron is carried away with various crops harvested. To provide optimal plant nutrition boron content in soil should be in the range 0.02-0.05 mg B per 100 g of soil. Species of boron, which can be assimilated in soil are mainly presented by boric acid (H_3BO_3) and its soluble salts. Boric acid both formed in soil and introduced into soil with fertilizers is quite mobile compound, poorly fixed by soil and able to be washed out with precipitation. Therefore, areas of excessive moisture of the soil are poor in mobile forms of boron. The least amount of boron is contained in the sod-podzolic soils.

The soils of the southern regions of Kazakhstan are rich in boron, but even that may be identified certain areas where the application of boron fertilizers may be effective. The content of boron depends on the texture of the soil and the amount of humus in it: humus is richer in boron than mineral layer of soil; clay soils contain more boron than sands. Availability of salts of boric acid in soil depends on the acidity. With increasing acidity, the hydrates of sesquioxides of Fe and A1 bind boron due to their hydroxy-ions and reduce boron availability. Similarly, boron availability is being reduced in liming process due to OH^- and Ca ions. Among the indicators of biochemical soil activity, chemical factor is essential one, contributing to boron accumulation in rice fields, which eventually has adverse impact on rice growth especially during germination period.

According to study conducted by Mamutov Zh.M., flooded meadow soils of Kazakhstan for several years revealed the high content of mobile boron: > 10 mg/kg of soil. The study of the causes of boron toxicity in meadow soils of rice fields and the development of boron regulation methods is of practical interest.

A distinctive feature of water-soluble forms of boron is a low limit of toxic concentration and narrow range of efficient concentration in soil solution. Typically, water-soluble fertilizers contain a dose of boron equal to 0.050-0.40 kg/ha or 0.2-1.0 mg/liter of soil, but for some crops the threshold concentration may be even lower, and the efficient range much narrower. Moderate excess of mobile boron in soil leads to delays in plant growth and reduces crop yield but significant boron excess acts as a general herbicide causing all the plants die.

The need for accurate and uniform soil application of low boron doses requires a high degree of farming. Disregarding and violating these requirements inevitably leads to failure and apparently becomes the basis of an unjustified fear of boron and exaggeration of its dangers.

In addition, it is necessary to take into account the fact that boron has high level of mobility, quickly and easily leachable from the soil. As it is known, boric acid, applied on soil, after the third rain could not be detected even qualitatively.

The main difficulties of using water-soluble boron fertilizers are due to the fact that a single dose to be applied on soil is limited **by** a low threshold of toxicity, but plants consume relatively high boron amount. In addition to this, a considerable portion of the boron is leached during irrigation and rain. As a result, the concentration of boron in soil solution rapidly falls below allowable limit and the plants begin to starve. Therefore, to maintain boron content in optimum concentration range is not easy. However, this challenging problem is solvable, but only with the help of water-soluble boron salts boron.

Usage of boron fertilizers in Kazakhstan however is considered with great caution, and as a rule, farmers prefer not to use boron fertilizers at all because of the frequent occurrence of “boron toxicity” in rice fields. Complexity of boron ionic composition in soil and water solutions defines the diversity and difficulties in determination of different forms of boron. Lack of reliable analytical methods for boron thus represents additional reason of non-usage of boron fertilizers in Kazakhstan.

Application of boron requires special attention, high culture in farming and precise work with trace doses of micronutrients. It is obvious that because of deficiency of mobile boron, which is frequently the case, the boron fertilizers become essential to obtain complete and high-quality crops. The development of boron identification and analysis methods becomes therefore a high priority problem in rice production.

In view of this, research and selection of existing methods for the determination of boron in soil and soil solution is relevant for Kazakhstan, as well as the development of new methods of express, accurate, sensitive and selective determination of boron.

For the first time more than 10 methods for determining boron in soils of various types of solid and soil solution were tested (in 33 samples of hard soils and 28 soil solutions). It was shown that the most effective methods for determining boron in relation to different types of soil in Kazakhstan should include:

- determination of boron without distillation by fusing ground with anhydrous sodium carbonate;
- determination of boron using carmine;
- determination of boron by azomethine H;
- determination of boron by extraction method with hot water, etc.

Based on the analysis, a review of scientific literature, patent and license marketing searches, evaluation work at the choice of methods for determining boron in soils was established that the most cost-effective and promising method is the determination of boron extraction with hot water in a colored compound with azomethine H.

It was found that the most effective method of express methods for determination of boron should be considered - a method of determination of boron using azomethine H. For the first time, using azomethine H procedures for boron determination was carried as a function of pH in 33 soil samples, the results are presented in tab.1.

Table 1 – Results of the analysis on the boron content (using Bergeru). λ = 420 nm

Sample	pH	Optical density	Boron content, mg / kg
	7,8	0,255	3,44
	7,71	0,53	3,38
	7,69	0,258	3,50
	7,70	0,245	3,32
	7,68	0,279	3,76
	7,67	0,302	4,00
	7,70	0,317	4,24
	7,70	0,270	3,64
	7,67	0,281	3,76
	7,67	0,287	3,92
	7,68	0,354	4,94
	7,68	0,354	4,94

It can be seen from the data of Table 1 that pH changes slightly, and within pH 7-8, boron is also in the normal range 3.32 - 4.94 mg\kg.

According to the IR spectra revealed that the forms of occurrence of boron in the soil solution are largely determined by the values of pH of the aqueous solution. Water-soluble form of boron in the soil corresponds to boric acid and sodium tetraborate. Determination of insoluble forms of boron in the soil as Asharites, gidroboratsita, colemanite requires further research.

A comparative study of pH and the content of total, private and borate alkalinity in soil was conducted and found complete correlation between the shape of alkalinity and mobile forms of boron compounds

Conclusion

From the literature concerning establishment the threshold of toxicity of boron it is known that the highest boron toxicity is manifested if the boron concentration equals 6mg/kg (soil) for young plants. As can be seen from our data on the study of boron in the 11 soil samples, the boron content has not reached a certain “threshold of toxicity”. One of the current challenges is to develop ameliorant techniques against their toxic effects on boron. However, there is no consensus in addressing this problem up to date. In our opinion, the development of ameliorant receptions against their toxic effects of boron, one must know the form of finding boron

compounds in saline soils of rice fields. In this regard, we are carrying out the first attempts to study the quality of the borate compounds in soil samples of rice fields of Kazakhstan.

References

1 Жикишкина П.И. Агрохимические методы исследования почв. – М.: Наука, 1965. – С. 333-344.

2 Nable, R.O., Banuelos, J.S., Paull, J.G. Boron toxicity // Plant and Soil. – 1997. – Vol. 193. – P. 181-198.

3 Ehsan-UI-Haq Mehmood, Rizwana Kausar, Muhammad Akram. Is Boron required to improve rice growth yield in saline environment? // Pakistan Journ. Bot. – 2009. – Vol. 41(3). – P. 1339-1350.

4 Бейсембаева Л.К., Пономаренко О.И., Омарова А., Танашева М.Р. Борсодержащие химические мелиоранты из техногенных отходов // Вестник КазНУ, Сер. химич. – 2011. – № 4(64). – С. 38-41.

5 Bassom W.D., Bolmier R.Y. and Stanton F.A. An automated procedure for the determination of boron in plant tissue // Analyst. – 1969. – Vol. 94(4). – P. 1125-1135.

6 Омаров Т.Т., Танашева М.Р. Бор қосылыстарының химиясы мен технологиясы. – Алматы: Қазақ университеті, 2002. – Б.40-62.

7 Мамутов Ж.У., Есимбеков М.Б. Вклад У.У. Успанова в развитие почвоведения Казахстана. – Алматы, 2006. – С. 153-159.

8 Есимбеков М.Б. Токсическое действие бора на культуру риса // Вестник с.-х. науки Казахстана. – 2010. – № 4. – С. 34-38.

9 Малюга Д.П., Чепурко Н.Л., Махова Н.Н. О содержании бора в почвах и растениях на орошаемых землях долины р. Сырдарья / В сб.: Биологическая роль микроэлементов и их применение в сельском хозяйстве и медицине. – М: Наука, 1970. – 71 с.

10 Алимханова О.А. Токсическое действия бора на растение // Агрохимия. – 1980. – № 7. – С. 98-102.

М.Р. Танашева, О.И. Пономаренко, Л.К. Бейсембаева, М.К. Қалабаева

Топырақтағы және топырақ ерітінділеріндегі борды анықтаудың тиімді әдістерін зерттеу

Табиғи ортаның экологиялық бұзушылығының дамытуымен дәл қазір байланысты күріштіктердің толық немесе жартылай жатсынуына алып келген ҚР-дың әртүрлі өлкелеріндегі бор тұздалу деңгейінің түбегейлі өсуі байқалады. Күріштіктердің топырақтарындағы бор токсикозының себептерінің зерттеуі және оның реттеуінің әдістерінің өңдеуі ауылшаруашылық ғылым және алдыңғы тәжірибе үшін ең маңызды міндет болып саналады. Бұл мәселе топырақтың топырақ ерітінділер дер кезінде және тұщы талдауымен анықталады.

Түйін сөздер: бор, ұлылық, бордың жылжымалы формасы, борды анықтау әдістері.

М.Р. Танашева, О.И. Пономаренко, Л.К. Бейсембаева, М.К. Калабаева

Разработка эффективных способов определения бора в почвах и почвенных растворах

В настоящее время в связи с развитием экологического нарушения природной среды наблюдается значительный рост уровня борного засоления в различных регионах РК, что приводит к полному или частичному отчуждению рисовых полей. Изучение причин борного токсикоза в почвах рисовых полей и разработка способов его регулирования является важнейшей задачей для сельскохозяйственной науки и передовой практики. Решение этой проблемы определяется своевременным и экспресным анализом почвы и почвенных растворов на содержание бора.

Ключевые слова: бор, токсичность, подвижные формы бора, методики определения бора.