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Change characteristics of soil moisture content under different planting patterns and evaluation on crop economic benefits

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Abstract. In order to clarify the changes in the soil moisture content in different soil layers under different planting patterns, this paper uses the field experiment. This paper also analyzes the soil moisture content and crop yield and other related results under the treatment of three kinds of planting patterns of winter wheat-summer maize (T0), season spring maize (T1) and herbage-spring maize (T2) from 2010 to 2011 and evaluates the economic benefits. The results show that the annual yields under T0, T1 and T2 planting patterns are 12.2, 9.9 and 10.4t/hm2 respectively, and the total yield of T0 crops is 20.2% higher than that of T1 and T2. According to the analysis of economic benefits of wheat and maize purchase price and planting cost in 2011, the net incomes of T0, T1 and T2 planting patterns are 5679, 8690 and 12517 Yuan /hm2 respectively and the economic benefit of T0 planting pattern is 46.4% lower than that of T1 and T2. The soil water content of T1 and T2 planting patterns gradually increases with the soil depth, and the water change range of the two planting patterns is the same. The soil moisture content of the T0 planting pattern increases first and then decreases with the depth, and the water change range is lower than that of the T1 and T2 planting patterns. The test results show that the economic benefit of T0 planting pattern is 46.4% lower than the average value of T1 and T2. In the North China Plain, the possible choice to ensure food safety and minimize irrigation water is to plant the season spring maize, but it is necessary to increase the yield of spring maize by more than 20% based on the existing foundation through other measures.

1. Introduction

China is short of water resources in general, but the per capita amount of water resources is only 2250m^3, which accounts for only 1/4 of the average world level, ranks 121 in the world, and is one of the world's 13 poorest countries of water resources per capita [1] (Jiang Wenlai, 2005). The North China Plain, as one of the largest grain production bases in China, has a great demand for water. The shortage of surface water resources leads to the massive exploitation of groundwater as irrigation water in this region, resulting in the decline of groundwater level, the occurrence of underground funnel and other problems [2-3]. There are many planting patterns in the North China Plain, where the planting pattern of winter wheat-summer maize is a more traditional planting pattern in North China. However, there is a significant difference between the spatial and temporal distribution and coupling degree of water consumption of different crops and effective precipitation in all planting patterns [4-5]. What kind of planting pattern is suitable for the sustainable agricultural development? Many researchers have come up with a series of views [6-8]. In view of the above problems, we have confirmed for many years that to a certain extent, the reduced irrigation for the winter wheat cannot achieve the exploitation and supply balance of groundwater resources, and in the long term, we should reduce the planting area of winter wheat to increase the proportion of low water consumption crops [9-10]. The test makes clear moisture changes of different planting patterns by comparing the change characteristics of soil moisture content in different soil layers under the three patterns, such as winter wheat-summer maize planting pattern, herbage-spring maize planting pattern and season spring maize planting model. It provides a theoretical basis for the sustainable development of water resources and the planting patterns of food security in the North China Plain.

2. Materials and methods

2.1. General situation of research areas

Located at the Shangzhuang experimental station of China Agricultural University, found in September 2004, the test is located at 116°11’ E and 40°8’ N in Xinlitun Village, Shangzhuang Town, Northwestern Haidian District, Beijing with 50m attitude. Its landform belongs to the North China alluvial plain, its main soil type is alluvial soil, and its soil texture is sandy loam.

2.2. Test design

The total area of the test area is 45 m×60 m, and the test plot area is 16 m×13 m. According to crop planting patterns in agricultural production, we divide the test into 3 treatments, which are as follows:

(1) Under the traditional planting pattern of winter wheat-summer maize (T0), on October 6, 2010, we sowed the winter wheat in the test plot and planted the summer maize after the harvest on June 2, 2011.

(2) Under the planting pattern of season spring maize (T1), on October 5, 2010, we smashed the summer maize stalk to cover the soil surface, and planed the spring maize on May 15, 2011.

(3) Under the planting pattern of herbage-spring maize (T2), we sowed herbages (triticale) on October 6, 2010, turned herbages into soil as green manure on May 14, 2011 and planted spring maize on May 15, 2011.

2.3. Crop variety and field management

Winter wheat variety is Nongda 211, summer maize 335, spring maize Zhuodan 10, and gramineous forage grass triticale is a new winter and spring feed crop.

Before sowing wheat and herbage, we smash the maize stalk to cover the soil surface in the soil corresponding to test plots, sow seeds by using human ridging machines. With 30cm of furrow width, 300 kg/hm^2 of sowing amount and 20cm of row spacing, we sow two rows in each ditch at the edge of the ridge. We carry out the test in the field under adequate water supply and adopt the flood irrigation, and we carry out fertilization and field management according to local customs.

For maize planting treatment, spring and summer maize uses ridge planting with 20 ridges in each district, 70 cm of ridge width, 16m of ridge length, 60000 plants/hm^2 of sowing amount, 50cm of row spacing and 15cm of row spacing.

Field management of test crops includes irrigation (irrigation time and irrigation amount), top application (fertilization time and fertilization amount), weed control, harvest (harvest time and yield),

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all of which are carried out in the local routine. Summer maize fertilization and irrigation method: field management of summer maize is consistent with that of spring maize.

2.4. Determination contents and calculation methods

2.4.1. Crop yield determination. Wheat yield calculation: in order to prevent the influence of the marginal effect, we select 2m^2 wheat in each plot (except 0.5m edge) for threshing and air drying to determine the yield.

Maize yield calculation: in order to prevent the influence of the marginal effect, we select 2 rows of wheat in each plot (except 0.5m edge) for threshing and air drying to determine the yield.

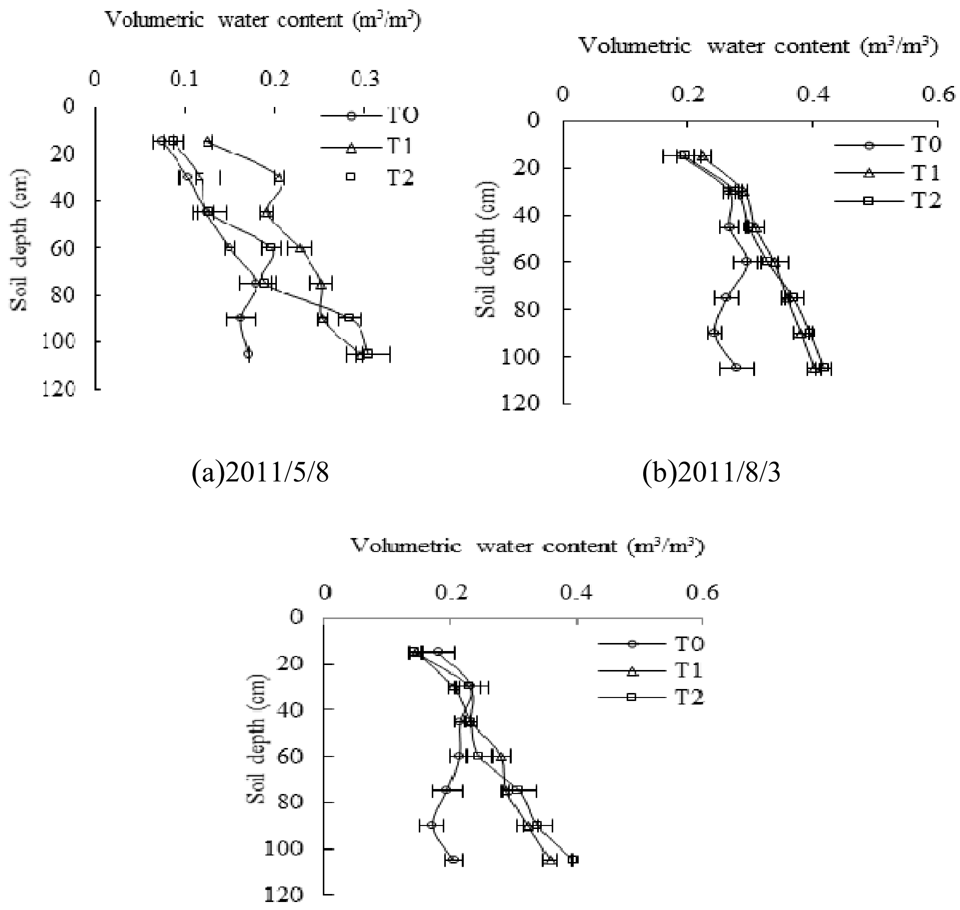
3. Result and analysis

3.1. Characteristics of soil moisture content with the change of soil depths under different treatments

On May 8, 2011, it is the booming period of herbage and wheat growth in the test region without spring maize and summer maize planting. According to Figure 1, the soil moisture content of three treatments at 0~105cm shows an increasing trend with the increase of soil depth, and the soil moisture content of T0 and T2 treatments at 0cm~60 cm has a consistent change trend with the change range of 7 $m^3 \cdot m^{-3}$～19 $m^3 \cdot m^{-3}$. However, the soil moisture content of T1 treatment at 0cm~60 cm ranges from 13 $m^3 \cdot m^{-3}$ to 23 $m^3 \cdot m^{-3}$, because at 0～60 cm, it is the main activity area of herbage and wheat roots, while in the T1 treatment, there is no water consumption for crop growth at this time, and the exuberant growth of herbage and wheat needs to consume soil water, resulting in soil water content at 0-60 cm lower than that of T1 treatment.

From planting spring maize (May 15, 2011) to harvesting summer maize (September 24, 2011), maize has a same field management measure. It is the booming period of summer maize and spring maize on August 3, 2011, and at this time, due to the heavy rainfall in July, the soil moisture content at 0~105 cm increases significantly compared with before. As shown in Figure 11, the soil moisture content of T1 and T2 treatments at 0~105 cm increases with the increase of soil depths, and the change range and trend of water content are all consistent with the change range of about 20 $m^3 \cdot m^{-3}$～40 $m^3 \cdot m^{-3}$. The change trend of water content of T0 treatment at 0~60 cm is consistent with that of T1 and T2 treatments, but the range is from 15 $m^3 \cdot m^{-3}$ to 28 $m^3 \cdot m^{-3}$. It is lower than the water content of T1 and T2 treatments because the deficit of soil moisture content after harvest of winter wheat does not recover at this time. The reason for low soil moisture content of T0 treatment at 60~105cm is consistent with the previous improvement.

We will harvest spring maize and summer maize on September 24, 2011, and the three treatments will complete a rotation cycle. At this time, the trend of soil moisture content with the change of depth is consistent with the change trend in Figure 12, but the change range is not same. At this time, the change range of soil moisture content of T1 and T2 treatments at 0cm~105 cm is about 16 $m^3 \cdot m^{-3}$～36 $m^3 \cdot m^{-3}$, while the variation range of T0 treatment is 15 $m^3 \cdot m^{-3}$～23 $m^3 \cdot m^{-3}$ because crop growth needs to consume soil moisture with decreased rainfall after August, resulting in the decrease of soil water content.



(a)2011/5/8 (b)2011/8/3

(c)2011/9/24

Fig. 1 Dynamic change of soil rate of volumetric water content with the soil depth at different periods

3.2. Analysis of crop yield under different planting patterns

From Table 1, we can see that there is a significant difference in yield between T0 treatment and T1 treatment/T2 treatment, but there is no significant difference between T1 treatment and T2 treatment. The yield of T1 treatment is about 18.8% lower than that of T0 treatment, and the total yield of T2 treatment is 14.8% lower than that of T0 treatment. The total yield of crops of T0 treatment increases by 16.8% in average compared with that of the other two treatments, indicating that the total yield of winter wheat-summer maize traditional planting pattern is higher than that of single season spring maize.

Table 1. Crop yield and water use efficiency under different planting patterns

Treatment	*P*/mm	*I*/mm	ΔW/mm	*ET*/mm	Yield (kg·hm^{-2})	*WU*(kg·m^{-3})
Single season wheat	56.9	307.6	-31.85	396.35	6353.1	1.60
Single season summer maize	485.1	0	9.86	475.70	5833.8	1.23
T1-single season spring maize	511.3	86.5	48.93	548.87	9897.6	1.80
T2- single season spring maize	511.3	120.2	97.03	534.47	10382.9	1.94
T0 in one year	542	307.6	-21.99	871.59	12186.9a	1.40a
T1 in one year	542	86.5	23.62	604.88	9897.6b	1.63b
T2 in one year	542	120.2	43.61	618.59	10 382.9b	1.69b

3.3. Analysis of economic benefits under different planting patterns

From Table 2, by comparing the total costs of the three kinds of planting patterns, we can see the winter wheat-summer maize planting pattern > herbage-spring maize planting pattern > season spring maize planting pattern.

From table 3, by comparing the pure income of the three kinds of planting patterns, we can see the herbage-spring maize > season spring corn planting pattern > winter wheat-summer maize planting pattern, and in the three crops, the income of spring maize is higher, which is about 10,000 Yuan /hm2.

The total cost of T0 treatment accounts for 78.8% of the total output value, the total cost of T1 treatment accounts for about 60.4% of the total output value, and the total cost of T2 treatment accounts for 53.7% of the total output value. The economic benefit of T0 treatment is the worst, because there is more winter wheat irrigation and low summer maize yield, and its total cost accounts for 88.1% of the total output value, resulting in the poor economic benefit of the whole treatment. In general, herbage-spring maize has the best economic benefit.

Table 2. Cost analysis of different planting patterns

Crops	Total cost (Yuan $\cdot hm^{-2}$)	Cost contents (Yuan $\cdot hm^{-2}$)						
		Arable land	Straw smashing	Irrigation cost	Seeds	Organic fertilizers	Compound fertilizers	Urea
Winter wheat	9 610	900	750	3125	900	/	2 250	1 685
Summer maize	11 512	/	750	/	900	4 808	2 886	2 168
T0 winter wheat + summer maize	21 122	900	750	3125	1 800	4 808	5 136	3 853
T1 spring maize	13 284	900	750	872	900	4 808	2 886	2 168
T2 spring maize and triticale	14 533	900	750	1221	1 800	4 808	2 886	2 168

Note: The cost of Shangzhuang test station includes 500 Yuan /t organic fertilizer, 3000 Yuan /t compound fertilizer, 2500 Yuan /t urea and electricity 50 Yuan /h electric charge.

Table 3. Economic benefit analysis of different planting patterns

Treatment	Crops	Total output value (Yuan $\cdot hm^{-2}$)	Total cost (Yuan $\cdot hm^{-2}$)	Net income (Yuan $\cdot hm^{-2}$)
T**0**	Winter wheat	13 850	9 610	4 240
T**0**	Summer maize	12 951	11 512	1 439
T**0** in one year	Winter wheat, summer maize	26 801	21 122	5 679
T**1** in one year	Spring maize	21 974	13 284	8 690
T**2** in one year	Spring maize	27 050	14 533	12 517

Note: in 2011, the purchase price of winter wheat was 2,180 Yuan /t, and the purchase price of maize was 2,220 Yuan /t.

4. Conclusion

1) From the characteristics of soil moisture content with the change of soil depth, the soil moisture content under T1 and T2 treatments increases gradually with the increase of soil depth, and the range of moisture change under the two treatments is consistent. The soil moisture content under the T0 treatment increases first, then decreases and finally increases with the increase of soil depth, and the range of moisture change is lower than that of T1 and T2 treatments.

2) Under the T0 treatment, the annual yield is 12.2 t/hm^2 and the yields of maize under the T1 and T2 treatments are 9.9 and 10.4 t/hm2 respectively, and the total grain yield of T0 treatment is 20.2% higher than that of T1 and T2 treatments. The yield of T0 treatment is higher than that of T1 and T2 treatments, but its rainfall is low in proportion to the total water consumption and it needs more than 204 mm of groundwater consumption than T1 and T2 treatments in average. The rainfall under the T1 treatment can meet the crop water consumption to a higher extent, but its yield is the lowest among the three planting patterns. The rainfall under the T2 treatment can well meet the crop water consumption, and its yield is between that of the other two treatments.

3) The net incomes of T0, T1 and T2 treatments are 5,679, 8,690 and 12,517 Yuan / hm^2 respectively. The test results show that the economic benefit of T0 treatment is 46.4% lower than that of T1 and T2.

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