Soil conditions and the iron chlorosis of mature vine

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Abstract. Iron-deficiency chlorosis is a usual routine problem on calcareous carbonated soils of Crimea. Different reasons cause vine chlorosis: soil properties, physiological status of plants and others. It was shown that chlorosis spot in the vineyard has constant location. Chlorosis can be identified visually and instrumentally. In this study, an attempt was made to find the relationship between soil electrical resistance and the spread of vine chlorosis.

1. Introduction
Predominately, the vineyard areas are situated in the southern foothill areas of Crimea, at altitudes of 150-400 meters above sea level. In order to create new vineyards, it is necessary to survey the territories; first of all to find the soil with suitable condition for vine [1]. The main problem of the Crimean soils is alkaline reaction (pH > 8), and such soil condition often leads to iron-deficiency chlorosis. Also, other causes of chlorosis can be saline soil or rootstock problems. For areas with conditions favorable for chlorosis different regimes of soil treatment and planting care are recommended [2]. Formerly, the influence of calcium soil on the development of chlorosis was studied by many soil scientists of Crimea. But now we have new instruments and methods for soil investigation and it is possible to predict sites with potential chlorosis problem before placing the vineyards terroir. The measurement of electrical conductivity (or electrical resistance) of soil in situ is the rapid method to estimate soil condition.

The goal of our research was to find correlation between iron chlorosis of mature vine and some chemical and physical soil properties: humus content and agrochemical properties, salinity and electrical resistance of soil.

2. Material and methods

2.1. Experimental Site
The investigations were conducted in June 2017 in Crimea 2 km to the North from Rodnoye village, at “Uppa biodynamic winery” (N 44,5603; E 33,7526) (figure 1, a). Climate in the Crimea region is temperate with dry hot summer. According to Köppen climate classification, climate code is Csa [3]. The average annual precipitation, including snow, is near 430–550 mm. Annual rainfall is about 80% of the total amount of precipitation. The average annual mean temperature is near 11°C. The soils at the study area are Brown mountain forest soils on carbonated subsoils, or Calcisols CL by FAO soil
classification [4]. The soil cover of the vineyard is heterogeneous, due to the influence of mountain relief and mixing of the topsoil and subsoil mass by previous landslides.

![Figure 1](image)

**Figure 1.** Site of Vineyard near Rodnoye (a), and placement of experimental points (b): red circles with the presence of vine chlorosis, green circles without vine chlorosis.

Two locations were established for the investigation: the couple of closely situated points with chlorosis and without chlorosis (figure 1, b; red circles and green circles respectively). The place sites were chosen after the remote estimation of NDVI and visual identification of chlorosis. **Location-1** is situated on slight slope (less than 4°) of southwest exposure. **Location-2** is situated on a steeper slope (about 12°) of south adret exposure. Chlorosis spots at vineyard were about 4–8 square meters. The nearby situated vine rows were without signs of chlorosis. The cultivar of vine is Riesling with density of planting 5000 vines ha\(^{-1}\) and planting pattern 2×1. So, chlorosis spots include 3–7 vine plants.
2.2. Methods of soil and vine survey

Instrumental investigations were carried out on chlorosis spots and closely on non-chlorosis vine rows. The plants were examined both by visual and instrumental methods for identification of chlorosis. Healthy and chlorosis vine-rows were investigated with GreenSeeker Handheld and with color photography in the visible range using mathematical processing of colored images (calculated L* A* B and H*S* V space with MATLAB). In the same locations, electrical resistance (ER) of soil was measured in the layers 0–20, 0–30, 0–40 and 0–60 cm (vertical-deep sounding with LandMapper [5]), and soil samples were taken to determine the main agrochemical properties. The agrochemical analysis of the soil has been carried out according to the generally accepted methods for carbonated soils. The pH was measured potentiometrically with electrode in suspension in the ratio of soil / normal water solution of KCl: 1/2.5. The phosphorus concentration in the soil was determined spectrophotometrically with the molybdenum blue from an extract solution of acetate-ammonium lactate. Also, the potassium supply was determined from this extract using flamephotometry. The concentration of heavy metal and iron in the soil samples were estimated with Spectroscan LiF200.

3. Results and discussion

3.1. Identification of vine leaves chlorosis

In the sites with chlorosis the values of NDVI were significantly lower, than in other places (figure 2). The same results were obtained in the evaluation of chlorosis presence by photographic method with mathematical processing of photographic images [6].

![Figure 2. NDVI value of vine Riesling leaves at the sites with chlorosis (1-1, 2-1) and without chlorosis (1-2, 2-2).](image-url)

A visual inspection of plants revealed the presence of damage to the rootstock and the grafting place, therefore development of chlorosis depended on the soil properties.
3.2. Soil agrochemical properties
The soil pH value varies from 7.9 to 8.1, and there was no correlation between chlorosis presence and pH value. The content of the soil organic carbon is approximately equal from one point to another. The concentration of soil organic carbon is 2.3–2.5%, and it is an average level of soil carbon capacity of such type of soil. Other agrochemical properties were comparable with an average level for brown mountain dry soil (table 1), and these soils were considered to have good conditions for vineyards. Therefore, no evident cause of chlorosis was detected. Only one significant difference was marked: amount of phosphorus at the point 2-1 was much lower comparing to the other sites. The total amount of manganese was very low in all soil samples; however, it is a common situation for carbonated soils.

| Table 1. Agrochemical properties of the soil and heavy metal concentration at four survey points. |
|---------------------------------|----------------|----------------|----------------|----------------|
| Criteria                        | 1-1 Chlorosis | 1-2 No Chlorosis | 2-1 Chlorosis | 2-2 No Chlorosis |
| pH<sub>KCl</sub>                | 7.90          | 8.00            | 8.00           | 8.10           |
| Soil organic carbon,%           | 2.26          | 2.37            | 2.42           | 2.51           |
| NO<sub>2</sub>, %               | 0.12          | 0.13            | 0.14           | 0.14           |
| P<sub>2</sub>O<sub>5</sub>, ppm | 26.89         | 26.03           | **7.91**       | 11.11          |
| K<sub>2</sub>O, ppm             | 251.74        | 233.54          | 260.47         | 292.57         |
| Fe<sub>2</sub>O<sub>3</sub>, %  | 1.34          | 0.89            | 1.25           | 1.92           |
| Mn, ppm                        | 0.003         | 0.004           | 0.003          | 0.004          |
| Cu, ppm                        | 2.94          | 1.30            | 2.03           | 0.01           |
| Zn, ppm                        | 9.60          | 4.63            | 7.77           | 10.08          |

The differences in pH, humus and basic mineral nutrients between the soil on which chlorosis occurs and the soil on which healthy plants grow are not significant. So, such condition does not correlate with the degree of chlorosis.

3.3. Soil agrophysical properties
Soil granulometric texture was evaluated by organoleptic method. The topsoil in all four sites was middle loamy, and subsoil was heavy loamy with calcium gravel inclusion.

Electrical resistance (ER) of soil layer was measured with LandMapper [5]. Four layers from 0 to 60 cm depth were selected for evaluation. Generally, the ER of soil was low and it decreased with increasing soil depth (figure 3). At the layer 0–60 cm the ER mean was minimal, 4–10 Ohm*m. At the topsoil 0–20 cm the ER varied significantly: in the Location-1 it was 35–45 Ohm*m, in the Location-2 it was 10–25 Ohm*m. It can be connected with the amount of soil electrolytes in-situ. Unfortunately, these results don’t give the answer about the reasons of chlorosis. Two studied locations were too different to capture the general trend of chlorosis. But in places of chlorosis presence Soil ER was lower than in places without chlorosis (figure 3). The tetrachoric test confirms that the lower was soil ER, the more pronounced were the symptoms of chlorosis. In this case, it is possible to recommend creating integrated maps of soil ER and the spread of chlorosis. After the combine analysis of such maps, it would be possible to discuss the connection of the contours of low soil ER with spreading of vine chlorosis. This technology of investigation could be used on the vineyard, and it is a useful tool for the site-specific management of iron-deficience chlorosis. In the case of the accumulation of a
large amount of data on the relationship of soil properties with vine chlorosis, these data could be used in the exploration of places for new vineyards.

![Figure 3. Evaluation of Soil Electrical Resistance at the sites with chlorosis (1-1, 2-1) and without chlorosis (1-2, 2-2) at four layers of soil.](image)

4. Conclusions
The detection of chlorosis spread zones with instrumental method combined with soil electric resistance estimation can be a useful tool for the precision agriculture and site-specific management of vineyards iron chlorosis. Also, the measurement of soil electrical properties can be recommended to predict the probability zones of iron chlorosis spreading in new places for vineyards.

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