Research Article

Shenglan Ye*, Tiancheng Liu, Yan Niu

Effects of organic fertilizer on water use, photosynthetic characteristics, and fruit quality of pear jujube in northern Shaanxi

https://doi.org/10.1515/chem-2020-0060
received April 28, 2019; accepted April 1, 2020

Abstract: This experiment is based on the 7-year-old dwarf and densely planted pear jujube in northern Shaanxi. The effects of applying organic fertilizer on water use, photosynthetic characteristics, and fruit quality of pear jujube are studied. The test has been carried out for two consecutive years. The results showed that fertilization treatments could promote soil moisture retention and utilization. Compared with the control (CK) in 2011, the average soil water content (SWC) of soybean cake fertilizer (SC) and sheep manure (SM) increased by 3.69 and 3.18 percentage points, respectively. The effect of SC on chlorophyll content was most significant. Fertilization can effectively improve the canopy structure of pear jujube. The transmittance of SC and SM decreased by 20.20% and 17.38%, respectively, in 2012. The gap scores were opposite to the leaf area index (LAI). Continuous application of organic fertilizer can significantly increase the net photosynthetic rate and stomatal conductance of pear jujube. The instantaneous water use efficiency of chemical fertilizer (CF), SC, SM, and biogas fertilizer (BM) increased by 0.44, 1.33, 0.96, and 0.61 percentage points, respectively. Organic fertilizer effectively increased the fruit setting rate, yield, and quality of fruits. After fertilization for two consecutive years, the quality of pear jujube fruit improved significantly. It indicated that long-term fertilization could effectively promote the growth and development, increase yield, and significantly improve the fruit quality of pear jujube in the loess hilly region of northern Shaanxi. The effect of soybean cake fertilizer was the most significant.

Keywords: pear jujube, soybean cake fertilizer, water use efficiency

1 Introduction

Pear jujube (Ziziphus jujuba Mill.) is a plant, which belongs to Rhamnaceae family. Pear jujube is a valuable variety of jujube fresh food. It has rich nutritional value. Jujube is resistant to drought and sorghum. It has strong adaptability to soil. It is resistant to barrenness, salt, and alkali. In the hilly and gully regions of the Loess Plateau in northern Shaanxi, the large number of pear jujube planted can not only green the barren hills, maintain water and soil, improve the ecological environment, but also increase the farmers’ economic income. Therefore, pear jujube has become the main fruit tree as returning farmland to forest and economic forest in northern Shaanxi [1]. Due to the climatic conditions of northern Shaanxi, the jujube is evenly colored, beautiful in appearance, and high in quality and commodity value. The pear jujube is obviously superior to the origin or other jujube areas. A good water and fertilizer environment can guarantee the long-term sustainable development of mountain jujube forest. However, chemical fertilizer is used to supply fertility for pear jujube, pesticide control pests and diseases in north Shaanxi. This will bring serious environmental pollution and affect the soil structure and the nutritional quality of pear jujube [2,3]. The organic fertilizer can improve soil fertility, provide comprehensive nutrition for long-term crops, improve soil physical and chemical properties, enhance soil water storage capacity, and improve crop quality [4–9]. Studies have
shown that organic fertilizer can improve soil moisture content and improve crop water use efficiency [10,11]. The application of organic fertilizer can improve the variety of the fruit, including increasing the sweetness, hardness, and vitamin content of the fruit [12,13]. Wu [14] found that organic fertilizer can promote the growth, yield, and quality of the upper part of the Huangguan pear. The research by Wang et al. [15] showed that the organic fertilizer can significantly increase the content of available nitrogen, phosphorus, potassium, and organic matter in the soil of peach forest and increase the porosity of soil capillary. The content of chlorophyll a was significantly increased in peach leaves. Wang et al. [16] also showed that organic fertilizer can improve the net photosynthetic rate and water use efficiency of jujube leaves. At present, there are few reports on the effects of organic fertilizer application on the growth, photosynthetic physiological characteristics, and water use of pear jujube in the hilly and gully regions of the Loess Plateau. Therefore, this study takes the pear jujube in the loess hilly region as the research object. The study site is a horizontal terrace on the slope. The soil water and fertilizer and other factors along the contour line are basically the same. The test area is 300 m². The planting density is 2 m × 3 m. Fertilization treatments were set under drip irrigation conditions: (1) control (CK): no fertilization; (2) conventional chemical fertilizer (CF): urea application (N 46%) 0.48 kg/plant, superphosphate (P2O5 12%) 1.35 kg/plant, potassium sulfate (K2O 50%) 0.61 kg/plant [19]; (3) fermented and decomposed soybean cake fertilizer (SC): 5 kg/plant; (4) decomposed sheep manure (SM): 15 kg/plant; (5) biogas fertilizer (BM): 100 kg/plant. The amount of fertilizer applied is calculated based on the content of nutrients in the organic fertilizer and the amount of chemical fertilizer. Individual plants are treated as one treatment. Set five repetitions per process. Fertilization method: centering on the tree pole, the annular groove is dug in the outer edge of the canopy vertical projection. The groove is 30 cm wide and the groove is 45 cm deep. Mix the fertilizer with the soil and fill it into the ditch (10–45 cm). Soybean cake is oil residue. It was sealed and fermented for 35 days under the condition of relative humidity reaching 70%, which is the decomposed soybean cake fertilizer. BM is a mixture of biogas slurry and biogas residue fermented by biogas. SM is a mixture of pulverized straw and sheep manure buried in a puddle and subjected to microbial anaerobic fermentation. The nutrient content of each organic fertilizer is shown in Table 1.

2.2 Test design

The 7-year-old mountain dwarf densely planted pear jujube with uniform tree body and good growth was selected as the research object. The study site is a horizontal terrace on the slope. The soil water and fertilizer and other factors along the contour line are basically the same. The test area is 300 m². The planting density is 2 m × 3 m. Fertilization treatments were set under drip irrigation conditions: (1) control (CK): no fertilization; (2) conventional chemical fertilizer (CF): urea application (N 46%) 0.48 kg/plant, superphosphate (P2O5 12%) 1.35 kg/plant, potassium sulfate (K2O 50%) 0.61 kg/plant [19]; (3) fermented and decomposed soybean cake fertilizer (SC): 5 kg/plant; (4) decomposed sheep manure (SM): 15 kg/plant; (5) biogas fertilizer (BM): 100 kg/plant. The amount of fertilizer applied is calculated based on the content of nutrients in the organic fertilizer and the amount of chemical fertilizer. Individual plants are treated as one treatment. Set five repetitions per process. Fertilization method: centering on the tree pole, the annular groove is dug in the outer edge of the canopy vertical projection. The groove is 30 cm wide and the groove is 45 cm deep. Mix the fertilizer with the soil and fill it into the ditch (10–45 cm). Soybean cake is oil residue. It was sealed and fermented for 35 days under the condition of relative humidity reaching 70%, which is the decomposed soybean cake fertilizer. BM is a mixture of biogas slurry and biogas residue fermented by biogas. SM is a mixture of pulverized straw and sheep manure buried in a puddle and subjected to microbial anaerobic fermentation. The nutrient content of each organic fertilizer is shown in Table 1.

2.3 Measurement items and methods

Organic fertilizer is applied at the beginning of April 10 each year. On May 31, June 6, June 14, June 22, and July 1, take the fixed eight-point bearing branch in different directions of jujube trees. The number of flowers and fruits was recorded in the flowering and fruiting stages, respectively. Fruit set rate = number of fruits/number of flowers × 100%.
Each jujube hang is fixed to select the fifth leaf at the top. Chlorophyll content, photosynthetic index, canopy index, and soil water content (SWC) were measured in June 15.

Yield: after the fruit is mature, the single-receipt method is adopted. Every time the fruit is picked, it is recorded until the fruit picking is completed. Calculate individual yield and convert to total yield. Mature fruits were collected for quality determination.

SWC [20]: the soil was taken by conventional soil drilling. The sampling location was 30 cm from the tree. The measured depth was 0–100 cm soil layer. The sampling interval was 20 cm. The soil samples were baked to constant weight at 105 ± 2°C to calculate the moisture content.

The chlorophyll content was determined by the acetone method [21]. The photosynthesis index was measured by LI-6400 portable photosynthetic analyzer. The instantaneous water use efficiency (WUEp) was calculated by the leaf net photosynthetic rate (Pn)/transpiration rate (Tr).

The canopy index was determined by WinsCanopy2005a canopy analysis, including leaf area index, gap fraction (GFR), total radiant flux on the canopy, and total radiant flux under the canopy. Canopy light interception density = average photosynthetically active radiation density above the canopy – average total photosynthetically active radiation density below the canopy [22].

Soluble solids (TSS) were measured using a 2WAJ-Abbe refractometer. The titratable acid (TA) was titrated by 0.1 mol/l NaOH standard solution [23]. Reduced vitamin C was titrated with 2,6-dichlorophenol [24]. The total flavonoid content was determined by NaNO3–Al(NO3)3 spectrophotometry [25].

The test data were statistically analyzed using Microsoft Excel 2003 and DPS 7.05 software.

Ethical approval: The conducted research is not related to human or animal use.

3 Results and analysis

3.1 Effects of different organic fertilizers on water use of pear jujube during flowering and fruiting period

3.1.1 Effect of different organic fertilizers on SWC of flowering and fruiting period of pear Jujube

The SWC of each treatment in different years increases rapidly with the depth of the soil layer and then tends to be slow in Figure 1. The SWC of organic fertilizer treatment is significantly higher than CF and CK. The

![Figure 1: Effects of different fertilizer treatments on SWC.](image-url)
moisture change of SC and SM is most significant. The reason is that the organic fertilizer can make the soil absorb a large amount of water and prevent the infiltration of water. In 2011, the average SWC of SC, SM, BM, and CF increase by 3.69, 3.18, 1.11, and 0.40 percentage points, respectively, compared with CK (9.37%). The SWC in 2012 is significantly higher than in 2011. On the one hand, it is due to external factors such as rainfall; on the other hand, the organic fertilizer is conducive to increasing the water content of the soil. The increase of SC is the largest, and the difference is significant compared with CK (probability $P < 0.05$).

### 3.1.2 Effects of different organic fertilizers on leaf water content of flowering and fruiting period of pear jujube

Pear jujube maintains a high leaf water content (RWC) which plays an important role in seating fruit and photosynthesis of pear jujube. Figure 2 shows that RWC of organic fertilizer treatment is higher than CK and CF in 2012. This may be because long-term application of organic fertilizer can improve soil moisture and protect the water requirements of plant leaves. On June 12, RWC decreased slightly. And the downward trend in the second year of fertilization has slowed down significantly. This may be due to the fact that the jujube tree enters the fruiting period in mid-June and requires a lot of water. Application of organic fertilizer can increase the RWC of pear jujube leaves. It can supply the water needed for flowering to the fruiting period then slowed down the trend of moisture. The RWC of each treated reached the highest in July 1. RWC of BM, SM, and SC are 94.20%, 92.40%, and 91.47% in 2011. They are significantly different from CK ($P < 0.05$). Therefore, application of organic fertilizer can increase the RWC of the pear jujube. RWC of BM, SM, and SC is increased by 4.52, 2.72, and 1.79 percentage points, respectively, compared with CF. The RWC gap between treatments decreased after 2 years of application of organic fertilizer. Among them, the change of SC is the most obvious.

### 3.2 Effects of different organic fertilizers on photosynthetic effects of flowering and fruiting stage of pear jujube

#### 3.2.1 Effects of different organic fertilizers on the chlorophyll content of pear jujube flowering fruit

The content of chlorophyll affects the absorption and conversion of light energy. The ratio of chlorophyll $a$ to chlorophyll $b$ (chl $a/b$) can reflect the photosynthetic activity of the leaves and the amount of light energy utilization by plants [26]. The photosynthetic performance of pear jujube directly affects the supply of nutrients required for flowering fruit of pear jujube. It is of great significance to the final production. Figure 3 shows that the total chlorophyll content of fertilization treatment is significantly higher than CK. In 2011, the total chlorophyll content of CF, SC, SM, and BM increased by 22.86%, 26.73%, 39.31%, and 43.01%, respectively, compared with CK. The organic fertilizer can significantly increase the content of chlorophyll $a$ in plants. The chlorophyll $b$ content was consistent with the total content. However, the chlorophyll content of

![Figure 2: Effects of different fertilizer treatments on the relative leaf water content of pear jujube.](image-url)
each organic fertilizer treatment was not significant. Figure 3 shows that the CK-treated chl $a/b$ is the highest, and the BM, SC, and CF are significantly smaller than CK. It may be that the effect of BM, SC, and CF treatment on chlorophyll $b$ synthesis is greater than that of chlorophyll $a$, which significantly increases the absorption of blue-green light and enhances the photosynthetic activity of leaves. Among them, the effect of SC treatment on chlorophyll content in 2012 was the most significant. Total chlorophyll was 10.72 mg/dm$^2$ and Chl $a/b$ only was 3.16.

3.2.2 Effects of different organic fertilizers on canopy structure and canopy optical properties of pear jujube flowering

Table 2 shows that the canopy structure of fertilization in the flowering and fruiting period has been found to be significantly changed for two consecutive years. Canopy photosynthetically active radiation is the most important indicator for evaluating canopy transmittance and light interception ability. The canopy light interception density of different treatments was significantly higher than CK. The canopy transmittance was consistent in 2011 and 2012. In 2012, the light transmittance of each treatment reduced by 25.17%, 20.20%, 17.38%, and 8.16%, respectively. Fertilization treatments were significantly different from CK ($P < 0.05$). However, the difference in organic fertilizer treatment was not significant. The LAI of pear jujube after fertilization for 2 years was significantly higher than CK. In 2012, the SC is increased by 31.49% compared with CK. The gap scores of different treatments were opposite to those of LAI. The canopy structure of pear jujube changed significantly after application of organic fertilizer for 2 years. This change is more conducive to photosynthesis of pear jujube. It provides adequate nutritional support for fruit setting.

Table 2: Effects of different fertilizer treatments on canopy characteristics of pear jujube

| Year | Treatment | Transmittance (%) | Gap fraction (%) | The density of light (%) | LAI |
|------|-----------|------------------|-----------------|-------------------------|-----|
|      |           |                  |                 |                         |     |
| 2011 | CK        | 27.53 ± 2.04 a   | 27.41 ± 1.44 a  | 33.06 ± 1.57 c          | 1.74 ± 0.17 c |
|      | CF        | 25.15 ± 1.35 ab  | 24.91 ± 1.03 b  | 36.87 ± 2.06 ab         | 2.01 ± 0.21 b |
|      | SC        | 23.46 ± 1.07 bc  | 27.49 ± 1.62 a  | 35.98 ± 1.95 b          | 1.96 ± 0.15 b |
|      | SM        | 21.58 ± 1.28 c   | 24.97 ± 1.53 b  | 35.69 ± 1.38 b          | 2.02 ± 0.11 b |
|      | BM        | 18.13 ± 0.97 d   | 21.64 ± 1.02 c  | 38.06 ± 2.00 a          | 2.17 ± 0.09 a |
| 2012 | CK        | 26.34 ± 1.47 a   | 26.55 ± 1.04 a  | 34.45 ± 1.53 b          | 1.81 ± 0.10 c |
|      | CF        | 24.19 ± 1.58 b   | 23.72 ± 1.11 b  | 36.71 ± 1.53 ab         | 2.22 ± 0.07 b |
|      | SC        | 21.76 ± 1.33 c   | 25.31 ± 2.03 ab | 37.26 ± 1.53 a          | 2.38 ± 0.09 ab|
|      | SM        | 21.02 ± 1.08 c   | 23.89 ± 1.47 b  | 37.08 ± 1.53 a          | 2.31 ± 0.11 b |
|      | BM        | 19.71 ± 1.85 c   | 21.77 ± 1.16 c  | 37.98 ± 1.53 a          | 2.57 ± 0.08 a |

Note: Values followed by different letters in a column are significant among treatment at the 5% level. The two treatments have the same letter to indicate that the difference is not significant, and the different letters indicate significant differences. It was the same as below.
3.2.3 Effects of different organic fertilizers on photosynthetic characteristics and leaf water use efficiency of flowering and fruiting period of pear jujube

It can be seen from Table 3 that application of organic fertilizer can significantly increase the net photosynthetic rate (Pn) and stomatal conductance (Gs) of pear jujube. In 2011, BM processed the highest Pn and Gs. In 2012, the Pn of SC reached the maximum. The intercellular CO₂ concentration (Ci) of fertilization was less than CK. The Ci for each fertilization treatment decreased in 2012 compared with 2011. The concentration of Ci treated by SC was the largest. Transpiration and photosynthesis are regulated by many factors. Stomatal transpiration was the main mode of transpiration [27]. In 2012, the Tr of BM reached a maximum. This may be related to a higher LAI. The application of organic fertilizer can effectively improve the instantaneous water use efficiency of pear jujube. The effect is more significant after continuous fertilization. In 2012, the instantaneous water use efficiency of SC treatment was the highest. The instantaneous water use efficiency (WUEp) of CF, SC, SM, and BM increased by 0.44, 1.33, 0.96, and 0.61, respectively, percentage points compared with CK. Fertilization treatment was significantly different from CK (P < 0.05). The WUEp of leaves with SC, SM, and BM was higher than CF. They were increased by 0.89, 0.52, and 0.17 percentage points, respectively.

3.3 Effects of different organic fertilizers on reproductive growth of pear

Table 4 shows that the total number of flowers of SC, SM, and BM increased by 73.1%, 26.9%, and 39.1%, respectively, in 2012. The yield per plant was increased by 195.8%, 102.7%, and 152.0%, respectively, compared with CK. In 2012, fruit setting rate of BM and SC have increased by 2.17 and 1.90 percentage points, respectively. The difference was not significant. The yield of different fertilization treatments was significantly higher than CK. The different organic fertilizers have different effects on the reproductive growth of pear jujube. Based on the above indicators, SC has the most significant effect on the reproductive growth of pear jujube.

3.4 Effects of different organic fertilizers on the nutritional quality of pear jujube

Table 5 shows that each fertilization treatment can significantly improve the quality of pear jujube fruits. The water content of fruit (FWC) of SM in 2011 was slightly lower than CK. The FWC was higher than CK after continuing fertilization. The FWC of SC and BM increased by 9.54 and 8.87 percentage points, respectively, compared with CK; TA of SC is 0.28 percentage points lower than CK. The indexes of soluble solids (TSS), solid acid ratio (TSS/TA), vitamin c (Vc), and total flavonoids were higher than CK. The Vc and total flavonoid content of SC are increased by 82.6% and 45.6% than CK. The application of organic fertilizer significantly improved the quality indicators of pear jujube. After applying organic fertilizer for two consecutive years, the quality of pear jujube fruit is better.

4 Discussions

The jujube flowering and fruiting period lasts longer. The vegetative and reproductive growth are coexisting in

Table 3: Effects of different organic fertilizers on photosynthetic characters of pear jujube

| Year | Treatment | Pn [µmol/(m² s)] | Gs [mmol/(m² s)] | Ci (µmol/mol) | Tr (µmol/mol) | WUEp (%) |
|------|-----------|------------------|-----------------|---------------|--------------|----------|
| 2011 | CK        | 18.30 ± 1.87 c   | 0.401 ± 0.030 c | 270.2 ± 3.16 a| 8.54 ± 0.31 a| 2.14 ± 0.12 d|
|      | CF        | 20.80 ± 1.61 b   | 0.455 ± 0.046 b | 255.3 ± 4.67 bc| 8.30 ± 0.45 a| 2.51 ± 0.17 c|
|      | SC        | 22.19 ± 0.90 a   | 0.491 ± 0.032 a | 252.0 ± 4.11 c| 6.57 ± 0.33 c| 3.38 ± 0.26 a|
|      | SM        | 22.37 ± 0.49 a   | 0.499 ± 0.035 a | 255.9 ± 3.57 b| 7.67 ± 1.06 b| 2.92 ± 0.19 b|
|      | BM        | 22.38 ± 0.97 a   | 0.501 ± 0.033 a | 240.8 ± 3.74 d| 8.66 ± 0.20 a| 2.58 ± 0.13bc|

| Year | Treatment | Pn [µmol/(m² s)] | Gs [mmol/(m² s)] | Ci (µmol/mol) | Tr (µmol/mol) | WUEp (%) |
|------|-----------|------------------|-----------------|---------------|--------------|----------|
| 2012 | CK        | 18.16 ± 0.78 c   | 0.399 ± 0.021 c | 278.1 ± 2.59 a| 8.67 ± 0.24 a| 2.09 ± 0.12 d|
|      | CF        | 21.10 ± 1.24 b   | 0.462 ± 0.035 b | 257.5 ± 3.22 bc| 8.33 ± 0.35 ab| 2.53 ± 0.17 c|
|      | SC        | 23.65 ± 0.86 a   | 0.514 ± 0.019 a | 243.7 ± 2.98 cd| 6.91 ± 0.33 c| 3.42 ± 0.26 a|
|      | SM        | 23.49 ± 1.02 a   | 0.516 ± 0.044 a | 247.2 ± 3.10 c| 7.71 ± 1.06 b| 3.05 ± 0.19 b|
|      | BM        | 23.47 ± 0.99 a   | 0.517 ± 0.027 a | 238.6 ± 3.08 d| 8.68 ± 0.13 a| 2.70 ± 0.13bc|

Note: Values followed by different letters in a column are significant among treatment at the 5% level. The two treatments have the same letter to indicate that the difference is not significant, and the different letters indicate significant differences.
cake fertilizer can significantly improve water utilization, achieve water retention holding water, and meet the water demand of pear jujube flowering period.

Wang [33] showed that organic fertilizer can significantly increase the chlorophyll content of wheat leaves. The soil and plant analyzer development (SPAD) value is 58% higher than CK. Liu et al. [34] showed that organic fertilizer increased the net photosynthetic rate of golden pear. The transpiration rate of the leaves is adjusted. These are consistent with the results of this pilot study. The total content of chlorophyll in the fructification period of pear jujube was significantly higher than CK. The change trend of Pn and Gs was consistent with the chlorophyll content. The intercellular CO2 concentration was opposite to Pn and Gs. This may be due to nonporosity factors that reduce the utilization of CO2, resulting in the accumulation of CO2 [31–33]. Therefore, organic fertilizer significantly increased the chlorophyll content of the fructification period. Photosynthesis intensity was enhanced. It also reduced intercellular CO2 concentration and accelerated the synthesis and accumulation of photosynthesis products [31].

### Table 4: Effects of different fertilizer treatments on reproductive growth of pear jujube

| Year | Treatment | Flower no. (no./plant) | Fruit no. (no./plant) | Fruit setting rate (%) | Yield (kg/hm²) |
|------|-----------|------------------------|-----------------------|------------------------|---------------|
| 2011 | CK        | 14,790 ± 1,061 c       | 383 ± 19 c            | 2.59 ± 0.20 c          | 8,040 ± 568 d |
|      | CF        | 21,564 ± 1,660 b       | 748 ± 81 b            | 3.47 ± 0.65 b          | 11,797 ± 741 c|
|      | SC        | 27,629 ± 4,552 a       | 985 ± 121 a           | 3.57 ± 0.20 b          | 19,177 ± 836 a|
|      | SM        | 18,246 ± 2,044 bc      | 646 ± 51 b            | 3.54 ± 0.58 b          | 12,025 ± 891 c|
|      | BM        | 21,232 ± 5,072 bc      | 951 ± 132 a           | 4.48 ± 0.61 b          | 14,142 ± 812 b|
| 2012 | CK        | 15,045 ± 1,201 c       | 404 ± 20 c            | 2.69 ± 0.14 b          | 8,428 ± 479 d |
|      | CF        | 22,785 ± 2,127 b       | 814 ± 51 b            | 3.57 ± 0.52 c          | 12,356 ± 511 c|
|      | SC        | 26,047 ± 3,218 a       | 1,195 ± 102 a         | 4.59 ± 0.49 ab         | 22,018 ± 422 a|
|      | SM        | 19,094 ± 1,984 bc      | 819 ± 48 b            | 4.29 ± 0.57 bc         | 14,479 ± 567 c|
|      | BM        | 20,925 ± 2,108 bc      | 1018 ± 94 a           | 4.86 ± 0.61 a          | 17279 ± 601 b |

Note: Values followed by different letters in a column are significant among treatment at the 5% level. The two treatments have the same letter to indicate that the difference is not significant, and the different letters indicate significant differences.

### Table 5: Effects of different fertilizer treatments on nutrient quality of pear jujube

| Year | Treatment | FWC (%) | TSS (%) | TA (%) | TSS/TA | Vc (mg/kg) | Total flavones (mg/kg) |
|------|-----------|---------|---------|--------|--------|------------|------------------------|
| 2011 | CK        | 77.15 b | 15.45 c | 0.69 a | 22.39 c | 25.81 c    | 11.52 c               |
|      | SC        | 86.30 a | 18.48 a | 0.46 c | 40.17 a | 46.18 a    | 14.35 a               |
|      | SM        | 76.32 b | 16.63 bc| 0.53 b | 33.83 b | 37.00 b    | 13.48 b               |
|      | BM        | 85.41 a | 17.05 b | 0.51 b | 33.43 b | 41.19 b    | 12.58 b               |
| 2012 | CK        | 78.01 b | 15.91 c | 0.72 a | 22.10 c | 25.92 c    | 11.01 c               |
|      | SC        | 87.55 a | 20.14 a | 0.46 c | 45.78 a | 47.33 a    | 16.03 a               |
|      | SM        | 79.21 b | 17.55 bc| 0.50 b | 35.10 b | 39.71 b    | 14.98 b               |
|      | BM        | 86.88 a | 18.67 b | 0.47 b | 39.72 b | 43.52 b    | 14.11 b               |

Note: Values followed by different letters in a column are significant among treatment at the 5% level. The two treatments have the same letter to indicate that the difference is not significant, and the different letters indicate significant differences.
The total number of flowers CF was higher than SM and BM, while the fruit setting rate was lower than SM and BM. The reason is that chemical fertilizer could guarantee the nutrient supply during flowering period and promote flowering of plants, but the subsequent lack of fertility, water, and other factors affect the fruiting of pear jujube. These reasons ultimately affect the yield of pear jujube. The water content, solid acid ratio, and other qualities of the fruit directly affect the taste of pear jujube. After application of organic fertilizer, the water content of the fruit is significantly increased. SC and CK reached significant difference ($P < 0.05$). The soluble solids, solid-acid ratio, VC, and total flavonoids were all higher than CK. The titratable acid was lower than CK. Zhu [35] through the study of citrus showed that organic fertilizer can increase the ratio of soluble solids and solid acid in citrus. Luo et al. [36] shows that organic fertilizer can increase the VC content of Feicheng peach and reduce the content of titratable acid. The sustained slow release of organic fertilizers is conducive to synchronizing with the physiological needs of crops. It can effectively promote the balance of nutrient metabolism in crops. Thereby, it can ensure the high yield and quality of crops [37].

5 Conclusions

Organic fertilizers can promote the vegetative growth, reproductive growth, quality improvement, and water utilization of pear jujube. Soybean cake fertilizer is relatively effective. It can provide theoretical basis and reference for scientific fertilization of organic pear jujube in the loess hilly region. In future, we need further research about the amount of organic fertilizer added. Applying organic fertilizer will bring comprehensive effect. Long-term application of organic fertilizers will produce cumulative effects and effect on soil fertility.

Conflict of interest: Authors declare no conflict of interest.

References

[1] Wu PT, Wang YK, Xin XG, Zhu DL. Integration and demonstration of the date micro-irrigation technology in the hilly of Shanbei. Agric Res Arid Areas. 2008;26(4):1–6.

[2] Ramos C, Agut A, Lidon AL. Nitrate leaching in important crops of the valencian community region. Environ Pollut. 2002;118:215–23.

[3] Sheng DL, Cao FM, Li L. Development status and prospect of microbial organic fertilizer in China. China Soils Fertilizer. 2007;6:1–5.

[4] Lu WT, Jia ZK, Zhang P, Cai TY, Li R, et al. Effects of organic fertilization on winter wheat photosynthetic characteristics and water use efficiency in semi-arid areas of southern Ningxia. Plant Nutr Fertilizer Sci. 2011;17(5):1066–74.

[5] Sebastiana M, Juan C, Ruiz P. Chemical and biochemical properties in a silty loam soil under conventional and organic management. Soil Tillage Res. 2009;60:162–70.

[6] Li J, Song DT, Zou GY, Zhang Q, Nie JH, et al. Effect of different organic fertilizers on growth and quality of tomato. Chin Agric Sci Bull. 2008;24(10):300–5.

[7] Ma FF, Xin SB, Gan MQ, Liu PS, Huang Y, Gan XY, et al. Effects of substituting organic fertilizers for chemical fertilizers on rice yield, soil fertility and nitrogen and phosphorus loss in farmland. Crops. 2019;5:89–96.

[8] Yan PK, Chang SG, Sun Q, Wang R. Effects of application of bio-organic fertilizer on yield, quality and soil fertility of alfalfa. China Soil Fertilizer. 2019;5:112–8.

[9] Chen HJ, Zhang RL, Wu CY. Improved fertilization effect of long-term application of organic fertilizer on rice fields. Zhejiang Agric Sci. 2019;60(8):1356–9.

[10] Yin JD, Hou HZ, Zhang XC. Effects of enhanced application of organic fertilizer on water use and yield of spring wheat with full-film covered Soil. J Triticeae Crop. 2019;39(2):179–85.

[11] Wang XL. Density and organic manure improve the physiological basis of water use efficiency of covered spring maize. Yangling, China: Graduate School of Chinese Academy of Sciences (Center for Soil and Water Conservation and Eco-Environmental Research, Ministry of Education); 2016.

[12] Zhang HM, Li WG, Zhang CJ, Han X, Xi CL. Effects of different fertilizers on fruit quality of Hongfeng peach. Shanxi Agric Sci. 2019;47(5):845–8+853.

[13] Wu H, He YH, Xu ZY, Ni L, Wei J. Effects of organic fertilizer on fruit and mineral nutrition content of sand pear. J Yangzhou Univ (Agric Life Sci). 2017;38(4):112–5.

[14] Wu CC. Effects of continuous application of bio-organic fertilizer on growth and soil properties of Huangguan pear. Nanjing: Nanjing Agricultural University; 2016.

[15] Wang ZY, Zhang GN, Yu JX, Zhen YQ, Xu XH. Effects of EM bacteria combined with organic materials on soil physical and chemical properties and photosynthetic characteristics of peach leaves. J Ecol. 2018;37(9):2657–62.

[16] Yan YD, Jiang ZB, Xu WL, Wang YK, Zhou C. Analysis of soil texture and fertility status of jujube orchards in slopes of the Loess Plateau. Agric Res Arid Areas. 2008;27(3):174–8.

[17] Wang CF, Pati GL, Su LM, Jing SB, Dou XJ, Huang J, Fu YB, Wang ZG. Effects of different base fertilizers on photosynthetic fluorescence characteristics and yield of Jujube. Xinjiang Agric Sci. 2017;54(7):1250–8.

[18] Ye SL, Liu TC. Effects of different drip irrigation systems on yield and water use efficiency of Lizao Jujube in northern Shaanxi. J Irrig Drain. 2018;37(1):28–34.

[19] Yang Y. Study on effect of fertilization on Jujube growth and yield in northern shanxi under different water management. Shaanxi: Ms thesis, Institute of Soil and Water Conservation, Chinese Academy of Science and Ministry of Water Resources; 2011.
Shi DL. Determination and comparison on the dry matter and water content in fruit of jujube varieties. Anim Husb Feed Sci. 2009;30(1):17–8.

Shu Z, Zhang XS, Chen J, Chen GY, Xu DQ, et al. The simplification of chlorophyll content measurement. Plant Physiol Commun. 2010;46(4):399–402.

Gao DT, Han MY, Li BZ, Zhang LS, Bai R. The characteristic of light distribution in apple tree canopy using WinsCanopy2004a. Acta Agric Boreali-Occidentials Sin. 2006;15(3):166–70.

Zhao SJ, Shi GA, Dong XC. Plant physiology experiment guide. 1st ed. Beijing: China Agricultural Science and Technology Press; 2002. p. 84.

Gao JF. Plant physiology experiment guide. Beijing: Higher Education Press; 2006.

Li MF, Xi F, Li QL, Zhu HH. The extraction of flavonoids from red date and its analytical method. Acta Agric Univ Jiangxiensis. 2009;06:1156–9.

Hui HX, Xu X, Li QR. Effects of NaCl stress on betaine, chlorophyll fluorescence and chloroplast pigment of leaves of Lycium Barbarum L. Agric Res Arid Areas. 2004;22(3):109–14.

Ding SS, Su PX, Yan QD, Gao S, Zhang LM, et al. Photosynthetic characteristics of Chinese jujube under different intercropping conditions. Agric Res Arid Areas. 2009;27(1):184–9.

Wang XD, Wang HB, Qin D, Zhai H. Biological effects of organic manures on Potted Grapesines. Chin Agric Sci Bull. 2007;23(4):260–4.

Tang XM. Effects of manure on soil water-conversation and fertilizer betterment winter wheat yield in Loess Plateau Dryland. Res Soil Water Conserv. 2003;10(1):131–2.

Su Q, Jia ZK, Han QH, Li YP, Wang JP, et al. Effects of organic fertilization on soil moisture and crop productivity in semi-arid areas of southern Ningxia. Plant Nutr Fert Sci. 2009;15(6):1466–9.

Wang XJ, Jia ZK, Liang LY, Ding RX, Wang M, et al. Effects of organic fertilizer application rate on leaf photosynthetic characteristics and grain yield of dryland maize. Chin J Appl Ecol. 2012;23(2):419–25.

Angers D, Chantigny M, MacDonald J. Differential retention of carbon, nitrogen and phosphorus in grassland soil profiles with long-term manure application. Nutr Cycl Agroecol Syst. 2010;86(2):225–9.

Wang JL. The effect on long-term fertilization to chlorophyll content of winterwheat (Triticum aestivum) and summer corn (Zea mays). Chin Agric Sci Bull. 2010;26(6):182–4.

Liu Y, Gao XH, Yao XC. Research on nutrient effect of different botanical organic fertilizers on young pear plant [Pyrus pyrifolia (Burm.f.) Nakai] in sandy soil. Sci Agric Sin. 2008;41(8):2546–53.

Zhu CB, Wu SH, Zhang XY, Zhou DP, Fan JQ, et al. Effects of organic fertilizer application on soil fertility and leaf nutrients and fruit quality of citrus. Acta Agric Shanghai. 2012;8(1):65–8.

Luo H, Li M, Hu DG, Song HR, Hao YJ, et al. Effects of organic fertilization on fruit yield and quality of Feicheng peach. Plant Nutr Fert Sci. 2012;18(4):955–64

Wang YP, Liu YH, Ruan RS. Study on the effect of organic manure on improving the quality of farm products. Chin Agric Sci Bull. 2011;7(9):51–6.