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Influence of boron fertilization on productivity of grape plants

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Abstract. The aim of this article is to study the content of micronutrients in the soil of Terek sands region of the Chechen Republic and to identify the physiological response of the grape plants on micronutrients fertilization. The obtained data of the boron total content in the studied sandy soil showed that in 0–60 cm layer of the soil the boron total content ranges from 0.4 to 0.5 mg/kg, in 60–150 cm soil layer – from 0.75 to 0.78 mg/kg. The boron content in the sandy soils of studied area varies within wide limits and characterizes as insufficient. Fertilizing with boron is an effective agricultural technique for up-frost plants and productivity of grapes. This technique allows to increase the sugar content of the berries up to 0.8–1.4 g/cm^3, while substantially reducing the acidity of the juice. The yield of grape crystal grade in the variant with background + N90 P90 K90 + 2 kg of active boron addition was 76.8 t/ha, which is higher than in the control at 34.2 t/ha. The increasing of sugar berries in this variant was from 0.8 up to 1.4 g/cm^3. The highest rates for plants productivity were observed by introducing a complex of boron micronutrients, cobalt, manganese, molybdenum, zinc in the form VIII, wherein the yield totally was 89.4 c/ha.

1. Introduction

The role of microelements in the production of high-grade and high yields of grapes is very important as the main mineral nutrients: nitrogen, phosphorus, potassium, calcium, sulfur and magnesium (Corrales-Maldonado et al., 2010). Only in recent years has attracted the attention of scientists to study the boron as micronutrient element (Benito et al., 2013; Motuzova et al., 2014; Minkina et al., 2014B). Many plants needs in boron fertilization throughout the growing season. It is necessary for the development of the plants meristem. Boron addition increases the synthesis and movement of carbohydrates, especially sucrose from the leaves to the roots and fruiting bodies (Varduni et al., 2014).

In the literature, there is the evidence that boron improves the movement of growing plants and transfer of the ascorbic acid from the leaves to the fruiting bodies (Pinskii et al., 2014). It contributes to better utilization of calcium in the metabolic processes in plants. Therefore, when the plant boron deficiency can not properly utilize calcium, although the latter is in the soil in sufficient quantities. It was found that the absorption and accumulation of boron plant sizes increase with increasing potassium content in the soil (Bell et al., 2013). Boron plays an important role in cell division and protein synthesis is an essential component of cell membranes (Batukaev et al., 2014; Batukaev, 2010).

Extremely important is boron function in carbohydrate metabolism. The disadvantage in the medium causes the accumulation of sugars in the leaves of plants. This phenomenon is observed in the most responsive crops to boron fertilizers. According to physiological action the boron is fundamentally different from other micronutrients. It does not focus the enzyme or substrate for the active course of the reaction due to chelation processes as Mn^{2+}, Zn^{2+} or Mg^{2+}, it does not provide the implementation of the biochemical processes due to valence change as Fe^{2+}, Cu^{2+} or Mo (Minkina et al., 2014). The metabolic mechanism of boron ion reaction is similar to phosphate ion, as capable of forming boric acid esters with OH groups, primarily sugars (Saleh et al., 2013). Feature of boron nutrition is stable content of compound in plants because it cannot be destructed in a plant, so the disadvantage of this compound is detected primarily at the youngest parts of plants whose growth is severely limited (Mandzhieva et al., 2014). In this case the lower parts of plants experiencing boron defficiency may contain three times larger amount despite the fact that their upper parts have obvious signs of boron deficiency (Mayevskaya, 1983).

The vitality of plants decreases with an excess of boron. The shoots are shortened, the number of leaves is reduced, the roots develops poorly. If the content of boron in normally 6 mg/l and above, the edges of leaves are turned inwards and are closed in the upper part, they are very small escape. As a rule, strongly marked excess boron leaves protruding from the brown color on the edges and necrotic dots between the veins, which are then merged, the leaves wither (Kirilyuk, 1977).

According to AD Menagarashvili and V. Lezhava, after addition of boron and manganese fertilizers in the soil in the crop year of tests increased 1–3.5% pa, and the next year – 4–8%. In the third year after-effect was noted only in the areas where applied boron fertilizer (yield rose by 3%) (Menagarashvili, 1950).

The results of patent searches and summarizing of published data show that the comparative studies to establish the effect on yield quality grapes, frost roots, depend on the level of boron content in grapes plants on the sandy soils of the Chechen Republic was not carried out steel (Batukaev et al., 2014). Although these studies are not only of great practical but also theoretical value.

The aim of the research is to determine the content of boron in soils of Terek sands and to identify the physiological response of the vine plants on boron fertilizer and to determine the effect of boron root fertilization on the grapes varieties "Crystal" and "Flower" damaged by frost, it's recovery and productivity of vineyards.

2. Objects and methods

Studies were carried out on fruiting vines of the meadow soils of Valley Terek sands located in the south-eastern, eastern and north-eastern districts of the Terek sand. The methods of agrobiological counts (the number of buds, shoots, buds on the bushes, accounting harvest berries from the bush and 1 hectare, and the average mass of clusters) were performed on establishing the vineyards on industrial scale (Ghaly and Alhattab, 2013).

Soil and plant samples were collected simultane-ously for the determination of nitrogen, phosphorus, potassium, calcium, magnesium and boron microelements, cobalt, manganese, molybdenum, zinc by atomic absorption method. Selection of soil samples was carried out according state standard methods (GOST, 2008); general requirements for conducting soil analyzes (GOST, 2005); nitrate nitrogen in the soil (GOST, 1986); exchange ammonium in the soil (GOST, 1985); mobile forms of phosphorus and potassium in the soil by the Machigin exchange method (GOST, 1992).

Microelements content: boron, cobalt and manganese, molybdenum, zinc were detected by atomic absorption spectrophotometer "Quantum-AFA GKNZ" Using method "Atomic absorption method for determination of toxic elements" (GOST – 30178–96, 1996).

Sugar content of the berries (GOST, 1987) and titratable acidity (GOST, 2000) were determined according to according state standard methods. Statistics of results were determined by Statistica 7.0.

The purpose of field experiment is investigation of different doses and timing effects of boron fertilizer on growth, development and productivity of grapes varieties "Crystal" and "Flower". The scheme of the field experiment:

1. Variant: control (without micronutrients N90 R90 K90 Background).
2. Background: Nutrients N90 R90 K90.
3. Variant: background + Boron (2 kg/1000 liters of water).
4. Variant: background + Cobalt (1 kg/1000 liters of water).
5. Variant: background + Manganese (4 kg/1000 liters of water).
6. Variant: background + Molybdenum (3 kg/1000 liters of water).
7. Variant: background + Zink (6 kg/1000 liters of water).
8. Variant: background + Boron (2 kg/1000 liters of water) + Cobalt (1 kg/1000 liters of water) + Manganese (4 kg/1000 liters of water) + Molybdenum (3 kg/1000 liters of water) + Zink (6 kg/1000 liters of water).

Doses of micronutrients addition are counted for the active compound. Each grape row is separated by two experienced defensive right and left rows.

In the work were used different fertilizers: sulphate manganese, ammonium silitra, super phosphate, potassium salt. Fertilizers were injected into the soil during the phases of sap flow, or the flowering stage, or the phase growth and the beginning of the ripening berries by the hydro drills method at the distance of 80 cm from the bush, to a depth of 30 cm per year. There were totally 16 wells in performed by hydro drills in each experimental variant. Grapes were planting upon to 3 × 1.5 m scheme. The garden was organized in 1988. Variants of experience were laid in 3 replications four plants in each. Forming of vineyards is long sleeved, unsheltered.

3. Results and discussion

The content of humus in the 0–20 cm soil layer of studied sandy soils is 0.64%, in the 20–40 cm soil layer −0.71%, and in the 60–150 cm soil layer −0.92%. pH ranges from 8.3 to 8.5. The phosphorus content in the 0–20 cm soil layer is 13.4 mg/kg, in the 20–40 cm soil layer −10 mg/kg, and in the 60–150 cm soil layer −13.1 mg/kg of dry substance.

The average of potassium total amount at all soil profile depth varied from 122 to 137 mg/kg. The total carbonate content in studied soils is 2.2–2.4%. The content of nitrogen in the sandy loam soil is observed only in total analysis in a very small amount 0.03–0.06%. The average content of total boron in studied soils employed in the 0–60 cm soil layer – 0.4–0.5 mg/kg; in the 60–150 cm soil layer – 0.75–0.78 mg/kg (Table 1). The largest content of boron is observed in meadow soils of studied region.

The total boron content in soil is characterized by the relative increase in its amount in the soil layer from 60 to 150 cm. Redistribution of the total reserves of boron in the soil profile is mainly due to ornstein formation. The acid (20% HCl) becomes insignificant quantity extractor element is approximately 15–17% of boron inventories in the soil. Acid-soluble boron is irregular distributed in the soil profile. The soil layer 0–60 cm is associated with organic matter in the layer 60–150 cm there are predominantly hydrated hydroxides of iron and aluminum, therefore boron is less available for plant nutrition. The aqueous extract of boron becomes 5.6 times less than 20% of the recovered HCl. This indicates unavailability of grape plants to major reserves of this element.

From Table 1 it is clear that the boron content in the sandy soil in the soil profile of research area varies within wide limits and characterizes as insufficiently secured this element especially water-soluble boron.

The value of boron in the leaves during the growth of the shoots during the growing season is fairly constant 3.74 mg/kg in July, and 3.85 mg/kg in August. Studies show that the uptake of boron increases young sprouts prior to ripening, and reaches the shoots to 13 mg/kg, and then lowered up to 2.4 mg/kg of dry matter. The differences in the boron content in shoots significant during the analysis. The concentration of boron in the shoots and leaves can be decreased up to 50–80% after rainfall. Efficiency of drying the boron from plants depends on the number and intensity of rainfall in drought years boron salts may accumulate on the leaf surface in the form of

Table 1. Total content of boron and forms of boron compounds in a soils of studied region.

Forms of boron compounds	Content in soil, mg/kg		
	Selection depth, cm	Sandy soil, mg/kg of dry soil	Meadow soil, mg/kg
Total content	0–60	0.4	0.80
	60–150	0.75	12.4
Acid soluble forms	0–60	0.25	0.53
	60–150	0.61	8.7
Water soluble forms	0–60	0.06	0.16
	60–150	0.12	2.7

Table 2. Time and dose effect of boron and complex micronutrients fertilizer adding on growth, and productivity of grapes plants.

Variant of field experiment	The average length of shoots, cm	The average diameter of the shoots, mm	Yield, t/ha	Sugar content of the berries, g/dm3
1. Variant: control (without micronutrients N90 R90 K90 Background).	135.0	5.4	42.6	19.0
2. Background: Nutrients N90 R90 K90.	149.0	5.7	75.4	19.2
3. Variant: background + Boron (2 kg/1000 liters of water).	151.6	5.8	76.8	20.0
4. Variant: background + Cobalt (1 kg/1000 liters of water).	151.4	5.8	76.0	20.1
5. Variant: background + Manganese (4 kg/1000 liters of water).	157.3	6.0	78.5	21.2
6. Variant: background + Molybdenum (3 kg/1000 liters of water).	152.2	5.8	76.0	20.3
7. Variant: background + Zink (6 kg/1000 liters of water).	151.8	5.7	75.9	19.1
8. Variant: background + Boron (2 kg/1000 liters of water) + Cobalt (1 kg/1000 liters of water) + Manganese (4 kg/1000 liters of water) + Molybdenum (3 kg/1000 liters of water) + Zink (6 kg/1000 liters of water).	173.6	6.3	89.4	21.4

crystalline boron cannot be reduced because it does not income from old to young plant organs.

Therefore, signs of boric starvation appear primarily on the newly formed leaves.

Boron content considered harmful in plants leaves in an amount of 700 mg/kg and in cuttings in amount 100–300 mg/kg. Levy and Chaler (Levy, 1964) is considered, however, that the level of boron is toxic in the leaves upper than 60 mg/kg. Beyers considered the normal boron level in the leaves is 25-100 mg/kg and toxic level is above 400 mg/kg (Beyers, 1962).

In June in “Flower” varieties content of boron was 3.1 mg/kg of dry matter, at “Crystal” – 2.5 mg/kg. The maximum of boron content was at the beginning of ripening berries in July in “Flower” varieties was 4.4 mg/kg of dry matter, the variety “Crystal” contents 3.5 mg/kg. The boron content increased before the beginning of ripening in August in “Flower” varieties up to 4.3 mg/kg, in the variety “Crystal” to 3.3 mg/kg and remained at a constant level until the harvest. This content of boron for using grapes for vine production is extremely useful. In humans, plants and animals when feeding with excess boron 60–600 mg/kg of dry matter and more disturbed metabolism.

Factors reducing the boron content in the leaves and berries are drought, excessive moisture, damage to plantations in the winter frosts were favorable conditions for overwintering and grapes during the growing season. In determining the average weight of berries found that forest berries stimulates growth, significantly increasing their weight. Comparing variant background N90R90K90 with only macronutrients addition the yield of grade “Crystal” was 7.54 t/ha. The variant with an embodiment of background N90R90 K90 + Boron 2 kg of active ingredient yield increased up to 7.68 t/ha, increase was 1.4 t/ha. The differences in yield of variants in experience were significant ($P = 0.95$). Sugar content in berries increased up to 0.8–1.4 g/cm^3, and the highest rates in the development and productivity of plants obtained by introducing a complex boron micronutrients, cobalt, manganese, molybdenum, zinc in the form VIII. In this variant the yield was 8.94 t/ha or above 1.4 t/ha, compare with variant with addition only background fertilizer N90 R90 K90 (variant II) (Table 2).

The resulting difference in the grape yield for a variety of "Flower" compared with the background N90R90K90 was 1.2 t/ha and also reliable and mathematically proved. Adding boron fertilizer to the background has improved all morpho-biometric and physiological characteristics of plants during the growing season.

Multiple slices on wood of grapes showed the presence of frost damage to the bushes heads, hoses and vines. The temperature at the 30-sm soil depth in the studied region briefly dropped to minus 10–14°C. As a result, the depth of the root system of studied hybrid varieties of grapes has been damaged. Live roots are preserved, beginning at a depth of 35 cm.

In our experiments with fruit bushes in the embodiment where boron was introduced in the least damaged by frost than where background fertilizers were applied. Higher yields per hectare of vines damaged by frost obtained in the variant Background Boron + 2 kg. I this variant the yield was bigger than variant Background nitrogen, phosphorus, potassium at 2.08 t/ha and bugger than control variant up to 3.14 t/ha. Under the influence of boron positively changed the chemical composition of berries the sugar content increased.

In grade "Flower" in our experience it is established the identical positive impact of root fertilizing by boron on the development and productivity of plants.

4. Conclusion

The boron content in the sandy soils of the studied area varies within wide limits and characterizes as insufficiently provided by this element. Fertilizing with boron is an effective agricultural practices up-frost plants and productivity of grapes. This kind of fertilization allows to increase the sugar content of the grape berries at 0.8–1.4 g/cm^3, while substantially reducing the acidity of the juice.

The optimum mode of the fertilization of vineyards grade "Crystal" and "Flower" is addition of boron at a depth of 30-sm soil layer in an amount of 2 kg of active compound per ha with background: nitrogen 90, phosphorus 90, potassium 90. It will allow to accelerate the recovery of the root and aboveground plant system damaged by frosts and to enhance the development of reproductive organs in the studied sandy soils.

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