Research on the Relative Yields as Affected by Soil Moisture and Maize Planting Density

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Abstract: The thesis discussed the changes of soil moisture in maize fields at 2 representative experimental areas in the Songliao Plain, also the relations between soil moisture and yields, soil moisture and density, yield and density etc. It clarified that the most deficient soil moisture was in May under these experimental conditions, and from June to September, the soil moisture was slightly surplus. The yield increase potential of water supplement under different conditions were demonstrated. Coupling equations between soil moisture and density were established which provide a practical reference basis for maize planting in similar areas.

Key words
Maize, densities, soil moisture, yields.

General situations of the research area
Gongzhuling City and Changling County were chosen as experimental areas, the two areas are located at the main production area of the maize belt in China, and have semi humid and semiarid climatic environments. Their average annual precipitation is between 450 mm and 550mm. During the maize growth period, spring is arid; rain fall is concentrated in summer with less rain fall in autumn. The soil at Gongzhuling City is a black soil and that at Changling County is a black chernozem.

Experimental design
Gongzhuling experimental area:
(1) Density: 4 treatments of 45000, 55000, 65000, 85000 plants per hm2. Repeat the experiment 3 times. Plants were randomly arranged.
(2) Water supply: The total water supply amount (including precipitation and irrigation water) in the growth period were: 334mm, 426mm, 500mm, 600mm. Supplied artificially 5 times.
(3) Fertilization and maize varieties: The nutrients applied were: $N:P_2O_5:K_2O=215:92:60$ kg/hm^2. The maize varieties were Jidan 159 and Jidan 209.

Changling experimental area:
(1) Density: 4 treatments of 45000, 55000, 65000, 85000 plants per hm2. Repeat the experiment 3 times. Plants were randomly arranged.
(2) Water supply: The total water supply amount (including precipitation and irrigation water) in the growth period depended on total natural precipitation in the growth period. The target amount was 540mm.
(3) Fertilization and maize varieties: The nutrients applied were: $N:P_2O_5:K_2O=255:80:40$ kg/hm^2. The maize varieties were Yedan 19 and Simi 21.

Experimental methods
During the growth period of maize, soil samples from the soil layers of 0-20, 20-40, 40-60, 60-100 cm were collected from each plot; a drying method was used to determine soil moisture content. Statistical analysis was used to study soil water under different maize planting densities.

Results and discussion
By statistical analysis (Figure 1) the least precipitation months are April and May during the growth period with merely 42.8 mm, accounting for 10% of annual precipitation, which is the peak period of water deficiency, and seriously affected keeping a whole stand of seedlings and restrained maize growth. Local meteorological data reported probability of 30 mm or less precipitation in spring in the area reached 70% or more. The precipitation in June, July and August was 302 mm; accounting for 71% of annual precipitation, the precipitation in September was 41.7 mm, accounting for less than 10% of the annual precipitation.

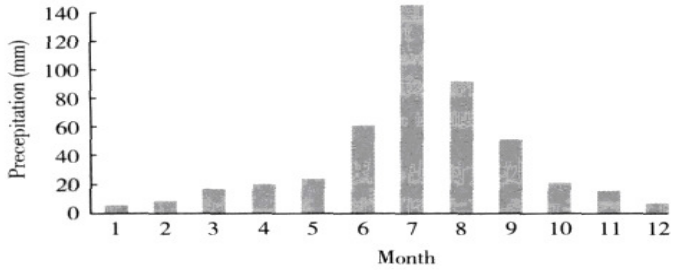

Figure 1. Precipitation distribution

A[illegible]nitoring at the 2 experimental areas (table 1), in Gongzhuling experimental area, the precipitation in the whole growth period was 486.7mm, in spring the deficiency of soil water storage was 26.3 mm, in summer the surplus was 29.8 mm, in autumn the deficiency was 14.5 mm, and in the whole growth period, soil water storage was at the deficient state, the deficiency was 11 mm, and the water deficiency in subsoil was most serious. Under the circumstances of the planting density of maize of 55,000 plants/hm^2, the required water amount was 539 mm, thus the water deficient amount was 176 mm, thus soil water was deficient in spring, surplus in summer and was deficient in autumn.

Table 1. The change of soil water in the whole growth period of maize

Gongzhuling experimental area	Month	March-May	June-August	September-October	Total amount
Precipitation	mm	89.9	313.3	83.5	486.7
Soil layer 0-30 cm	mm	-2.0	+4.5	-3.9	-1.4
Soil layer 30-60 cm	mm	-8.7	+9.9	-4.0	-2.8
Soil layer 60-100 cm	mm	-15.6	+15.3	-6.6	-6.9
Soil water surplus and deficiency in all layer	mm	-26.3	+29.8	-14.5	-11.0
Changling experimental area	**Month**	**June-July**	**August**	**September**	**Total amount**
Precipitation	mm	122	108.5	132.4	362.9
Consumed water amount in all layers	mm	397.4	84.9	56.6	538.9
Soil water surplus and deficiency	mm	-275.4	23.6	75.8	-176.0

The relationship between moisture and density

When 330 mm of water was supplied, the changes of soil water contents did not show changes with changes maize density.

Under the circumstances of water supply being more 426 mm only the density of 85,000 plants/hm^2 showed that moisture content is not enough for maize growing.

In Changling experimental area, under the same water supply circumstances, in soil layers of 0-40cm and 0-60cm, the soil water contents gradually increases in June, July and August, then reduces from high to low from August to October; the relationship between plant density and soil water content was not strong in soil layer 0-60cm; it showed significant effect of density and soil water content in the soil layer under 60cm.

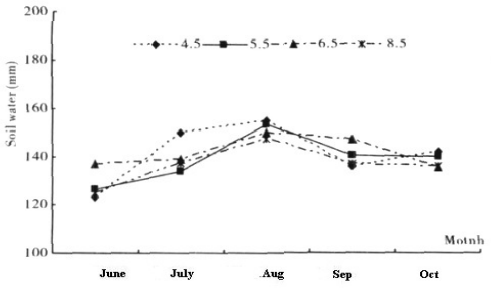

Fig.6 Change of water in 0–40cm layer

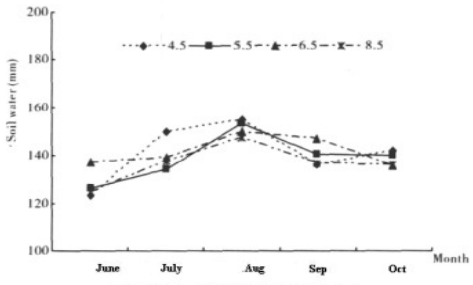

Fig.7 Change of water in 0–60cm layer

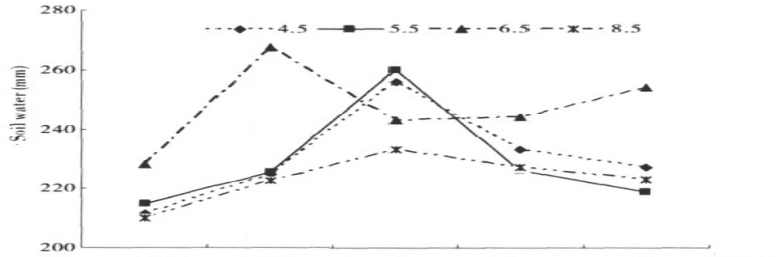

Fig.8 Change of water in 0–100cm layer

The relationship between water and yield

Water supply increased crop yield in from 9.0% ~ 43.4%. The yield increase effect of water supply treatment under 60000 plants per hm^2 were the best, the yield for water supply treatment was 1.4 times as much as that of the no-water supply treatment.

The relationship between yield and density

The maize yield of the maize variety Yedan 19 did not change remarkably with the increase of plant density, the yield at the lower density of 55000 plants per hm^2 was the highest and the yield increase was by 7.1%. The yield of Jidan 159 was reduced as its density increased, the yield for the lower density of 45000 plants per hm^2 was greatest and the yield increase was 20.7% (Table 2).

Table 2. Yield differences under different water conditions

Density	(plant/hm^2)	50000	60000	increase
no-water supply	（kg/hm^2）	6275	6300	0.4%
water supply	(kg/hm^2）	7226	7580	4.9%
Yield increase by water supply	%	15.2%	20.3%	

Analysis of the coupling relations between water and density

Density (x) and yield (y) regression equations are as follows:

Under the conditions of total soil water supply amount being 600mm (R^2=0.9593)

Y= -185X2 + 2090X + 2853.

Under the conditions of total soil water supply amount being 500mm (R^2=0.8247)

Y= -264X2 + 3107X + 1082.

Under the conditions of total soil water supply amount being 426mm (R^2=0.8865)

Y= -58X2 + 477X + 3907.

Under the conditions of total soil water supply being 334 mm (R^2=0.9680)

Y= -61X2 + 499X + 3233.

Conclusion

(1) Changes of soil water: The changes of soil water in the two experimental areas maize fields showed water deficiency at the more arid Changling experimental area was more significant. The temporal distribution of precipitation showed that it was arid in spring, surplus in summer and arid in autumn.

(2) Soil water and density: In the Gongzhuling experimental area and under the circumstances of different water supply, the soil water contents for the 3 densities of 45000, 55000, 65000 plants/hm^2 showed consistent changes from high to low, and then from low to high as maize was growing. Only soil water content of the higher density of 85000 plants per hm^2 showed the changes from low to high, from high to low and at last from low to high. In the Changling experimental area, the supply of soil water in all the layers were different due to different planting densities. In the soil layers of 0-40 cm and 0-60 cm, changes of soil water were not directly related to planting density, the change of soil water in deeper layer of 60-100 cm was closely related to planting density. To conclude that under the circumstances of different water supply amounts, the soil water in the deep layers was related to density. The density of 55000 plants per hm2 was the critical planting density affecting soil water.

(3) Soil water and yield: the amount of soil water directly affected maize yield; the highest yield for the water supply treatment was 1.4 times that for the non-water supply treatment.

(4) Yield and density: In a certain density range, the maize yield was increased with increase of density, but the yield potential of lower density was the greatest, and the yield was increased by 20.7%. There is close relationship between yield and density and the choice of appropriate density is very important.

(5) By simulating the coupling of soil water and planting densities the following information was found: The relations between total soil water supply amount (including precipitation and irrigation water amount) and planting density just has a "S" shape with 3 sections. In the semi-humid and semi-arid Gongzhuling maize planting area, when the total soil water supply amount was less than 400mm and more than 500mm, the upper and lower limits of the planting density of Yedan 19 is between 40000 and 60000 plants per hm^2 respectively. When the total soil water supply amount was between 400mm and 500mm, the maize planting density was linearly positively related to the water supply amount.