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Effect of Integral Control of Water and Fertilization on the Content of Mineral Nutrient in Leaves during Flower Bud Differentiation in Apple

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Abstract:

Apple is one of the most important fruit crops in the worldwide. Although Drip irrigation fertilization has been widely promoted and applied in agricultural developed countries such as Europe and America, but the ratio, application amount and use period of fertilizers for drip irrigation are not clear in China. Here, taking the traditional fertilization as the control, the effects of different N, P, K application rates on the nutrient elements content and growth of trees were studied under the condition of drip fertilization, in order to clarify the best period and application rate of drip fertilization during flower bud differentiation. We found that the peak of nitrogen demand in late June, and the K, Ca and Zn was related with the early stage of flower bud differentiation. Low Controlling fertilizer was beneficial to regulating branch capping. In short, nitrogen fertilizer needs to be applied before June of apple tree.

Keywords: *Apple, Drip irrigation, Nutrient elements, Flower, Traditional fertilization.*

I. INTRODUCTION

Apple (*Malus domestica* Borkh.) is one of the most important fruit crops in the worldwide. The planting area and output of apple have reached the first place in the world in China [1]. Although, the Loess Plateau, the Bohai Bay, the old yellow river channel and the southwest Cold Highland had formed four major apple-producing areas, due to the limitations of natural conditions and management level, compared with advanced level in world, there was still a certain gap in apple industry in China.

Nutrient elements are the material basis of fruit tree growth and fruit, and also play an

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important role in the process of flower bud differentiation. The leaves can reflect the nutritional status of trees in time and accurately, so the determination of nutrient element content in leaves is often used to guide fertilization. Water and fertilizer management played an important role in apple cultivation. The predecessors have done a lot of research on the amount of fertilizer, the proportion of fertilizer, the method of fertilization and the period of fertilization. Lu [2] believes that the best fertilizer effect when the potassium orchard K_2O 0.30 kg/ hm^2 plant in the full fruit period. Wang et al. [3] showed that 110 kg/hm^2 nitrogen fertilizer and 255 kg/hm^2 phosphorus fertilizer were the optimal treatments for the growth of Fuji saplings with different ratios of nitrogen, phosphorus and potassium. Hong *et al*. [4] showed that nitrogen and phosphorus were mainly applied in the early stage of growth, and phosphorus and potassium were mainly applied in the later stage. The yield could be increased by adding nitrogen properly. With the extension of the application time of nitrogen, phosphorus and potassium, some problems have emerged, such as groundwater nitrate pollution [5], fruit quality degradation, and soil compaction degradation [6], which have seriously threatened human health and sustainable development of production. Different rootstocks, varieties, tree ages, tree vigor, soil fertility status and climatic conditions all have certain effects on the balance of tree nutrient supply and demand. Therefore, it is impossible to recommend the same fertilization ratio, fertilization method, and application amount and application period for fruit trees planted in different areas and different tree ages in the same area.

Water and fertilizer synchronization irrigation is a significant characteristic of drip irrigation. Drip irrigation fertilization has been widely promoted and applied in agricultural developed countries such as Europe and America [7], which reduced the amount of fertilizer, and then, reduce the pollution of fertilizer to the environment. Compared with sprinkling irrigation, drip fertilization has higher yield and fruit quality, and lower water consumption [8]. Compared with traditional fertilization methods, the ratio, application amount and use period of fertilizers for drip irrigation are not clear. In this study, taking the traditional fertilization as the control, the effects of different N, P, K application rates on the nutrient elements content and growth of trees under the condition of drip fertilization were studied, in order to clarify the best period and application rate of drip fertilization during flower bud differentiation.

II. MATERIALS AND METHODS

2.1 Plant Material and Treatment

Four years old ‘Tianhong 2’ apple (*Malus domestica* Borkh. ‘Tianhong 2’) trees grafted on inter-stock SH40 and rootstock (*Malus robusta* Rehd.) were grown with spacing 1.5 × 4 m in the orchard of Liujiama village, in Baoding, Hebei Province of China (114°73’ E, 38°68’N). All plants were planted under the condition of drip irrigation. Sixteen rows of trees were divided into 4 groups, four rows in each group and sixty trees per row. The treatment 1 (T1), treatment 2 (T2) and treatment 3 (T3) were applied three times in sprout period, prophase of fruitswell period and metaphase of fruitswell period, respectively. The specific amount of fertilization was shown in TABLE I. The control 1 (C1) was applied four times in sprout period (26^{th} Mar, N

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5.11 kg/667m^2), young fruit period (24th May, N 4.60 kg/667m^2, P_2O_5 1.91 kg/667m^2, K_2O 1.25 kg/667m^2), Flower bud differentiation period (4th Jul, N 12.78 kg/667m^2, P_2O_5 2.89 kg/667m^2, K_2O 1.89 kg/667m^2) and metaphase of fruitswell period (15th Aug, P_2O_5 2.89 kg/667m^2, K_2O 1.89 kg/667m^2), drip irrigation.

Ten years old 'Tianhong 2' apple trees grafted on inter-stock SH40 and rootstock (*Malus robusta* Rehd.) were grown with routine management (spacing 2 × 3.5 m) in the comprehensive experimental station in Baoding, Hebei Province of China, which was the control 2 (C2) with traditional fertilization. The C2 was fertilization in three times: sprout period (24th Mar, N 25.43 kg/667m^2, P_2O_5 6.25 kg/667m^2, K_2O 6.25 kg/667m^2), prophase of fruitswell period (26th Jul, N 13.34 kg/667m^2, P_2O_5 4.17 kg/667m^2, K_2O 20.01 kg/667m^2), fructescence (4th Oct, N 25.01 kg/667m^2, P_2O_5 25.01 kg/667m^2, K_2O 25.01 kg/667m^2).

Fertilizers were applied, which were urea (46% N), diammonium phosphate (15% N, 45% P_2O_5), potassium phosphate monobasic (34% K_2O, 52% P_2O_5), and two water-soluble nitrogen-Phosphate-potassium fertilizers (N-P_2O_5-K_2O ratio, 18-8-25 and 15-5-30).

TABLE I. The time and fertilization amount of treatments

Treatment	Fertilization period and rate (kg/667m^2)			
	Sprout period (28th Mar)	Fruitswell Period(prophase) (12th Jul)	Fruitswell Period(metaphase)(15th Aug)	Total fertilizing amount
Treatment 1	N 1.28 P_2O_5 0 K_2O 0	N 0.83 P_2O_5 0.28 K_2O 0.67	N 0.47 P_2O_5 0.16 K_2O 0.94	N 2.58 P_2O_5 0.44 K_2O 1.61
Treatment 2	N 2.56 P_2O_5 0 K_2O 0	N 1.66 P_2O_5 0.56 K_2O 1.34	N 0.94 P_2O_5 0.32 K_2O 1.88	N 5.16 P_2O_5 0.88 K_2O 3.22
Treatment 3	N 3.84 P_2O_5 0 K_2O 0	N 2.49 P_2O_5 0.84 K_2O 2.01	N 1.41 P_2O_5 0.48 K_2O 2.82	N 7.74 P_2O_5 1.32 K_2O 4.83

2.2 Observation and Classification of Short Shoot Terminal Buds

Thirty terminal buds were randomly collected from 30 trees every 10 days from May 5th (the short branches stopped growing) to middle of November, the buds and leaves were numbered 1~30 respectively, and then the bud was observed by a stereoscopic anatomical microscope to classified into leaf buds flower buds with morphological differentiation seven stages referring to the previous methods [9,10] with some modification. The leaves were divided into flower bud leaves (FL) and leaf bud leaves (LL), used for detecting the content of nutrient elements later.

2.3 Determination of Nutrient Elements Content

One hundred and fifty leaves of annual branches were collected from five trees (from T1, T2, T3, C1 and C2) every 30 days from 25th May to 25th Oct, a total of six times, three biological replication. Leaves (annual branches from T1, T2, T3, C1, C2, and flower bud leaves

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and leaf bud leaves from C2) were washed with deionized water, dried at 70 ℃ and smashed in the machine. After soaked by deionized water (1 mL), the samples add 8mL mixed acid (H_2SO_4:$HClO_4$, 10:1) for digestion about 2.5 h from 100℃ to 280 ℃, with a constant volume of 100ml, N and P contents were determined by continuous flow analyzer (AA3 type). The content of K, Ca, Mg and Zn were determined by inductively coupled plasma method (ICP), which was digested by 25 mL mix acid (HNO_3:$HClO_4$, 5:1).

2.4 Measurement of Tree Growth

Fifteen trees were selected from T1, T2, T3, C1 and C2, respectively, which were divided into three repetitions. The length of spring shoots and the capping rate of new shoots were measured in mid-July, the length of autumn shoots and the perimeter of trunk during the defoliation period. The basic knowledge of the perimeter of trunk was measured before germination, so as to calculate the increment of trunk.

III. RESULTS AND ANALYSIS

3.1 Flower Buds Proportion and Differentiation Process of ‘Tianhong 2’ Apple

The floral initiation of ‘Tianhong 2’ apple flower buds appeared on early June (the short branch stopped for about 40 days). The proportion of flower buds was increased along with development, and reached 58.4% to 75.0% at the later stage of flower bud differentiation (Fig 1).

The observation results showed that the floral initiation began on 10th Jun, and was concentrated in the middle and later June. Initial differentiation initially appeared on 5th Jul, concentrated in the early July. Inflorescence primordium occurred on 5th Jul, concentrated in the middle and later July. Sepal primordium first appeared on 15th Jul, and concentrated in early August. The petal primordium occurred on 25th Jul and concentrated in early and middle August. The stamen primordium appeared slightly on 5th Aug, and concentrated between middle August and later September. The pistil primordium occurred on 25th Sep, and a large number of flower buds entered the pistil primordium stage in early October.

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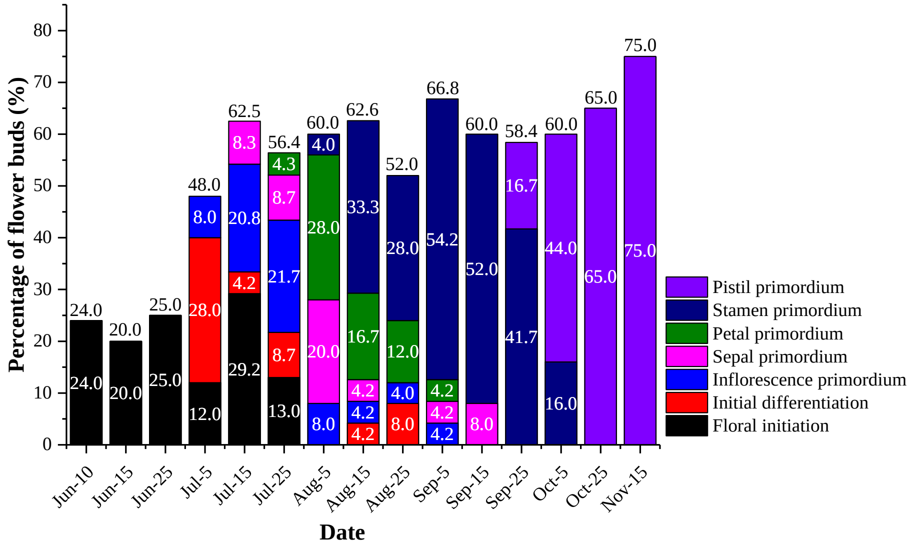

Fig 1: The flower buds percentage (%) and the flower bud differentiation process in 'Tianhong 2' apple.

3.2 Variation of N Content in Leaves

The N element of T3, C1 and C2 reached its peak on 25th Jun, which was significantly higher than that of T1, T2, and FL and LL (Fig 2). N content in leaves of three treatments was significantly lower than that of the control in August and September, while nitrogen was also tested in three treatments in August, which indicated that nitrogen supplement did not improve the nitrogen content of trees. It can be concluded that the peak of nitrogen demand in late June, and nitrogen fertilizer needs to be applied.

3.3 Variation of P Content in Leaves

Under the condition of drip irrigation, there was a rising period from May to June, reaching the highest content. During the whole flower bud differentiation, the P content of flower bud leaves and leaf bud leaves was significantly lower than that of annual branches leaves, and there was no significant difference between them(Fig 2).

3.4 Variation of K Content in Leaves

During the whole period of flower bud differentiation, the K content of FL and LL decreased, which was significantly higher than that in annual branches (Fig 2). Zhou et al. [11] showed that a certain concentration of K was beneficial to flower bud differentiation. K content of three treatments was significantly higher than that of two controls on 25th May, and K content of T1 was significantly lower than that of other treatments and controls from June to August.

3.5 Variation of Ca Content in Leaves

In the whole process of development, the content of Ca increased. Under the condition of traditional fertilization, the Ca content of annual branches leaves was significantly higher than that of others, and the Ca content of FL and LL was significantly higher than that of drip fertilization leaves before 25th Jul. The content of Ca in FL was significantly lower than that in

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LL on 25th Jul, which was in the stage of inflorescence primordium centralized differentiation (Fig 2). Luo et al. [12] also showed that Ca was related to strawberry inflorescence primordium differentiation. There was no significant difference in Ca between treatment and control.

3.6 Variation of Mg Content in Leaves

In the whole growing season, the content of Mg in the annual branches leaves under the condition of traditional fertilization was significantly higher than that under the condition of drip irrigation (Fig 2).

3.7 Variation of Zn Content in Leaves

In the whole growing season, the content of Zn in the annual branches leaves first decreased and then increased and decreased, reaching the highest value on 25th Aug (Fig 2). The content of Zn in the FL and LL was significantly higher than that in the annual branches leaves on 25th Jun, and the content of Zn in the flower bud leaves was significantly higher than that in the leaf bud leaves, indicating that the high content of Zn is conducive to the initial differentiation, Qiu et al. [13] also believed that the high content of Zn promoted the bud differentiation of vanilla.

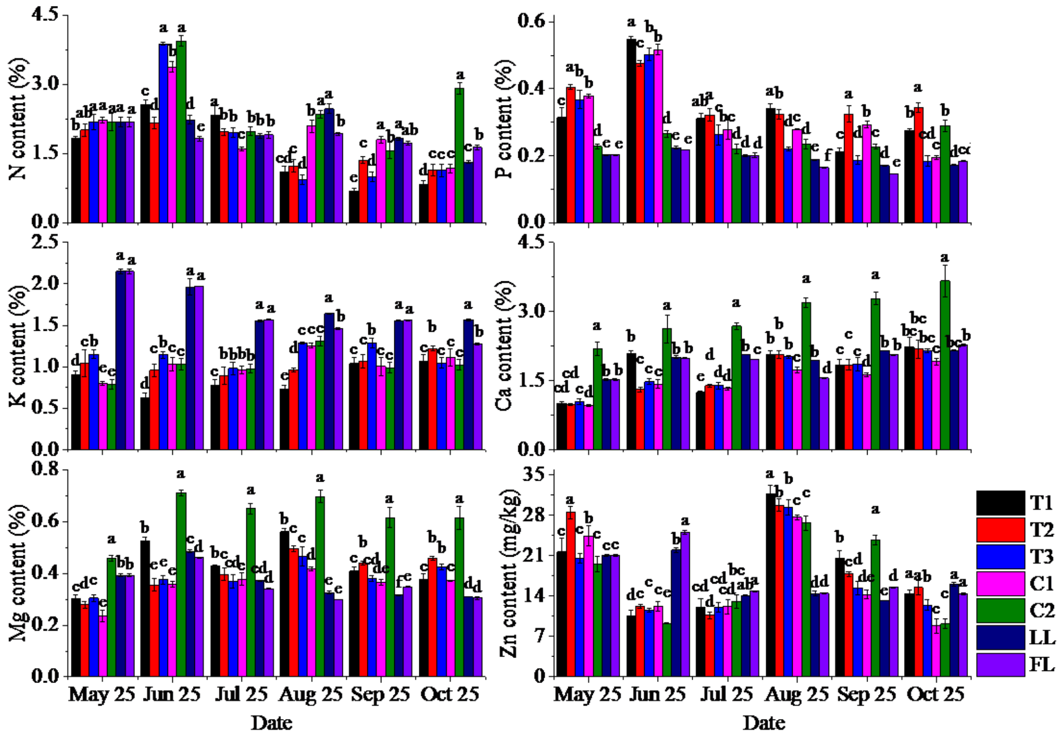

Fig 2: The content of nutrient elements in leaves.

3.8 Effects of Different Drip Irrigation and Fertilization on the Growth of Apple Tree

Under the traditional fertilization, the trunk girth increase, the length of spring shoots and autumn shoots were significantly higher than that of drip irrigation, but the shoot capping rate was significantly lower than that of drip irrigation (TABLE II). Under the condition of drip irrigation, there was no significant difference in the length of autumn shoots between the treatment and the control. The trunk girth increase of T1 was significantly lower than that of T2, T3 and C1. The length of spring shoots of T1 and T2 was significantly lower than that of T3

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and C1, and branch capping rate of the three treatments was significantly higher than that of control 1 (TABLE II).

TABLE II. The effect on the tree growth under the different of fertilization treatments on drip irrigation

Treatment	Trunk girth increase (cm)	Spring shoot length (cm)	Autumn shoot length(cm)	Cap rate (%)
T1	1.7 c	25.8 c	6.8 b	100 a
T2	3.5 b	29.9 c	8.0 b	95.5 ab
T3	3.1 b	37.1 b	10.8 b	94.1 b
C1	4.1 b	36.6 b	11.0 b	85.7 c
C2	6.2 a	62.3 a	20.0 a	74.0 d

Comprehensive analysis, under drip irrigation conditions, the annual fertilization amount with N 5.16~7.74 kg/667m^2, P 0.88~1.32 kg/667m^2 and K 3.22~4.83 kg/667m^2 can provide guarantee for the growth of apple trees. Compared with traditional fertilization, 87.3-91.5% N fertilizer, 96.3-97.5% P fertilizer and 90.6-93.7% K fertilizer were saved.

IV. CONCLUSION

In this study, we observed the process of apple flower bud differentiation, measured the changes in nutrient elements content of annual branches leaves on the basis of different fertilization methods, fertilization periods and fertilization amounts, and measured some growth indicators of apple. The result showed that the peak of N demand in late June, and N application was needed in advance, and the K, Ca and Zn was related with the early stage of flower bud differentiation. The growth of apple tree showed that low controlling fertilizer was beneficial to regulating branch capping.

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