RESPONSE OF FRAGRANT PEAR GROWTH TO DIFFERENT MICRO-IRRIGATION CONDITIONS

Zhao Zhi[1], Huang Xingfa[2], Wu Yang[3], Wang Wei[4]

ABSTRACT

The situation that water is becoming increasingly scarce and micro-irrigation can enhance water use efficiency is recognized worldwide. Until now, the Korla fragrant pear trees were irrigated by traditional flood irrigation in the west of China, so there is great potential to cut down agricultural water use. The response of fragrant pear trees to micro-irrigation management under field conditions in Xinjiang Uygur Autonomous Region was conducted in 2009. There were four irrigation approaches: (1) surface drip irrigation; (2) subsurface drip irrigation; (3) micro–sprinkling irrigation; (4) traditional flood irrigation. Three micro-irrigation treatments were fully irrigated to the 80% ET every week during the whole growing season. Soil water potential, vegetative growth, production and fruit quality were measured in this experiment.
Micro-irrigation treatments could save 700mm of total irrigation water, 50% of that with flood irrigation. Results indicated that pear fruit yield and fruit quality were slightly influenced. In particular, the VC content of pears at micro-sprinkler treatment exceeded 60% of that with flood irrigation, at the level of 0.24mg/100g. Wherefore, changing the inefficient irrigation method to micro-irrigation is necessary for Korla fragrant pear in Xinjiang region.

1. INTRODUCTION

Located in the middle of Eurasia, Xinjiang Uygur Autonomous Region has an arid climate and low precipitation. The mean annual precipitation is less than 150mm (Zhang Wangfeng, 2002). However, as the main commercial crop, Korla fragrant pear is still irrigated by traditional flood irrigation, which causes great waste of water. Micro-irrigation technology has excellent superiority in water saving and increasing production. In recent years, micro-irrigation has a rapid expansion in developing countries. Especially, a number of scientists concentrate on studying subsurface drip irrigation (Li Guangyong, 2001). Micro-irrigation has found an increasingly wide utilization in corn, vegetable and fruit, etc., but the related research on Korla fragrant pear is scarce and rare (Thind H S, 2007; Metin S Sezen, 2001). Up to 2010, the orchard area of fragrant pear had been enlarged to a large scale as a part of the special types of fruits. The area of special fruit industry will reach to one million hectares in Xinjiang Uygur Autonomous Region, while 800,000 ha around Xinjiang's

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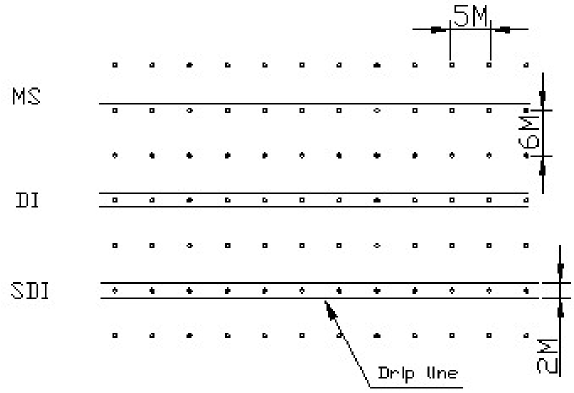
Tarim Basin. Therefore, if the inefficient irrigation regime can be changed into drip irrigation, there will be huge potential for water saving and multiply advantages. On the one hand, with intelligent control, the user can adjust the time and quantity of irrigation conveniently; on the other hand, based on micro-irrigation technology, advanced irrigation management, such as regulated deficit irrigation(Mitchell P D, 1984; Perez-Perez J G, 2009) and alternate partial root-zone irrigation (Claudia R de Souza, 2003), could put into real practice. Wherefore, this is the basic work of the whole study. Fragrant pear is famous for its distinctive taste and rich nutrients, but it could grow only under particular climatic conditions. The most typical one is the main origin-Korla. Existing research results about fragrant pear were focused on its physiological and biological characters. Whereas, the research on the growth and water consumption about Korla fragrant pear trees under micro-sprinkler conditions is extremely little. The main purpose of this paper is to grasp the response of fragrant pear under the conditions changed from flooding irrigation to micro-irrigation under special climate, to analyze the water consumption and optimize irrigation scheduling, to quantify the fruit growth, yield and quality under micro-irrigation condition. In this paper, a field test was carried on in the orchard of Xinjiang Korla fragrant pear fruit trees.

2. Material And Method

Field experiment was carried out at orchard of the Bazhou Agricultural Science Institute, Korla City, Xinjiang Uygur Autonomous Region. It was located at N41°43′, E86°6 ′. The fragrant pear tree orchard was managed and fertilized similar to the local average level. The climate of Korla belongs to a temperate continental arid one. The soil in the study area was silt loam (international system, sand 44.09 % , silt 50.36% ,clay 5.55%), and the average soil bulk density was 1.5g/cm^2. Experimental trees were 24-year-old Korla fragrant pear trees, with spacing of 5m×6m. Weather information was recorded by automatic weather station near the orchard.

2.1 Experiment design

Four difference irrigation methods were designed in the experiment, i.e., (1) surface drip irrigation (DI). In this treatment, two drip lines, with emitter spacing 50cm (Lei Tingwu, 1994), were laid along tree row, with 1 meter apart from the tree row for each drip line; (2) subsurface drip irrigation (SDI), which was 30cm depth underground, with the same format as DI; (3) micro - sprinkling irrigation treatment (MS). In this treatment, the lateral was laid 1 meter apart from the tree row, with one sprinkler for each tree. The throw distance of the micro-sprinkler was 0.5m; (4) conventional flooding irrigation (CK). In this treatment, water was applied once a month as accustomed approach. During the growing season, water was applied once a week to 80% ET for micro-irrigation treatments. The same level of agronomy management and fertilizing was taken for each treatment. The layout of the experimental plots is shown in Figure 1.



MS: micro - sprinkling irrigation, DI: Surface drip irrigation, SDI: subsurface drip irrigation (The same as below)
Figure 1. Experiment design layout

2.2. Measurements and instruments

Evaporation: The evaporation was estimated by a US Class A pan (with diameter of 120.7cm, depth of 25cm).The US class A pan was established on an open area with favorable conditions of irradiation and venting (Huang Xingfa, 2002).The decline of water depth was daily recorded, as the diurnal evaporation. Irrigation water was applied based on the data collected from the US class A pan.

Soil water potential: The soil water potential was monitored by gypsum blocks. Gypsum blocks were buried at 30cm underground, with the distance of 1 meter to the center line of tree row. It was measured before and after irrigations through the whole growing season.

Vegetative growth: Vegetative growth included the growth of new shoots and summer pruned shoot quantity. Six typical trees were selected for measuring shoot quantity of summer pruning by recording the weight of pruned shoots (mainly contained strong shoots).The new shoot growth curve was recorded since it was 10cm long. Ten shoots on each of the six trees for each treatment were tagged to measure changes in shoot length. Shoots were checked according to the growth of branches, which the main purpose was to replace the strong shoots (Zeng Dechao, 2001). The shoot growth curve can be drawn based on the data during the whole growing season.

Fruit size: Ten fruits in each of the five trees for each treatment were tagged and numbered to measure the changes of length and diameter during the whole growing season, which its volume could be calculated based on these length and diameter data.

Yield: Six typical trees were selected to estimate fruit yield for each treatment. Statistic analysis was done by using SPSS software.

Fruit quality: Fruit quality indexes included soluble solids(measured according to GB12295 - 90), titrable acidity (measured according to GB12293 - 90), soluble sugar (measured according to GB6194 - 86) and VC (measured according to GB6195 - 86).

3. Results and discussion

3.1. Soil water potential changes during the growing season

The distinction of water potential of different treatments at 30cm depth during growth period was shown in Figure 2. Through the whole growth stage, micro-irrigation treatments revealed a uniform trend. The first valley appeared after full flowering period, for trees consumed larger quantity of water. Since early May, soil water potential slowly decreased: With few exceptions, at the middle of June soil water potential reached to the level of – 40 kPa; then, it glided down to – 50 kPa from June to early September. The soil water potential showed that no water pressure was taken place in micro-sprinkler conditions; In the most of growing season, the soil water potential in the micro - sprinkling irrigation was the lowest, and the subsurface drip irrigation remained the highest level. Micro - sprinkling irrigation water jet into air directly resulted in more evaporation, while it could improve and regulate the orchard micro-climate conditions.

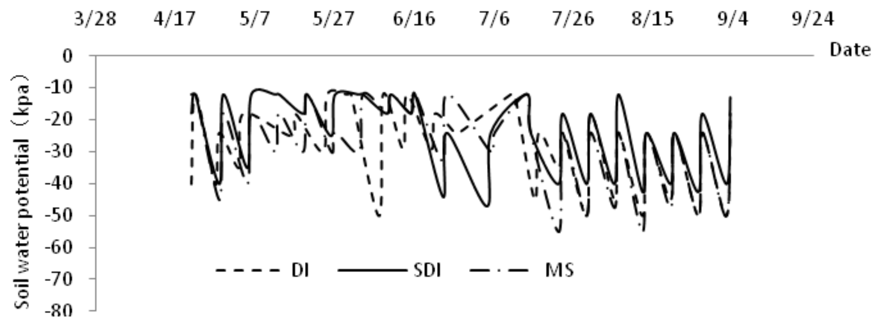


Figure 2. Soil water potential under different drip irrigation treatments

3.2. Irrigation quantity and water consumption

1) Total irrigation water

The effective precipitation at the experiment site was 21.4mm in 2009 growing season. Irrigation started on April 21, and ended on September 2, with its interval of one week. Flooding irrigation was applied once a month according to the traditional irrigation regime. The total amount of water applied to the treatment was 652mm for DI, 632mm for SDI, 625mm for MS and 1500mm for CK. Compared with flooding irrigation, water consumption was reduced by 56.2%, 57.3% and 57.3% for DI, SDI and MS, respectively.

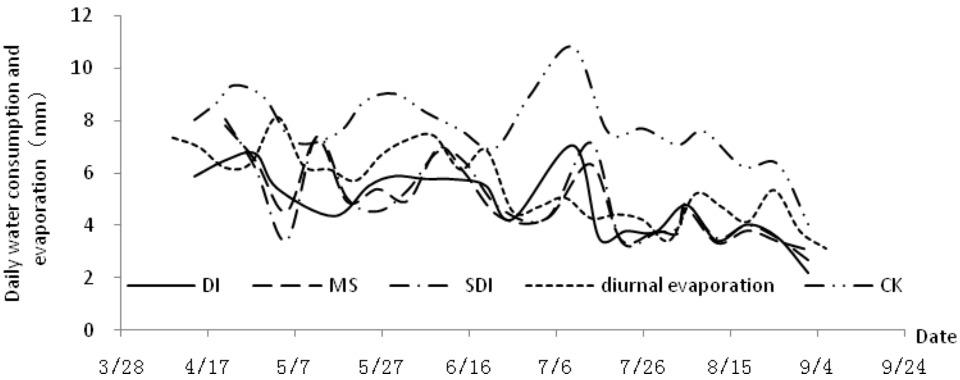
2) Daily water consumption

Water consumption was calculated by the water balance method. Equation was as follow:

$$ET_C = \Delta W + I + P - S + WT$$

where, ET_C is crop water use, mm; ΔW is soil water content changes in the wetting soil, mm; I stands for irrigation water, mm; P is precipitation, mm; S is deep seepage, mm; and WT represents groundwater recharge, mm. The total precipitation was 21.4mm during the growing season. Groundwater recharge and deep seepage were 0 in the study case.

The daily water consumption was shown in Figure 3.The data revealed that water consumption of each treatment was time declining, and it accorded with the trend of daily evaporation. Analogous bottom of daily water consumption appeared at the end of April, nearly 5mm, since this was the specific time when it stepped into the stage of full bloom of pear tree. The next period was vegetative growth from early May to the end of June, when the daily water consumption remained between 4mm and 7mm.There was significant reduction since July, for water consumption was kept at 3 - 5mm/day. From July to mature of fruit, it was the period of fruit rapid growth and expanded, and also pear trees stepped into maximum physical water use stage. Local climate did not promote evaporation after July. Irrigation water applied went down with daily water evaporation, and the crop water demand should be higher than that shown in Figure 3. During the whole stage, daily water consumption of CK was much higher than those of all micro-irrigation treatments.



CK: flood irrigation (the same as follows)

Figure 3. Daily water use

3) Pan coefficients

The ratio of crop water use to pan evaporation is called pan coefficient. Because of its simplicity, relatively low cost of its measuring equipment, it is widely used in the United States, Australia and other countries for real time determination of irrigation scheduling (Huang Xingfa, 2001). The pan coefficient in this article is referred to US Class A pan. As shown in Figure 4, values of pan coefficients in all irrigation treatments were similar to the trend of daily water consumption. It is observed that except for a few points, the pan coefficients were between 0.6 - 1.2. The pan coefficients of all treatments kept above 0.8 from the end of May to the end of irrigation, which reflected that water consumption was mainly determined by irrigation quantity.

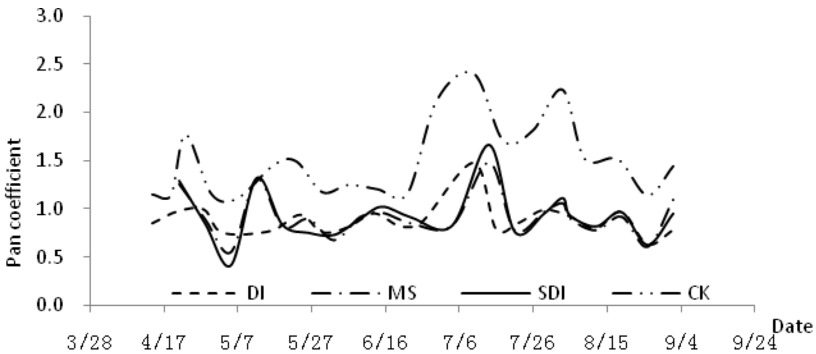


Figure 4. Crop water of fragrant pear tree

4) Cumulative water consumption and evaporation

Cumulative evaporation and water consumption were shown in Figure 5. The total evaporation was 836.8mm.Cumulative water consumption of DI was 717.1mm and average pan coefficient was 0.86. Cumulative water consumption of MS was 698.5mm and average pan coefficient was 0.83. The cumulative water consumption of SDI was the minimum in the all treatments, i.e., 701.9 and average pan coefficient was 0.84.

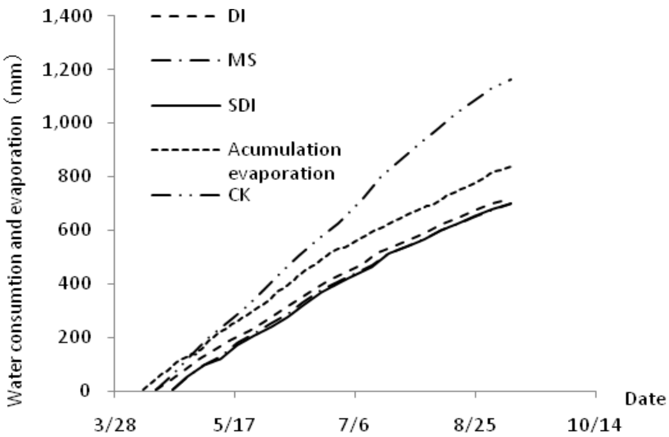


Figure 5. Acumulated pan evaporation and water use

3.3 Vegetative growth

1) Shoot growth

Effects of new shoot growth was observed and shown in Figure 6. The data showed that the shoot growth was inhibited by micro- irrigation, and accordingly it can be divided into two periods: the first period was rapid growth stage from early April to middle May, and the length of new shoots can reached to above 25cm; the second period was the following four months, which the new shoot stepped into slow growth stage and developed about 10cm. As can be seen from Table 1, shoot growth was obviously controlled by micro- irrigation, with the highest value was observed in treatment of DI, which is decreased by11.9%. Flood irrigation had the highest mean weight of pruned strong shoots. Among micro-irrigation treatments, MS had the highest mean weight of pruned strong shoots, as MS was good for vegetative growth.

Analysis of variance showed that subsurface drip irrigation didn't decrease the length of new shoots significantly, while drip irrigation and micro - sprinkling irrigation had the difference significantly. Mean pruned weight percentage was reduced by 30.6%, 43.5% and 29.4%, respectively, in drip irrigation, subsurface drip irrigation and micro - sprinkling irrigation. Micro-irrigation treatments resulted in difference of strong shoots growth compared with flood irrigation. In addition, subsurface drip irrigation affected strong shoots growth to maximum extent.

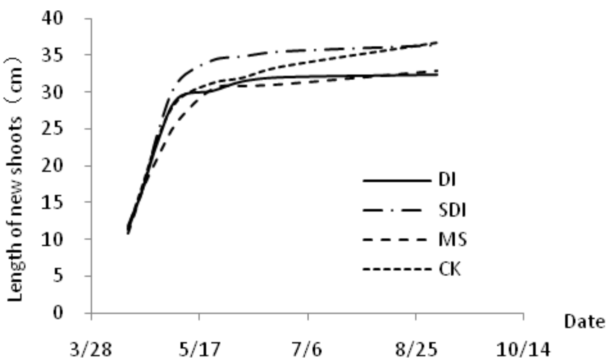


Figure 6. Shoot growth curves of fragrant pear trees

2) Yield response

As shown in Figure 7, the fruit growth of three micro-irrigation treatments were similar to that of flooding irrigation and the fruit development can divided into two periods: the slow growth stage of fruit before the early July, and fast growth stage of fruit for the rest of growing season.

As Table 1 revealed, the fruit sizes of all treatments were not significantly restrain by irrigation methods. Fruit volume from treatment of subsurface drip irrigation was 100.65cm^3, which was the maximum volume in the all treatments.

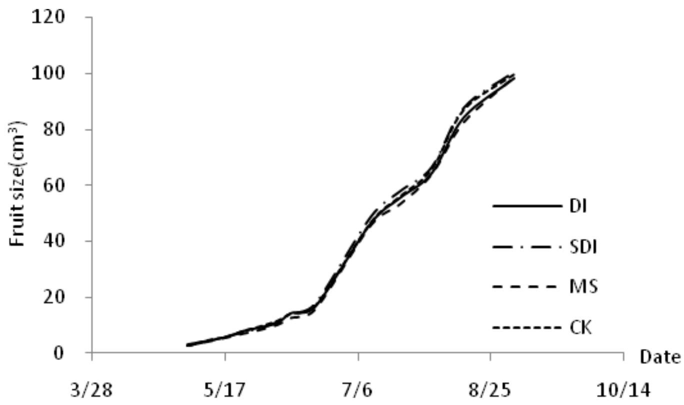


Figure 7. Fruit growth curves of fragrant pear trees

Table 1. Growth indexes of fragrant pear tree

Treatments	Final length of shoot (cm)	Weight of pruned shoots (kg/tree)	Average fruit size (cm^3)	Yield (ton/ha)
DI	32.43a	5.9a	98.20a	18.62a
SDI	36.35bc	4.8b	100.65a	18.40a
MS	32.97ab	6.0a	98.78a	19.72a
CK	36.82c	8.5c	99.55a	18.46a

Note: ($p<0.05$)

The effects of micro-irrigation treatments on the fragrant pear yield were slight, and there was no significant difference. The total fruit yield with surface drip irrigation and micro-sprinkling irrigation were higher than that with the control, and case with subsurface irrigation was similar to that with the control. The fruit volume in the treatment of micro-sprinkling irrigation was not the highest but the yield was the highest. The reason may be that the micro-sprinkling irrigation changed the surrounding microclimate and enhanced fruit set percentage.

3.4 Effects at the fruit maturation stage

Fruit quality indexes, namely soluble solid, soluble sugar, titratable acidity and VC were presented in Table 2. Results indicated that there were no obvious differences among all treatments. The VC content of pears at micro-sprinkler treatment was 0.24mg/100g, which was 60% more than the other treatments and control.

Table 2. Indexes of fragrant pear fruit quality

Treatments	Soluble solid (g/100g)	Soluble sugar (g/100g)	Titratable acidity (mmol/100g)	VC (mg/100g)
DI	11.50	6.93	0.83	0.15
SDI	11.70	7.58	0.83	0.12
MS	10.90	7.86	0.89	0.24
CK	11.80	7.86	0.84	0.15

note: soluble sugar content calculated by glucose content.

4. CONCLUSION

The results of the field experiment revealed that the changing of irrigation method would not affect the volume of single fruit, fruit quality and the final production. On the contrary, the shoot growth was restrained by micro-irrigation obviously. Micro-irrigation caused reduction in short shoot and strong shoot growth. The strong shoot weight with treatment of subsurface drip irrigation was reduced by 43.5% compared with the control, while with no significantly influence on short shoot growth.

Changing irrigation approach from flooding irrigation to micro-irrigation can save more than fifty percent of irrigation water, with no harm to yield and quality. Therefore, micro-irrigation method is acceptable to Korla fragrant pear in arid region. Users could choose suitable micro-irrigation method, for there are advantages and disadvantages for each micro-irrigation method. In addition, if irrigation scheduling is determined by pan coefficient, it will be much more convenient and can meet the water requirement for crop growth.

ACKNOWLEDGEMENTS

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