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Response of Nutrients in Apple Leaves to Regulation of Water and Fertilizers in Loess Hilly Area

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Abstract

Aiming at the problem of the low utilization ratio of water resource and fertilizers in apple orchard in loess hilly area, which is the result of both water shortage and improper fertilization, a field experiment of the regulation of water and fertilizers is carried out in a typical apple orchard in this area to make analysis of nutrients in apple leaves under different treatments of water and fertilizers. The results show that: in the experimental area: 1) the total nitrogen content in apple leaves maintains at a low level of 1.87% - 3.17%; the total phosphorus content in apple leaves maintains at a low or normal level of 0.13% - 0.16%; and the total potassium content in apple leaves maintains at a deficient level of 0.46% - 0.64%; 2) the regulation of water and fertilizers has some effect on promoting the trees to adsorb both the total nitrogen and the total potassium, but it has no apparent effect on promoting the leaves to adsorb the total phosphorus. In the management of water and fertilizers in this apple orchard, the effects of the water and the fertilizers should be properly regulated to make full use of the limited water resource and improve the utilization ratio of the fertilizers as well, so as to achieve the three goals of saving water, saving fertilizers and improving quality.

Keywords

Regulation of Water and Fertilizer, Mountain Apple, Leaf Nutrient

1. Introduction

Compared to the index of soil nutrients, the content of mineral nutrients in

leaves is better to represent the nutritional status in tree trunk and can reflect the distribution of soil nutrients as well [1]. Because mineral nutrients in trunk are new compositions of substances and also the nutritional base for the growth of fruits, the nutritional status in trunk reflected by the content of leaf nutrients can be used as an approach to estimate whether soil nutrients are deficient or not [2]. Through changing both the content of nutritional elements in soil and the environment where nutrients are adsorbed by root, irrigation and fertilization can generate effect on the content of mineral nutrients in trunk. Studying leaf nutrients under different treatments of irrigation and fertilization and investigating the correlation between leaf nutrients and fruit quality are meaningful to optimize the management of water and fertilizers in this area.

2. Materials and Methods

2.1. Profile of the Experimental Area

The area in our study is located in Ansai district, Yan'an city, and it is a site of loess accumulation situated deeply in the Loess Plateau in northwest China, where there are loess ridges, hills and gullies [3]. Agricultural development in this area depends mainly on fruit trees. The area is in the temperate zone that has the climate of continental semi-arid monsoon and distinct seasonal changes. In this area, the mean annual temperature is 8.8˚C, the mean annual precipitation is 505.3 mm and there are 157 frost-free days. Our experiment is carried out in Fangta orchard in Ansai district. For the 0 - 40 cm soil layer in this orchard, the volume-weight is 1.21 - 1.66 $g.cm^{-3}$, the soil porosity is 0.39% - 0.64% and the pH value is 6.02 - 7.36. The age of the trees is 18a and the spacing between most tree rows is 4 m × 5 m.

2.2. Experiment Design

The design of the 3-factor and 3-level orthogonal experiment [4]:

1) The three factors:

A: the degree of irrigation; B: the time of irrigation; C: the amount of fertilization.

2) The three levels:

The degree of irrigation (A). A1: 40%, A2: 60% field capacity, and A3: 80% field capacity, in which, field capacity represents the water-holding capacity in the experimental field.

The time of irrigation (B). B1: 5 times of irrigation in winter (middle November) + pre-flowering period (from late March to early April) + the first fruit expanding stage (late June) + the second fruit expanding stage (late July) + fruit transition (coloring) period (late August); B2: 3 times of irrigation in – winter + the first fruit expanding stage + the second fruit expanding stage; B3: 2 times of irrigation in – winter + the second fruit expanding stage.

The amount of fertilization (C): C1: 0.25 kg per tree; C2: 0.5 kg per tree; C3: 1 kg per tree.

Each treatment is repeated 3 times and a control group contains 3 trees that are normally managed. Trees in orchards A, AF and E are treated in the same way. The irrigation water is taken from the rainwater harvesting cistern. The fertilizers are calcium superphosphate (containing 15% P_2O_5) and potassium sulphate (containing 51% K_2O) which have been commonly used by farmers in this area. Mix the two fertilizers together and control the mixture of P_2O_5 and K_2O at the pure mass ratio of 1:2.

The scheme of different treatments in the 3-factor and 3-level orthogonal experiment is shown in Table 1.

2.3. Sample Collection and Processing

A number of outer leaves of each tree in the experiment were collected from all directions after the fruits had been picked (in (middle October) in 2016. For each tree, 7 - 9 leaves were put into a plastic bag and taken back to the lab. Use deionized water to clean the leaves and put them into envelopes after they have been spin-dried. Put the envelops in an environment at the temperature of 105˚C for 15 min to deactivate enzymes, them dry them at 75˚C till the weight keeps constant. After that, use a 100-mesh sieve to screen them. Seal them in a plastic bag.

Detection items include: the contents of total nitrogen, total phosphorus and total potassium in leaves. The leaves are boiled in H_2O_2-H_2SO_4 and detected by using the continuous flow analyzer FLOWSYS.

2.4. Data Processing

Use EXCEL and SPSS to process and analyze the data.

3. Results and Analysis

Through changing the moisture and nutritional environment around the root system, the regulation of water and fertilizers can create better material conditions for the tree to adsorb mineral elements. In this experiment, the purpose of irrigation and fertilization is to change the contents of water, phosphatic fertilizer

Table 1. Different treatments of irrigation and fertilization.

Treatment No.	Irrigation quota (L/tree)	Irrigation time	Fertilization amount (kg/tree)
1	A1	B1	C1
2	A1	B2	C2
3	A1	B3	C3
4	A2	B1	C3
5	A2	B2	C1
6	A2	B3	C2
7	A3	B1	C2
8	A3	B2	C3
9	A3	B3	C1

and potassic fertilizer in root-zone soil. For orchard fertilization, a proper proportion of mineral elements is very important, because the mineral elements are positively or negatively interacting with each other when the tree is adsorbing nutrients [5]. The change of contents of water, phosphorus and potassium may result in the adsorption of other elements, such as nitrogen. The content of leaf nutrients can be a reflection of the amount of nutrients adsorbed by the entire tree, and a portion of the leaf nutrients is conveyed along with water for the growth of fruits [6]. Therefore, the nutritional status in leaves has a direct effect on fruit quality and it is distinctly related to the fruit indexes of total sugar, total acid, weight, shape and yield [6] [7] [8]. The standard range of apple leaf nutritional elements in Shaanxi province was given in a previous study [9], see **Table 2**.

3.1. Response of the Content of Total Nitrogen in Leaves to the Regulation of Water and Fertilizers

Figure 1 is a description of the contents of total nitrogen in leaves under different treatments of irrigation and fertilization. It can be concluded from the analysis of **Figure 1** that: there is no big difference between the contents of total nitrogen in leaves in orchard A and AF, but the content of total nitrogen in leaves in orchard E is relatively low. With regard to **Table 2**, it can be known that 2.15% - 2.30% is a low level for the content of leaf nitrogen while 2.31% - 2.50% is a normal level. For orchard A, the contents of total nitrogen in leave maintain at a normal level under treatment 4, 6 and 7, but are low under other treatments. For orchard AF, the contents of total nitrogen in leaves maintain at a normal

Table 2. The standard range of apple leaf nutritional elements in Shaanxi province (An Guiyang, 2004).

Elements	Deficiency	Lower	Normal value	Higher	Excess
N (%)	<2.15	2.15 - 2.30	2.31 - 2.50	2.51 - 2.66	>2.66
P (%)	<0.118	0.118 - 0.137	0.138 - 0.166	0.167 - 0.186	>0.186
K (%)	0.55	0.55 - 0.72	0.73 - 0.98	0.99 - 1.16	>1.16

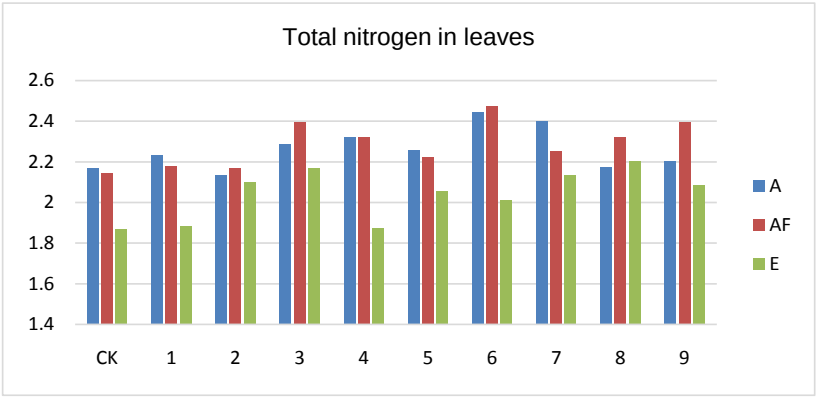

Figure 1. The contents of total nitrogen in leaves under different treatments of irrigation and fertilization.

level under treatment 3, 4, 6, 8 and 9, but are low under other treatments. For orchard E, the contents of total nitrogen in leaves are highest under treatment 3, 7 and 8, but in general, the contents are lower than the normal level. Compared with the control group, the contents of total nitrogen in leaves that had been treated with the irrigation and fertilization are generally higher, which proves that the irrigation and fertilization can promote apple trees to adsorb the element of nitrogen.

3.2. Response of the Content of Total Phosphorus in Leaves to the Regulation of Water and Fertilizers

Total phosphorus can promote the growth of fruits and a proper amount of phosphori is beneficial to the yield, but excess phosphori will generate a negative effect on the synthesis of sugar and, as a result, affect the taste of the fruit. Figure 2 is a description of the contents of total phosphorus in leaves under different treatments of irrigation and fertilization. It can be seen that the contents of total phosphorus in leaves in all the orchards maintain at a normal or higher level, which indicates that the irrigation and fertilization can promote apple trees to adsorb the element of phosphorus. However, the promotion effect is unstable in different fields. A possible reason is the relative small amount of the phosphatic fertilizer designed in the experiment (calcium superphosphate 0.083 kg - 0.33 kg/tree each time), which is not enough to generate a distinct effect on the adsorption of phosphorus.

3.3. Response of the Content of Total Potassium in Leaves to the Regulation of Water and Fertilizers

The element of potassium is a participant and a promoter of the synthesis of both sugar and acid in fruit. Figure 3 is a describe the contents of total potassium in leaves under different treatments of irrigation and fertilization. It can be known that there is a big difference between the contents of total potassium in leaves under different treatments, and the highest content occurs under treatment

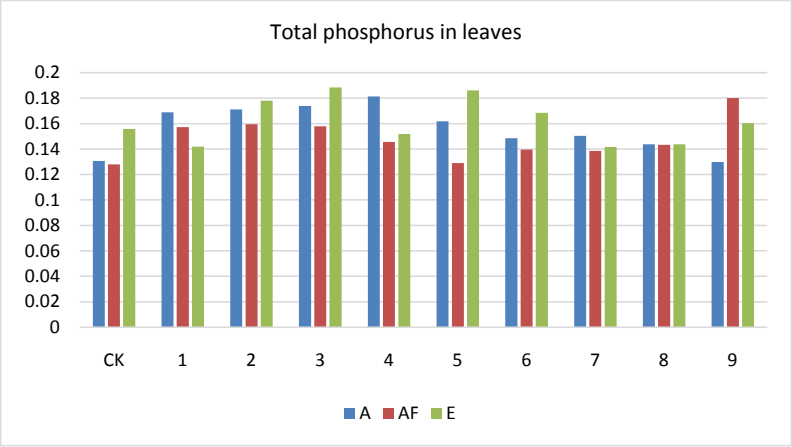

Figure 2. The contents of total phosphorus in leaves under different treatments of irrigation and fertilization.

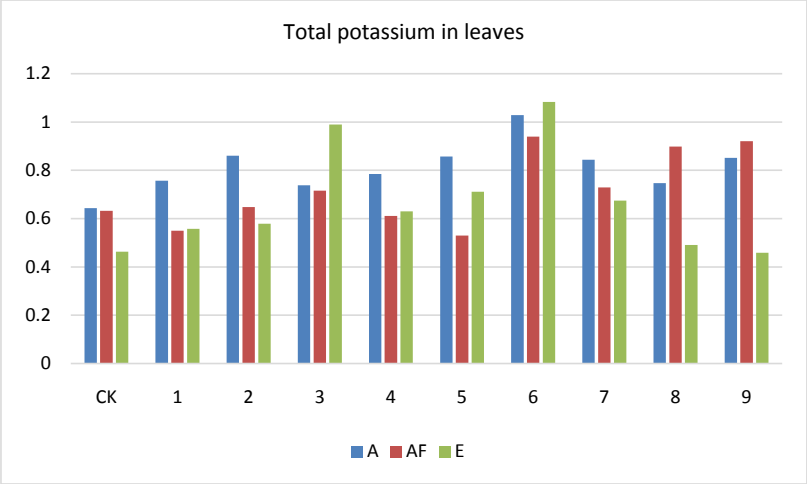

Figure 3. The contents of total potassium in leaves under different treatments of irrigation and fertilization.

6. The contents of total potassium in leaves in orchard A and AF show that: under treatment 7, 8 and 9 in which the degree of irrigation is the highest, the contents of total potassium in leaves are higher than those under other treatments, which reflect that irrigation can promote apple trees to adsorb the element of potassium.

4. Conclusions

1) On the whole, the contents of total nitrogen, total phosphorus and total potassium in apple leaves in this area maintain at a deficient level. In previous management, the amount of the fertilizers applied to the trees is far larger than that being adsorbed. So, the way of fertilizing should be changed to raise the efficiency of adsorbing nutrients.

2) The regulation of water and fertilizers can promote the trees to adsorb nitrogen. Basically, the content of total potassium in leaves is higher if the degree of irrigation is greater. Sufficient irrigation has an effect on promoting the trees to adsorb the element of potassium. For trees in different orchards, the contents of total phosphorus in leaves under different treatments do not change in the same way.

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