On the loss regularity of water and fertilizer in sandy soil with abundance of underground water but lack of cultivated layer

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Abstract. To explore the loss regularity of water and fertilizer in the ancient course of the Yellow River in cultivation of Chaenomeles sinensis and Prunus armeniaca × sibirica, three water management measures were employed: mulching with plastic films (Wmp), mulching with cornstalk (Wmc) and conventional management (Wck). Meanwhile, the effects of irrigation times, namely slow-release N, P and K fertilizer (NPK SRFs), compound N, P and K fertilizer (NPK CFs), urea fertilizer (Urea Fs), and unfertilized (Fck) were studied. Results showed that the soil water content was effectively increased using Wmp and Wmc, Wmp effectively extended the water retention time and soil temperature stability. After three irrigations, NPK SRFs, NPK CFs and Urea Fs were completely lost. The compound fertilizer had a significantly higher nutrient maintenance capacity than urea. Furthermore, the application of urea had to be balanced to avoid an excessive rise in soil pH. The growth of C. sinensis and P. armeniaca × sibirica was significantly better than traditional model. It is suggested to use crop straw to maintain water levels and improve soil organic matter, and replace urea by applying a compound fertilizer in the early and late growing season in sandy soil.

1. Introduction
The ancient course of the Yellow River stretches for hundreds of kilometers from western to eastern China, and its breadth exceeds 10 kilometers on both sides of the river. Its route passes through Inner Mongolia, Shanxi, Henan and Shandong provinces, and it has a wide range, covers a large area and has considerable influence [1]. The total area is about 903 thousand hm² and contains about 316 thousand hm² of sand area and 45 thousand hm² of sediment area. The soil types are mainly riverbank sand, middle-low yield saline-alkali land and low-lying waterlogged land [1,2]. The soil in this area is sandy and barren, causing water and fertilizer leakage. There are very few tree species in the area, with a low forest coverage and poor biodiversity, and it therefore has a poor environmental carrying capacity and is easily affected by wind erosion. In turn, this leads to a dry topsoil and sandstorms formations in winter and spring. The ancient course of the Yellow River has been listed as a key...
desertification area in China [3-5]. However, in this region the land is soft, broad and flat which makes it convenient for the use of mechanization, and the underground water level is high. Therefore, it will be an important future source of arable land in China with a scarce reserve of soil.

The moisture content in the soil is the primary factor limiting plant growth and development [6]. The inability of ancient course of the Yellow River to retain water and fertilizer leads to insufficient moisture and nutrient contents in the farming layer of the soil, and this has been the main factor restricting agricultural production in this area. A series of important achievements have been made globally in the field of water and fertilizer research. For instance, the quality and yield of the sand cucumber [7] and potato [8] was effectively improved through appropriate integrated measures of irrigation and fertilization. The water retention of sandy soil was also improved by adding other substances [9]. Current research on the ancient course of the Yellow River sand has focused on the ecological benefits of wetlands [10], soil biological characteristics and quality [4,5], controlling wind erosion by planting vegetation [5] etc. In the field of water and fertilizer research, Chen et al [2] studied the effects of different irrigation methods on the Robinia pseudoacacia seeding. Hou et al [11] studied the dynamic effects of orchard grass on the soil fertility of a pear garden. In these studies, the scholars focused on how to improve the effective water content of sandy soil and the effects of single (water or fertilizer) factors on trees in the soil. However, there has been no relevant research on the regularity of water and fertilizer loss in the ancient course of the Yellow River or analogous areas. As a result, it is difficult to devise a precise management strategy for agricultural crops in this area. Combined with the current frequent application of fertilizers and indiscriminate irrigation measures of the soil and underground water pollution [12], secondary salinization [13] has become an urgent agricultural ecological and environmental problems to be solved in this area.

Our previous research [1,14,15] has shown that unlike the site conditions in desert areas, due to the sandy area of the ancient course near the Yellow River, long-term river erosion and multiple road diversions lead to a lack of water in the cultivated layer (0–30 cm) and an abundance of underground water (250–300 cm). It can be reasonably speculated that the trees in this area can grow and develop by forming a large root system after entering the adult stage, using natural precipitation in normal years and deep groundwater in other years, without the need of a large economic investment in the construction of an irrigation system. The critical period for the survival of the trees is the period between one to three years on this sandy land.

In this study, we used a sandy region with middle to low yield saline-alkali land, which is the second largest region of the Yellow River, as the research site to uncover the loss regularity of water and fertilizers. Through the analysis of these regularities, the water and fertilizer management measures of papaya and kernel-apricot were optimized. This work can provide a reference for the other species of fruit trees in the region.

2. Materials and methods

2.1. Location and materials

- Experimental site

The experimental site is in the town of Xiguo, Mengzhou city, Henan province, which is a long-term sample plot of the Non-timber Forestry Research and Development Center, Chinese Academy of Forestry (112°42′51″ E, 34°51′35″ N). This region has a warm temperate climate and is located in the continental monsoon climate. It experiences four distinct seasons. The annual average duration of sunshine and the average temperature are 2160.4 hours and 14.2℃, respectively. The average annual rainfall is 586.9 millimeters with an average annual evaporation of 1599.0 mm. The frost-free period is 209 days. The soil type is the sandy land of the Yellow River and the vertical profiles can be divided into seven layers (figure 1). Within 25 cm of the soil surface, the total nitrogen content of the soil contains is 33 mg kg⁻¹, the hydrolyzed nitrogen content is 48.79 mg kg⁻¹, the available phosphorus content is 4.80 mg kg⁻¹, the available potassium content is 156.62 mg kg⁻¹, the total phosphorus content is 0.05%, the total potassium content is 0.10%, and the organic matter
content is 0.41%. The soil pH value is 8.67, and the underground water level is 250–300 cm. The period from June to August, in this region is the fast-growing period for most non-timber forests such as papaya and apricot. This period exhibits high rainfall and evaporation, alternating occurrence of drought and flood, and obvious soil and fertilizer leakage, which are quite detrimental to crop production.

**Figure 1.** Soil profile in the test area.

- **Plant materials**
  The planting materials were papaya (*Chaenomeles sinensis*) and kernel-apricot (*Prunus armeniaca × sibirica*). The variety of papaya is *C. sinensis cv Jinshuai* (Jinshuai) which has a large golden fruit with middle drought resistance, approved by the Non-timber Forestry Research and Development Center, Chinese Academy of Forestry in 2015. The kernel-apricot variety is *P. armeniaca × sibirica cv Zhongren No. 1* (Zhongren No. 1). It is characterized by a sweet kernel, with a strong drought resistance, and high yield and quality, and was approved by the Non-timber Forestry Research and Development Center, Chinese Academy of Forestry in 2011.

2.2. **Methods**
- **Experimental design of the soil water conservation at different irrigation treatments**
  Three soil irrigation treatments were designed. Treatment Wck (Control check) is a conventional management method, which simulated normal farmland water management measures, with a construction of a furrow at 1 m wide, 25 ~ 30 cm deep, as the daily management of the irrigation and nutrition supply. Treatment Wmp (Mulching with plastic-films) used a black polyethylene film (grass
control) with a thickness of 0.06 mm and a width of 70 cm to lay the soil film along the central line of the nutrient belt, the other conditions were the same as WcK. In the Wmc treatment (Mulching with cornstalk), the maize straw was crushed into 5.0 cm long fragments and was covered with soil in the nutrient zone, the straw layer thickness was 8.0–10.0 cm and was covered with a layer 5.0–8.0 cm thick of soil. The three treatments were fully irrigated to the soil saturated state, and the ventilation windows around the plastic greenhouse were opened after the treatment to keep similar conditions to the field climate. The detection of soil volume water was set layer 5 cm and 20 cm depth, the temperature of the soil at 20cm depth and the air humidity was placed 50 cm above the surface which was measured every 5 days. The measurement time was from June to August in 2014 and 2015, with sunny and windless conditions at 17:00 PM, taking 30 days as the test period. Each treatment was randomly sampled using the 5-point sampling method and repeated 3 times. The total experimental area was about 190 m².

- Experimental design of the soil fertilizer loss at different chemical fertilizers

Four types of fertilizer were set in the plastic greenhouse for the simulation of fertilization. Treatment NPK SRFs is a slow-release N, P and K fertilizer. The fertilizer nutrient content was 50% or more, and the ratio of N: P: K was 30:10:10. It is commercially available, from Hebei. Treatment NPK CFs is a compound of N, P and K fertilizer. The fertilizer nutrient content was greater than or equals to 45%, the ratio of N: P: K was 15:15:15, it is commercially available and produced in Yunnan province. Treatment Urea Fs is a urea fertilizer. The fertilizer nitrogen nutrient content was 46% and it is a commercially available also, produced in Yunnan; Treatment Fck, the control check, did not have any chemical fertilizer applied.

The soil sample were dug according to the cultivation density of 3.0 m × 4.0 m, with a depth and diameter of 20-25 cm. 0.50 kg of the several types of chemical fertilizers were applied to each site. After fertilizing, the soil was fully irrigated to the saturated state. Samples were collected at a depth of 30 cm in the soil at 17:00 PM on the second day after each irrigation, and soil samples were collected randomly using 5-point sampling method for each treatment, with 3 repetitions. The test area had an area of 600 m².

- Preparation of test area and materials

In March 2015 (20 days before the planting of the papaya and kernel apricot) 75 t·hm⁻³ rotting cow dung was applied as the base fertilizer in the land. The papaya and kernel apricots were planted with a density of 3.0 m × 4.0 m, and the cultivation of the tree was conducted according to conventional field management measures. From May 2016, the papaya and apricot kernel with uniform growth were selected as samples, and the management measures were optimized according to the simulated experiment results in this study.

2.3. Data acquisition and analysis

- Determination of soil moisture, soil temperature and air humidity

The soil moisture speed measurement system with soil temperature and air humidity sensors (TZS-3X, Zhejiang Top Instrument Co., Ltd, Hangzhou, China) was adopted.

- Soil nutrient content determination

The soil samples were dried, ground into powder and sifted in preparation of the experiment. The determination of hydrolysis nitrogen (using the alkali hydrolysis diffusion method), available phosphorus (using the sodium bicarbonate extraction - molybdenum antilormetry method), available potassium (using the ammonium acetate extraction - flame photometry), and soil pH value (using the glass electrode method) were measurement at the Institute of Soil, Fertilizer and Water-saving Agriculture, Gansu Academy of Agriculture Sciences.

- Measurement of biomass indexes

In the October 2015 and 2016, the growth of new shoots and crown width were measured by a meter scale, and the diameter of the trunk of the trees at 50 cm above the ground were measured by a circumference scale. Six trees were randomly selected for each treatment and measured in four directions of the crown.
Data processing

The Microsoft excel 2016 software was used for data entry and construction. The DPS (Data Processing System) 7.05 software [16] was used for data processing. The data analyzed using one-way analysis of variance and Duncan's new complex range method was used to analyze the difference between mean values. The significance level was set as 0.05 and 0.01. The Student’s t test was used to compare the two groups.

3. Results

3.1. Effects of three treatments on water retention and agricultural microclimate

Effects of the three treatments on water retention

Irrigation is the most important method to improve the soil water content. This study revealed that different treatment methods led to different abilities to maintain soil water (figure 2A). The soil moisture content at 5 cm underground in treatment Wmp and Wck showed a trend of continuous decrease. While treatment Wmc showed first a decrease, then increase and finally a drop wave form trend (figure 2A). After 15 days of irrigating the Wck treatment the soil moisture content at 5 cm almost approached the drought threshold (4%) and 20 days after it reached to the extent of severe drought (3%). Treatment Wmp can adequately maintain the effective moisture content at a 5 cm depth in the soil, the soil moisture remained at around 8.0% after 15 days of irrigation, and then rapidly declined to the level of severe drought at 4.0% by the 20th day. Wmc effectively extended the soil moisture retention time at 5 cm, the soil moisture content remained at around 10.0% after 15 days. The soil moisture content first increased and then decreased after 20th days. In general, Treatment Wmc had the strongest water-retaining capacity at a 5 cm depth of soil for more than 30 days, followed by Wmp for about 15 days, and Wck was the least effective at about 10 days.

All three treatments showed a trend of continuous decrease in soil moisture content at 20 cm underground, but the rate of decline was different (figure 2B). Treatment Wck showed two obvious peaks for the declining trend of soil moisture content at 20 cm: The water content dropped from 20% to below 10% from the 5th day to the 10th day; The second rapid decline peak occurred from the 20th day to the 30th day, and soil moisture content decreased from 9.0% to about 3.5%. The decreasing trend of water content at the 20 cm soil depth that was treated using treatment Wmp and Wmc was gentle, but the two-time nodes at the 5th day and 25th day after irrigation showed an extremely significant difference ($p < 0.01$) (figure 2B). On the 5th day after irrigation, the soil moisture content at 20 cm treated by Wmc reached 17.0%, significantly higher than the treatment Wmp level of 15% (figure 2B), and the difference between the two treatments was not significant from the 10th day to the 20th day. On the 25th day and 30th day after irrigation, the Wmc soil moisture content was 10.0% and 9.0% respectively, extremely significant difference higher than treatment Wmp ($p < 0.01$). It indicates that Wmc had extremely significant higher soil moisture retention capacity at 20 cm among the three treatments, followed by Wmp, and Wck which was the weakest.
Figure 2. The changes of soil water and temperature at different water treatments. A. The changes of soil water underground 5 centimeters; B. The changes of soil water underground 20 centimeters; C. The changes of soil temperature underground 5 centimeters; D. The changes of air temperature aboveground 0.5 meters. For each column, mean values with different letters are significantly different, lowercase letters show significant difference ($p < 0.05$), capital show highly significant ($p < 0.01$). The same as below.

- Effects of the three treatments on temperature in the soil and air

A suitable soil temperature has a significant positive effect on plant root development, and water has a large specific heat capacity and a strong temperature maintenance ability. In this study, the three irrigation strategies significantly affected the change of soil temperature within 20 cm (figure 2C). On the 15th day and 25th day after irrigation, the effects of three treatments at the 20 cm soil depth temperature were extremely significantly different ($p < 0.01$). The Wmp treatment had the highest temperature (33.1°C, 33.3°C), followed by Wck (29.5°C, 30.6°C) and Wmc which had the lowest temperature (25.9°C, 25.9°C). On the 20th day, Wmp had a peak at 20 cm soil depth with a temperature of 33.6°C, followed by Wck (32.7°C) while Wmc (24.1°C) was significantly ($p < 0.01$) lower than the other two. Overall, treatment Wmc had the least fluctuation in temperature and especially improving the 20 cm soil temperature.

Air temperature directly affects the change of soil temperature. The near surface air temperature fluctuations in Wmp and Wck both showed a "high to low to high to low" bimodal curve, the temperature change range was 40.7°C (25th day) to 24.4°C (15th day). The difference between the two treatments on the first 10 days was not significant, and the difference on the following 20 days was significant ($p < 0.05$) (figure 2D). The Wmc treatment had a stronger ability to maintain air temperature (figure 2D). The changes of near surface air temperature showed a gentle trend with "high to low to high" single curve which ranged between 36.8°C (25th day) and 26.2°C (15th day) (figure
2D). It indicated that straw mulching can significantly reduce the air temperature variation within the range of 0.5 m.

- Effects of rapid nutrient leaching on soil pH

![Figure 3](image.png)

**Figure 3.** The content changes of hydrolyzable nitrogen, phosphate, potash and pH value at different sampling times. A. The loss rule of available nitrogen; B. The loss rule of available phosphorus; C. The loss rule of available potassium. D. The changes of soil pH.

The growth rate of trees is determined by the content of available nutrients during the fast-growth stage. In our study, the available states of N, P and K showed a rapid downward trend with the increase of irrigation, but there were certain differences in different nutrient types (figures 3A-3C). The content of available nitrogen in each treatment after the first irrigation was maintained in the range of 528.1 to 678.5 mg kg⁻¹, which was more than 11 times the control (figure 3A). The nitrogen content of urea was the highest of the three fertilizers, but the level of nitrogen content after the first irrigation was extremely significant difference (p < 0.01) lower than that of the compound fertilizer. It indicated that the available nitrogen maintenance ability of the compound fertilizer was significant (p < 0.05) better than the single nitrogen element. After the second irrigation, the content of available nitrogen in each treatment was maintained in the range of 180.3 to 298.7 mg kg⁻¹, which was more than 4 times the Fck treatment, and the rate of available nitrogen decrease was different in each fertilizer type. The available nitrogen in NPK SRFs decreased by about 74.0%, Urea was down 57.0%, and the NPK CFs descent rate was the slowest, at about 53.6%. Whereas Fck treatment only dropped by about 8.5 % and the difference between treatments was extremely significant difference (p < 0.01). The results showed that the fertilizer applied after the second watering still had a higher fertilizer efficiency and among them NPK SRFs had the strongest release capacity. After the third irrigation, the rate of available nitrogen declines between different treatments all slowed down significantly. The
content of available nitrogen in each treatment was maintained in the range of 130 to 150 mg\cdot kg^{-1}, more than 3 times the Fck treatment, and the difference between the treatments was not significant but still extremely significantly \((p < 0.01)\) higher than the control. It showed that after three events of irrigation, the levels of available nitrogen and nutrients in each treatment were consistent but still maintained a higher level of fertility than the control group. After the fourth irrigation, the content of available nitrogen in each treatment was maintained in the range of 53.9 to 59.4 mg\cdot kg^{-1}. Although it was significantly higher than the Fck treatment (34.8 mg\cdot kg^{-1}), the overall fertility level was the same as that of the foundation fertility level of 48.8 mg\cdot kg^{-1} which was in a lacking state and could not meet the needs of the trees for available nitrogen in the fast-growth period and needed to be supplemented (figure 3A).

In terms of available phosphorus, except urea in itself contains only trace amounts of the phosphate element and is at a low level, the other two treatments showed a decline rule roughly consistent with that of available nitrogen after the first three events of irrigation, and the difference appeared after the fourth irrigation (figure 3B). After the first irrigation, the nutrient level of the two compound fertilizers was maintained at 398.2 to 419.3 mg\cdot kg^{-1} and the difference was not significant. After the second irrigation, the nutrient level rapidly decreased to 117.1 to 232.9 mg\cdot kg^{-1}, and the content between NPK SRFs was extremely significant difference \((p < 0.01)\) lower than NPK CFs. After the third irrigation, the available phosphate in the two combined fertilizers was maintained in the range of 110.4 to 150.2 mg\cdot kg^{-1} and the difference between them was not significant \((p < 0.05)\). After the fourth irrigation, the available phosphate fertilizer in the two combined fertilizers still maintained a higher range of 88.3 to 139.7 mg\cdot kg^{-1}, in which NPK SRFs contained a higher available phosphate fertilizer that extremely significantly higher than that of NPK CFs \((p < 0.01)\). On the one hand, this indicated that the mobility of available phosphorus in sandy soil was weak, and four applications of irrigation can still maintain abundant available phosphorus. On the other hand, it revealed that NPK SRFs had a better sustained release effect on the phosphate fertilizer.

In the case of available potassium, the difference observed between the previous three irrigation events and the potassium fertilizer was the same as that of available phosphorus, and the difference also increased after the fourth irrigation (figure 3C). After the first irrigation, the two types of compound fertilizer were maintained at the level of 905.2 to 1084.9 mg\cdot kg^{-1} and the difference was not significant. After the second irrigation, the available potassium fertilizer of the two types of compound fertilizer maintained an elevated level of 353.2 to 442.8 mg\cdot kg^{-1}, but NPK SRFs treatment was significantly \((p < 0.05)\) higher than NPK CFs. After the third irrigation, the rate of rapid decline of available potassium of the two combined fertilizers was significantly reduced and it still maintained at an elevated level of 276.2 to 360.9 mg\cdot kg^{-1} and there was no significant difference. However, this is different for rapidly available phosphorus. The content of rapidly available phosphorus in NPK CFs treatment was significantly lower than that of treatment NPK SRFs after the fourth irrigation, but remained in the range of medium and superior fertility between 74.9 and 144.5 mg\cdot kg^{-1}. This indicated that treatment NPK SRFs had a strong capability of available phosphorus retention.

Different fertilizer types led to the fluctuation of soil pH value but were less affected by irrigation times (figure 3D). Applying Urea Fs for topdressing increased the soil pH in the ancient course of the Yellow River, while treatment NPK SRFs decreased the soil pH (figure 3D). After the first irrigation, the application of Urea Fs significantly increased the soil pH value from 8.67 to 9.17, while the combined fertilizer reduced the soil pH value among which NPK SRFs had the most significant effect which decreased from 8.67 to 8.19. After the second irrigation, the effect of the different treatments on soil pH value showed a similar trend to the first irrigation, and there was no significant difference between their changes. After the third irrigation, treatment NPK CFs caused a significant decrease in soil pH value (7.81), but there was no significant difference compared to Fck (8.23), and no significant change in soil pH value between the other two treatments compared to the second irrigation. After the fourth irrigation, although all treatments showed a downward trend compared with the first irrigation, they were kept in the alkaline range from 7.9 to 8.7. There was a remarkable fact that urea caused the significant increase of soil pH in treatment Fs compared with Fck but there was no significant
difference ($p < 0.05$) between Fs and Fck in the other two treatments.

- Improved method of field management based on the loss regularity of water and fertilizer in papaya and apricot

The appropriate soil nutrient and moisture content played a key role in obtaining a higher economic income. Nitrogen fertilizer could be significant in promoting plant growth and development, especially for nutrient growth [13,17,18], meanwhile, the elements phosphorus and potassium are important guarantees in promoting the balanced development of above and underground sections of plants [15]. A suitable degree of drought can significantly improve plant root development [1], quality and yield [17,19]. The balance of soil water and nutrient content determines the growth and development of plants and is especially important in the juvenile stage of plants [18]. Currently, the juvenile stage management of papaya and apricot kernels had been affected by traditional concepts. The heavy application of nitrogen fertilizer and light application of compound fertilizer together with frequent irrigation resulted in serious nutrient loss (table 1) and caused the low efficiency of fertilizer utilization. It was not conducive to plant growth and had destroyed the soil ecological balance. In view of these problems, based on the research results of the water and fertilizer loss rule of sand in this paper and the existing management methods of papaya and apricot kernel in the field, we have developed new management methods of papaya and apricot in its juvenile stage (table 1).

**Table 1. Methods of traditional and improved management between C. sinensis and P. armeniaca × sibirica.**

| Plant types | Traditional management (CK) | Improved management (Treatments) |
|-------------|-----------------------------|----------------------------------|
| ‘Jinshuai’  | TM-CSCK: From May to September, irrigated every 20 days. In combination with watering, urea was applied once every month from May to August. In September, NPK CFs fertilizer was applied at 100 g each time. Fertilize five times in total. Appropriately delay watering if there was rainfall during the period. | IM-CS: From May to September, cover the soil surface with straw and irrigate it every 30 days. In combination with watering, NPK CFs fertilizer was applied at 150 g for each tree in the early May. In middle of July, applied urea 150g for each tree. Suspended fertilization in August and 150g of NPK CFs compound was applied to each plant from late September to early October. Fertilize three times in total. Appropriately delay watering if there was rainfall during the period. |
| ‘Zhongren No.1’ | TM-PSCK: From May to September, irrigated every 30 days. In combination with watering, urea was applied once every month from May to August. NPK CFs fertilizer was applied at 100 g each time in the middle of September. Fertilize four times in total. Appropriately delay watering if there was rainfall during the period. | IM-PS: From May to September, cover the soil surface with straw and irrigate it every 40 days. In combination with watering, NPK CFs fertilizer was applied at 150 g for each tree in the early May. In middle of July, applied urea 150g for each tree. Suspended fertilization in August and 150g of NPK CFs compound was applied to each plant from late September to early October. Fertilize three times in total. Appropriately delay watering if there was rainfall during the period. |

When exploring the regularity of water and fertilizer loss in the ancient course of the Yellow River, we reduced the irrigation frequency 1 to 2 times and increased the fertilizer amount by 50 g each time. It was proven by two consecutive years of measurement that the length, ground diameter and crown width of papaya increased by 86.1%, 42.2% and 50.0% respectively compared with the control and kernel-apricot increased by 37.5%, 54.5% and 72.7% respectively. The growth rates were extremely significantly ($p < 0.01$) higher than the traditional cultivation method (table 2). Our improved water and fertilizer management reduced the erosion of fertilizer by irrigation, reduced labor intensity and economic input (labor use decreases by 1 or 2 person-times, 80 RMB·d$^{-1}$ per person, average price of fertilizer is 1,500 RMB·t$^{-1}$) simultaneously. Therefore, their comprehensive benefits were better than traditional method.
4. Discussions

In the long-term of evolution, plants have formed the ability to adjust their behavior systematically according to environmental changes as well as, initiating different physiological and biochemical stress responses to guarantee its growth and development [20]. Soil moisture, nutrients [21] and the pH value are direct impact factors on plant growth and development of the most important series of soil environmental factors. Suitable water and fertilizer conditions can not only satisfy the growth and development of plants [18] and obtain higher economic benefits [22] but could also reduce the load on the ecological environment. Especially for sandy soil, a reasonable decrease in irrigation times can maintain the same crop yield meanwhile reducing water leakage and nutrient leaching significantly, Its economic benefit is optimal.

Crop straws, such as corn straws and wheat straws, show the rejection of water due to their smooth surface or attached lipids. However, with the accelerated process of biological fermentation, hydrophobic substances are degraded and the ability of absorbing water is gradually improved, making it an ideal natural water-retaining material. Wu et al. ’s study found that after 6 months of being buried (0.5 m underground), the soil water retention capacity of straw could be significantly improved [23]. The difference between this study and Wu et al. was that we covered the top of the plants’ roots with corn stalks. Because the sand soil surface exposure can be more than 45°C after in summer, but the optimum temperature for an apricot root system to develop is 15°C to 25°C [24]. Maize straw can isolate heat and prevent rapid evaporation of underground water, simultaneously, the heat of biological fermentation can be used in the morning and evening to form a higher temperature difference with the atmosphere, which promotes condensation of moisture in the air. As a result, the soil moisture content remained around 10.0% after 15 days of irrigation, and the soil moisture content increased at a 5 cm depth after 20 days due to the dew gathered, 30 days after the irrigation, the soil moisture content remained around 8%. Although the water retention performance of corn stalk is weaker than that of a water retention agent such as sewage sludge, biochar etc. [23], but as microbial activity accelerates, its advantages of water retention and low cost will expand. At the same time, the application of maize straw significantly improves the physical structure and exhibits characteristics of increasing the soil capacity of sandy soil [25] which is worth promoting and applying in production. Non-timber forestry such as papaya and apricot have a strong main root system. During the period of 1 year after transplantation, the above-ground section developed slowly, and the main roots of the underground section grew rapidly and vertically, reaching a depth more than 2 m, but its lateral roots were mainly distributed in the 20 to 30 cm tillage layer, which was the main layer that absorbed water and fertilizer. Crops such as cucumber [7], potato [8,21], etc. growing on sand are usually inferior in developing main roots, and their roots are relatively shallow in the soil concentration distribution so that they must rely on external water and nutrients to meet their own needs and complete the life cycle. But papaya and apricots can use strong root absorption and natural rainfall to complete their own growth and development as soon as they surpass their juvenile stage. A high biomass accumulation can be achieved without the investment on constructing a large integrated water and fertilizer infrastructure. It has high practical value for the ancient course of the Yellow River, which has poor infrastructure and a high groundwater level.

Table 2. Effect of improved management for biomass between C. sinensis and P. armeniaca × sibirica.

| Plant types | Treatments | Length of shoots / cm | Range of variation / % | Ground diameter / cm | Range of variation / % | Crown breadth / m | Range of variation / % |
|-------------|------------|-----------------------|-----------------------|---------------------|-----------------------|-------------------|-----------------------|
| ‘Jinshuai’  | IM-CS      | 80.2±5.3A             | ↑ 86.1±11.9           | 6.4±1.9A            | ↑ 42.2±5.5            | 1.8±0.2A          | ↑ 50.0±6.3          |
|             | TM-CSCK    | 43.1±2.5B             |                       | 4.5±0.7B            |                       | 1.2±0.5B          |                       |
| ‘Zhongren’  | IM-PS      | 63.1±3.2A             | ↑ 37.5±3.8            | 8.5±0.9A            | ↑ 54.5±4.7            | 3.8±0.5A          | ↑ 72.7±9.1          |
| No. 1’      | TM-PSCK    | 45.9±2.1B             |                       | 5.5±0.5B            |                       | 2.2±0.5B          |                       |
5. Conclusions
In the ancient course of the Yellow River, the treatment including maize straw with a thickness of 5 cm and covered with soil thickness 8 to 10 cm on the soil surface layer can not only efficiently extend the effective water retention time of soil at a depth of 5 cm and 20 cm but also maintain a constant soil temperature. The compound fertilizer applied in this area had a higher nutrient retention capacity than urea. The application of available nitrogenous fertilizer, phosphorus or potassium need be supplemented after 3 irrigation events. It should be noted that the nitrogen fertilizer should be applied as evenly as possible to avoid the high local soil pH cause the decay of the root system. For papaya, kernel-apricot and other fruit trees it is suggested to use a crop straw cover on the ground to increase soil effective water content and duration. According to the regularity of the tree’s needs, using a compound fertilizer to replace urea in the early and late growing season of their juvenile stage, the economic benefits can be maximized.

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References
[1] Xu M S, Zhao H, Zhou X X, Wuyun T N, Li F D and Zhu G P 2016 Responses of photosynthetic physiology and biomass accumulation of sweet kernel apricot (Prunus armeniaca × sibirica) seedling to soil drought stress in the ancient course of the middle Yellow River Taiwan J. Forest. Sci. 31 271-84
[2] Tian Y, Li Y G and Jiang H 2010 On the regional ecological planning of the ancient yellow river course in Shangqiu City J. Landsc. Res. 2 35-9
[3] Chen J P, Lan Z P, Yang S J, Zhang X P, Sun S W and Wu P J 2015 Water use efficiency and plantation forest under different irrigation methods in old course of the Yellow River area Acta Ecol. Sin. 35 252-256
[4] Zhu X Y, Hu Y C and Lu J 2014 Evaluation on soil biological characteristics and quality of the wetlands in ancient bed of the Yellow River of east He’nan province Res. Soil Water Conserv. 21 27-32
[5] Liu J S, Wang R Q, Dai J L, Zhang Y L and Wang Q 2008 Soil environmental background concentrations in old course of the Yellow River in Shandong province Environ. Sci. 29 1699-705
[6] Yu X N, Huang Y M, Li E G, Li X Y and Guo W H 2018 Effects of rainfall and vegetation to soil water input and output processes in the Mu Us sandy land, northwest China Catena 161 96-103
[7] Yang J H, Yan F, Sun L L, Zhou X T, Hu X H and Zou Z R 2014 Effects of different water-fertilizer combinations on yield and quality of greenhouse cucumber cultivated in sand J. Northeast Agricult. Forest. Univ. 42 111-8
[8] Feng Z W, Kang Y H, Wan S Q and Liu S P 2017 Effect of drip fertigation levels on potato growth and the water and fertilizer efficiency on sandy soil in Inner Mongolia Agricul. Res. Arid Area 35 242-9
[9] Machekposhti M F, Pla C and Valdes-Abellan J 2018 Improving hydraulic properties of sandy soil with lime powder addition Eur. Geosci. Union 20 12195
[10] Li H, Dong Z, Li Y Q and Cui G S 2007 Research on effect of wind erosion control after planting grasses in wind-sand region of the Yellow River old riverway Chinese J. Grassl. 29 61-5
[11] Hou Q C, Mei S W and Tang L L 2009 Analysis of soil fertility variability in pear orchards in the old course of the Yellow River area Jiangsu Agricul. Sci. 12 329-30
[12] Liu R, Kang Y, Zhang C, Pei L, Wan S Q, Jiang S F, Liu S P, Ren Z Y and Yang Y 2014 Chemical fertilizer pollution control using drip fertigation for conservation of water quality
in Danjiangkou Reservoir *Nutr. Cycl. Agroeco.* **98** 295-307

[13] Li S, Tian Y H, Wu K, Ye Y F, Yu J P, Zhang J Q, Liu Q, Hu M Y, Li H, Tong Y P, Harberd N P and Fu X D 2018 Modulating plant growth–metabolism coordination for sustainable agriculture *Nature* **560** 595-600

[14] Xu M S, Zhu G P, Fu G Q, Zhou X X, Zhao H, Wuyun T N and Li F D 2017 Effects of N, P and K deficiency on growth and nutrient uptake of *Prunus armeniaca* seedlings *J. Northeast Agr. Forest. Univ.* **45** 81-90

[15] Xu M S 2016 The physiological role of N, P, K in sweet kernel apricot leaf during transition from juvenile stage to adult (Beijing: Chinese Academy of Forestry)

[16] Tang Q Y and Zhang C X 2013 Data Processing System (DPS) software with experimental design, statistical analysis and data mining developed for use in entomological research *Insect Sci.* **20** 254-60

[17] Zhou Z J, Plauborg F, Liu F L, Kristian K and Andersen M N 2018 Yield and crop growth of table potato affected by different split-N fertigation regimes in sandy soil *Eur. J. Agric.* **92** 41-50

[18] Yin C, Palmroth S, Pang X, Tang B, Liu Q and Oren R 2018 Differential responses of *Picea asperata* and *Betula albosinensis* to nitrogen supply imposed by water availability *Tree Physiol.* **38** 1694-1705

[19] Cantore V, Wassar F, Yamaç S S, Sellami M H, Albrizio R, Stellacci A M and Todorovic M 2014 Yield and water use efficiency of early potato grown under different irrigation regimes *Int. J. Plant Prod.* **8** 409-28

[20] Xu W Z, Zhu L X and Zhao G 2006 Application of plant ecological adaptability in hydroponics *Subtrop. Plant Sci.* **35** 28-32

[21] Badra M A, El-Tohamy W A and Zaghloul A M 2012 Yield and water use efficiency of potato grown under different irrigation and nitrogen levels in an arid region *Agric. Water Manag.* **110** 9-15

[22] Zhang F, Yue G, Jiao W and Wenhui H U 2017 Effects of water and fertilizer supply on growth, water and nutrient use efficiencies of potato in sandy soil of Yulin area *Chinese Soc. Agric. Machinery* **48** 270-8

[23] Wu C F, Wen Q, Han Y L, Wang Q, Jiang Y and Li P 2017 Effect of water retaining agent and strawapplications on water and fertilizer status and wheat yield in sandy Chao soil *Chinese J. Soil Sci.* **48** 692-700

[24] Li F D, Wuyun T N and Zhu G P 2018 *Cultivation Operative Technology of Kernel-Apricot* (Beijing: Chinese Forest Press)

[25] Głąb T, Żabiński A, Sadowska U, Gondek K, Kopeć M, Mierzwa–Hersztek M and Tabor S 2018 Effects of co-composted maize, sewage sludge, and biochar mixtures on hydrological and physical qualities of sandy soil *Geoderma* **31** 27-35