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# Analysis on Responses of Drought Stress on Soil Moisture and Maize Yield Structure

Ji Xiaona, Chen Yunxi, Yu Huayou
Inner Mongolia Ningcheng bureau of meteorology, China, Chifeng
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**Abstract.** Taking the drought stress and normal irrigation fields where plant the same varieties of corn, an experiment by drilling soil was conducted to study the effects of drought stress on characteristics of the soil gravimetric moisture content, water storage and water consumption. The result showed that the effect of drought stress enhanced significantly after the tasseling stage, the soil moisture was markedly lower than that in the normal irrigation field. During the reproductive period, the soil water storage of drought stress area was lower than the normal irrigation field, and the variation of the soil water storage in shallow layer was bigger and smaller in the deep layer. Moreover, the drought stress influenced on the maize yield seriously, and the indexes of maize yield under the drought stress were significantly lower than the normal water treatment, the hundred grain weight decreased by 23.3%, and the grain yield fell by 35.6%.

**Keywords:** Drought stress; soil gravimetric moisture content; Water storage; Water consumption

## 1. Introduction

Ningcheng county is a semi-arid monsoon climate zone located in the south of Chifeng city. Its topography is high in west and low in east, and solar-thermal resources is abundant, but lack of natural precipitation, and uneven distribution of time and space. Under the comprehensive influence of climate, hydrology, geology, soil and topography factors, floods occur occasionally. There are two rivers that across the county from southwest to northeast and form the backbone of irrigation and drainage, and its irrigation condition is better. The county is divided into four seasons obviously: Spring warm up quickly, wind is far larger and more, rainfall is less, climate is dry, and spring drought is frequent. In summer, the condition of high temperature, concentrated rainfall, simultaneous rain and heat is favorable for the growth of crops, but sometimes heavy rain causes flooding, and summer drought is frequent in recent years. Autumn is short and fast, temperature drops quickly, enough sunlight is beneficial to mature and harvest of crops, but the change probability of rain is large in autumn, sometimes the continuous wet weather occurs. The cold and dry winter has less rainfall, and a cold wave invades regularly. In conclusion, the weather of county is complex and changeable, disasters is various, frequent and large-scale, these seriously restrict the economic development, and drought is one of the most serious meteorological disaster.

Ningcheng county dominated by agriculture is an important commodity grain base in Inner Mongolia. In 2015, the crop planting area of county is 1.59 million unit area which covers corn of 975000 unit area that accounts for about 60% of the cultivated area. Drought reduces the maize yield by 25% ~ 30%, even lead to rejection in parts of the regions, is the first limiting factor which influence corn growth and yield in arid and semiarid regions[1-2]. Rahmat (2007) indicated that the yield components and grain yield were significantly affected by water supply. Sen (1952) recorded highest yields from irrigation and recommended irrigation at the tasseling and flowering stages. For insufficient water in Ningcheng, the research on influence on the soil moisture change and corn yield under the drought stress is helpful to find a more reasonable irrigation mode to enhance production on the basis of reducing appropriately irrigation water, which improves fully the efficiency of using water and provides scientifically decision-making serve for field management.

## 2. Materials and Methods

### 2.1 Materials

The experimental data is from the observation data in the whole growth period of corn in 2015, the corn planting area is located in a village of Ningcheng where annual average temperature is 7.3℃, annual rainfall is 444.5mm or so, April-September rainfall is 404.1mm. The soil texture is silt , pH value is 8.58 and a weak alkaline, underground water level is about 8m, the volume weight of soil between 10cm and 50cm is 1.37 ~

1.48 g/cm3, field moisture capacity is 21.1%～28.5%, wilting moisture is 2.6%～5.7%. In 2015, the average temperature is 8.2℃ higher than the calendar year 0.9℃, the annual precipitation is 365.2mm fewer than the calendar year 17.8%.

In 2015, maize variety is 'Jade 4' which was sowed on April 20 and mature on September 22, the growth period is 155d. The experimental field was divided into normal irrigation(NI) and drought stress(DS) field, whose acreage was 0.11hm2 and 0.1hm2 respectively. The two fields adopted the horse-drawn plough, seeding rate was 60kg/hm2, sowing depth about 0.06m, spacing 0.5m, planting distance 0.37m, and fertilized diammonium phosphate 375 kg/hm2 before sowing. NI irrigation mode: the first irrigation was completed on June 25 with 1046.2m3, the second on August 4 with 900.0m3, and the last on August 21 with 200.0m3. DS irrigation mode is without irrigation in the whole growth period. There are 55 rainfall in the whole growth period with 263.5mm.

### 2.2 Methods

During the period of getting the experimental data, we drilled the soil of two fields to get the weight of soil moisture content of the sample on the eighth day every ten-day, double repeated experiment from 10cm to 50cm for a layer of per 10cm were conducted in each section, each experiment repeated 50cm. Soil gravimetric moisture content was measured by drying and weighing the soil sample, and calculated the total soil moisture storage( $S$ ) and water consumption( $CW$ ) [5] further.

$$S = 10 \times \sum_i \rho_i \times w_i \times h_i$$

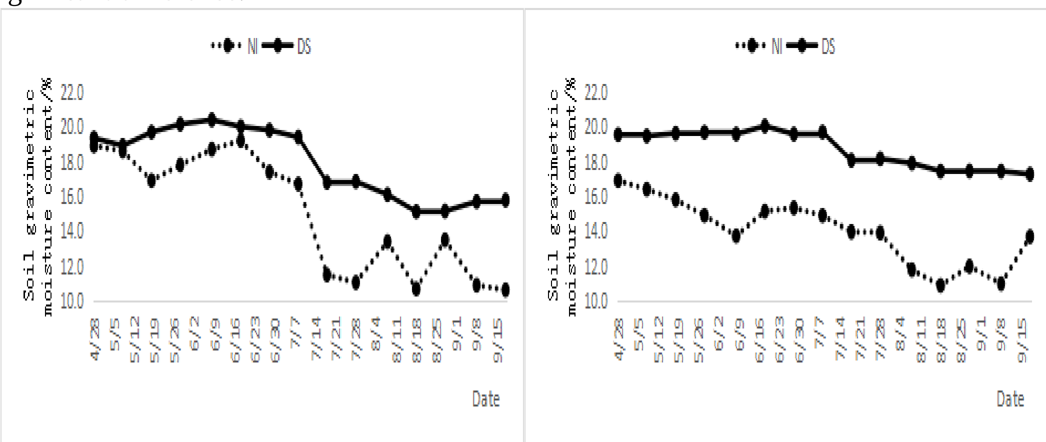
Among them, $\rho_i$ 、 $w_i$ 、 $h_i$ is the volume weight of soil、the soil gravimetric moisture content and the soil thickness in the -th layer respectively, $i = 1,2,\ldots 5$ is the soil layer.

$$CW = R + I + \Delta S$$

And $R$ is the precipitation, $I$ is the irrigation amount, and $\Delta S$ is the change of the soil water storage. For the drought stress area, $I = 0$ . Moreover, due to the groundwater level is more than 8m, supplemental groundwater is neglected.

## 3. Results and Analysis

As shown in fig. 1a), the soil moisture between 10cm and 20cm change relatively severe under drought stress, the soil gravimetric moisture content is lower than that under normal irrigation 16.9% in the whole growth period. Due to abundant rain, the change trend of soil moisture content of two fields is close from sowing to seeding stage. In late June, crop enter the jointing stage, and have a gradual increase in demand for water, the weight of soil moisture content curve has a downward trend. Especially in July, the weight of soil moisture content decline obviously under drought stress at the beginning of drought, and begin to be lower than the normal water supply field. After supplying water on July 20, the soil moisture content of two fields appear a significant difference.

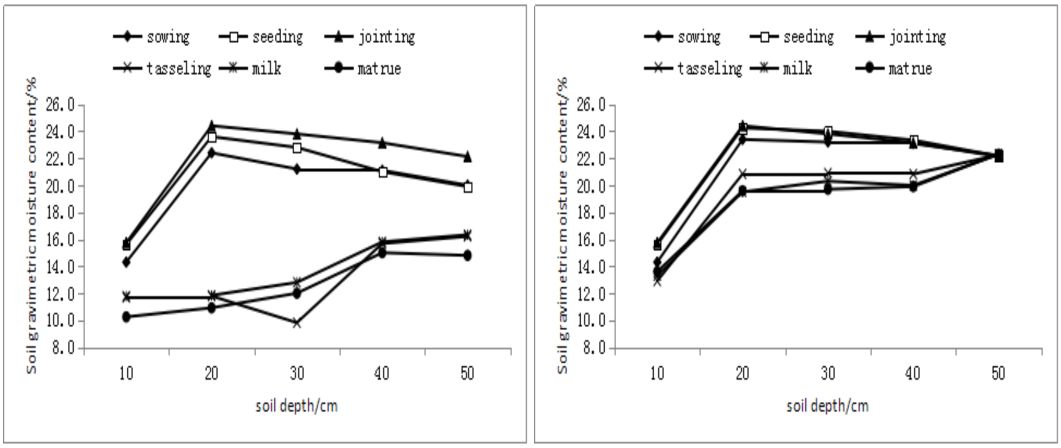



a) 10 ~ 20cm soil moisture content b) 30 ~ 50cm soil moisture content

Fig.1. Soil gravimetric moisture content under drought stress

As you can see from fig. 1 b), the soil moisture content of 30~50cm change relatively flat than 10~20cm under drought stress. With the growth of crops and duration of drought stress, the shallow soil is not enough to supply moisture that crop require for normal growth and development, and root increase gradually the use of deep water, resulting in a bigger decline of the soil moisture content in deep soil layer. The soil gravimetric moisture content of two fields have a downward trend, and that under drought stress is decreased in large amplitude, especially after tasseling(July 18), the difference of soil moisture content has an increasing gap. The soil gravimetric moisture content in normal water supply field between 30cm and 50cm is higher than that in drought stress field 33.5%. Drought stress, therefore, is to improve the utilization of deep soil moisture.

As showed by fig. 2, the variation curves of the weight of soil gravimetric moisture content at two fields are almost unanimous before the implementation of water control, and the longitudinal distribution of the soil gravimetric moisture content under drought stress appears an obvious separation zone after the implementation of water control. It shows that with the increase of demand for water, drought stress effect increases significantly after the implementation of water control, the soil moisture decreases gradually, and reaches its minimum level in the mature stage. The longitudinal range of the soil moisture content in normal water supply field is 4.8% or so in the whole growth period, smoother than that under drought stress for 14.0%.




a) drought stress field b) normal water supply field

Fig.2. Longitudinal distribution of the weight of soil moisture content at each stage of development

Fig. 3 shows that summer is a minimum phase of water storage. Before the implementation of water control, the soil water storage in two fields which has a minor difference shows a trend of gradual decline. After pouring the water at jointing stage, the soil water storage maintains high level in normal irrigation field and that under drought stress continues to decline. As demand for water of corn growth increased, the soil water storage has certain decline, especially fall fast at corn tasseling stage, but the irrigation quickly replenishes the soil moisture, and ensures the water condition of crop. Due to lack of irrigation in drought stress field, soil water storage is falling, and significantly lower than that in normal irrigation treatment.

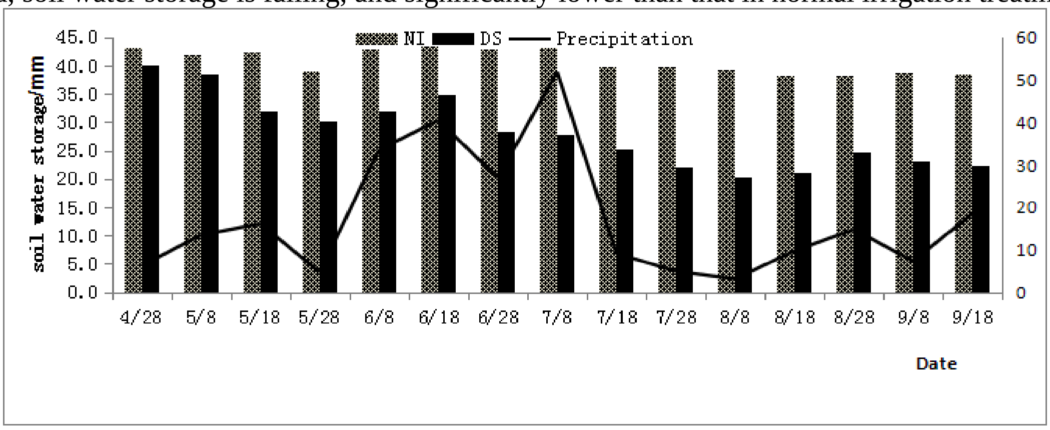



Fig. 3. Variation of soil water storage and precipitation under drought stress

As shown in fig. 4, the soil moisture variation in shallow(10~20 cm) is bigger, and that in deep(30~50cm) is stable relatively, it illustrate the crop growth and development mainly consume the moisture in shallow soil. The soil moisture under drought stress is better at the seeding stage on account of the precipitation, but entering the seedling stage, soil moisture loss speed up, soil water storage decline significantly. At the jointing stage, abundant rain adds the shallow soil moisture effectively. with the increasing demand for water of corn germ development, soil moisture runs off faster after the tasseling stage, and reaches the minimum at the mature stage.

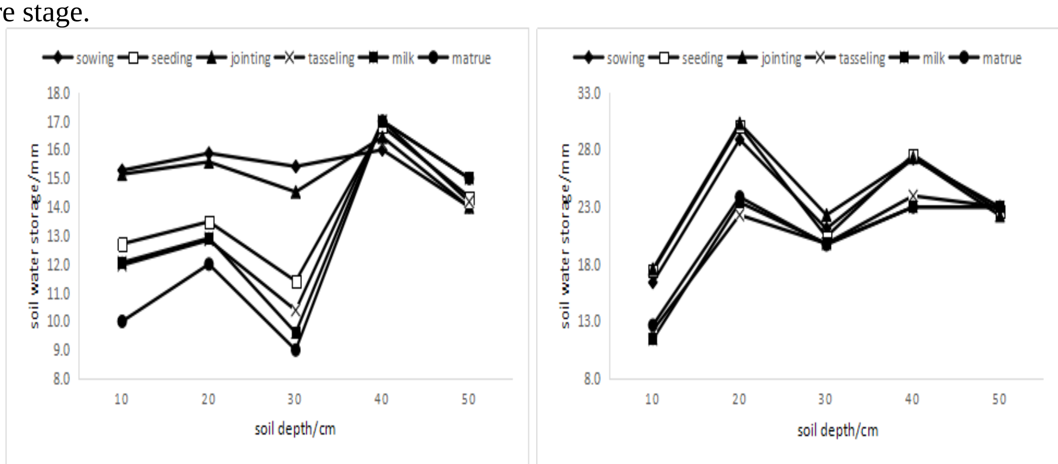



Fig. 4. Longitudinal variation of soil water storage under drought stress and normal water supply

Showed in table 1, irrigation is the main factor affecting the water consumption at each growth stage of corn, water consumption under drought stress is significantly higher than normal water supply field, and with the development of growth period, the water consumption at each stage increase gradually, and reaches its peak between the jointing and milk stage, and starts drop after the milk stage, it shows that the water requirement of crop growth is up to its maximum at the tasseling stage. Affected by precipitation, water is enough in the vegetative growth stage under drought stress, its water consumption intensity reaches a peak between the jointing and tasseling stage, but decreases significantly after the water control. Coupled with the corn growth change from vegetative to reproductive, the demand for water increases, so the water consumption is high always, but is still significantly lower than the normal irrigation treatment because of water control.

Table 1 Water consumption of maize at each growth stage under drought stress (mm)

| Field | sowing-seeding | seeding-jointing | jointing -tasseling | tasseling-milk | milk-mature |
|---|---|---|---|---|---|
| Normal irrigation | 54.0 | 148.0 | 193.2 | 183.8 | 150.6 |
| Drought stress | 48.5 | 75.4 | 114.2 | 102.4 | 50.3 |

As shown in table 2, the maize yield factors of two fields have significant difference, the drought stress affects greatly the external form, yield components and seed setting rate of corn. The height, ear length, stem diameter, ear diameter under drought stress is less than normal irrigation field 15.8%, 15.0%, 26.5%, 17.7%. The stalk empty rate under drought stress reaches 18.1%, it shows that drought lead to fine and short plants and high empty stalk rate, resulting in reduced production. In addition, by measuring the plant grain weight, hundred grain weight, stem weight of mature corns, drought stress field shows 18.0%, 23.3%, 11.9% lower level respectively than the normal water supply.

Table 2 Variation of maize yield factors under drought stress

| Field | height(cm) | ear length(cm) | stem diameter(cm) | ear diameter(cm) | yield(kg/hm$^2$) |
|---|---|---|---|---|---|
| Normal irrigation | 298 | 29.4 | 3.4 | 6.2 | 16350.0 |
| Drought stress | 251 | 25 | 2.5 | 5.1 | 10525.0 |

## 4. Conclusion

1) Soil water characteristics: the variation on weight of soil moisture content and vertical distribution of soil moisture shows drought stress effect is significant after the tasseling stage, soil moisture is lower significantly than the normal water supply field. In addition, the low deep soil moisture in the drought stress field shows the appropriate water control can improve the utilization of deep soil water.

2) Soil water storage features: the soil water storage under drought stress is lower significantly than the normal irrigation treatment, differing by 31.3%. From the vertical distribution, the variation in the shallow layer is bigger than that in the deep. It shows that as long as the suitable shallow water, can satisfy the normal growth of crops. So in order to avoid waste of water, we do not advocate broad irrigation. It is best for sprinkler irrigation or micro-irrigation given certain conditions to optimize truly irrigation.
3) Maize yield factors: drought stress caused serious influence on corn yield, resulting in its production indexes of maize are significantly lower than normal water treatment, the hundred grain weight decrease by 23.3%, and production by 35.6%. The peak of water consumption at the jointing-milk stage illustrate the demand for water of corn is the largest at the reproductive growth stage, so seizing the favorable opportunity for irrigation is helpful to increase production.

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