Water-saving and Anti-drought Combined Technological Measures' Influences on Maize Yield Formation Factors and Water Utilization Efficiency in Semi-arid Region

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Abstract: Adopting the split sections design method, the influences of water-saving and anti-drought combined technological measures (bed-irrigating sowing, seedling stage mending irrigation, and ridge plotted field water conservation) on maize yield formation factors and water utilization efficiency (WUE) in semi-arid region in china was studied. Through the intensive studies on the dry matter accumulation status, on changes to leaf area, to LAD, to net assimilation rate, to yields and to WUE under different technological measures, the relations between maize yield and the amount of limited water supply and ridge plotted field were obtained, and through the optimization analysis, the regress equations of maize yields under the conditions with and without ridge plotted field were established respectively, and the extent of the water amount for bed-irrigating and mending irrigation were proposed in the paper. [Nature and Science. 2005;3(1):88-94].

Key words: semi-arid region, maize, yield, technology integration, water-saving, anti-drought, water utilization efficiency (WUE)

1 Preface

The scarcity of water resources has been always the restrictive factor on agriculture sustainable intensive development in northeast semi-arid area of china. Utilizing water resources sufficiently, increasing water utilization ratio, developing water-saving irrigation agriculture are efficient measures for the agriculture sustainable development of the region. The influences of water-saving and anti-drought combined technological measure (mechanized implicit bed-irrigating sowing, mechanized seeding stage implicit mending irrigation, and ridge plotted field water conservation) on maize yield formation factors and water utilization efficiency (WUE) have been studied.

Bed-irrigating sowing is a kind of local irrigation method of injecting some fixed quality water into local soil, so that the minimal amount of water for seeds budding can be met. The method has lower cost and easy operation, and it is suitable for the conditions of lower soil water content when sowing in northeast semi-arid regions. Seeding stage mending irrigation is a method of fulfilling cropland crops' water demand by field mending irrigation when cultivation, and it has good effects on anti-drought. Ridge plotted field is a method of dealing with sloping cultivated land. Earth blocks are built in ridges of sloping arable land, Continuous water storage shallow holes are formed, which have effects of holding back rainfall, deferring path flows, preventing from soil erosion, and increasing crop yield.

2 Experimentation conditions and study methods

2.1 Basic conditions of experimentation region

The experimentation locus was selected in the demonstration area of national "863" project named "experimentation and demonstration of Water-saving agriculture integration technology system in anti-drought irrigation area in northeast semi-arid region in china". The concrete experimental locus was in Dongxing village, Gannan County, Heilongjiang province, China. In this region, spring drought was the main restraining factor on agriculture production. The main reasons for spring drought were the shortage of spring rainfall, heavy evaporation quantum; strong spring wind; thin soil layer, coarse texture, no soil-water conservation and large acreage of wind erosion soil.

2.2 Experimentation design

Adopting split sections experimentation design, taking the disposals with and without ridge plotted field as two main disposals, taking the disposals with different amount of water supply (including bed-irrigating and mending irrigation) as subsidiary disposals, we made the experimentation plan. That is, among these sections, the sections with and without ridge plotted field are called main sections (complete sections), the sections divided by the amount of limited water supply are called subsidiary sections (split sections), split sections distributed in main sections. For the two factors including bed-irrigating and mending irrigation in the subsidiary disposals an experimentation plan called two factors twice satiation D-optimization design was adopted. There were 6 experimental disposals, 3 iterations, and all together 36 experimental sections. Each section had a length of 12 m, width of 2.6 m, acreage of 31.2 m^2, and the arrangement was random. The amount of water supply for bed-irrigating and mending irrigation can been seen Table 1.

2.3 Collection and mensuration of samples

Sampling periods included emergence stage, jointing stage, teaselling stage, silking stage, grain filling stage, milk ripe stage, and harvest stage. After analyses and computings, we got physiological parameters such as leaf area, LAD, net assimilation ratio, dry matter weight, economic coefficient, water utilization efficiency and etc, and gained spike length, kilo-grain weight, single grain weigh etc.

Table 1. The amount of water supply for bed-irrigating and mending irrigation

Disposals	Bed-irrigating quantum（m^3/hm^2）	Mending irrigation quantum（m^3/hm^2）
1	0	0
2	120	0
3	0	120
4	52.05	52.05
5	120	83.70
6	83.70	120

Crop variety for experimentation was maize (Haiyu 4).

3 Results and analyses

3.1 Dry matter accumulation status under different technological measures

The results indicate that the dry matter for single plant above ground measured continuously fits the "S" type of plant growth in the whole procreation process. At the same time, under different water supply conditions, dry matter accumulation of different procreation stage represents distinctive diversity. From the view of water supply gross, the more supplied water, the more dry matter accumulation of disposals (Figure 1, 2). Contrasting the effects between bed-irrigating and mending irrigation, we can draw the conclusion that mending irrigation has more distinct help for the increase of dry matter accumulation than bed-irrigating under the same condition of water supply gross. From the view of effects of ridge plotted field, disposals with ridge plotted field increase 5.6% to disposals without ridge plotted field in average.

3.2 Changes to leaf area under different technological measures

The main photosynthesis organ of maize is leaf, namely the more leaf area, the more absorption of solar energy, the more yields [3]. So study on leaves changes of different disposals is necessary for the study on yields under different technological measures.

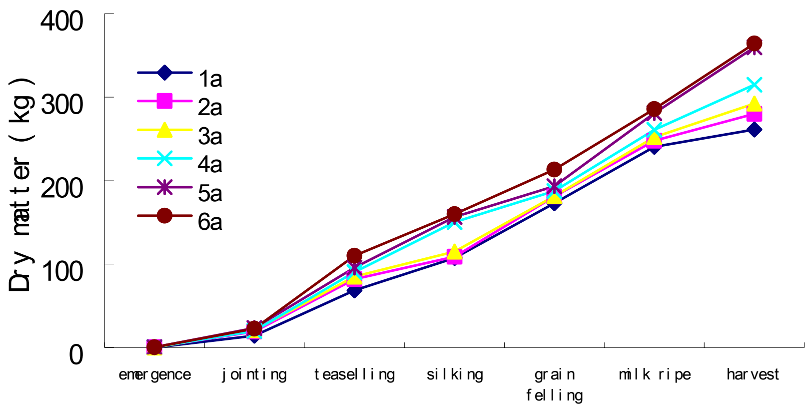

Figure 1. Contrasts on maize dry matter accumulation without ridge plotted field

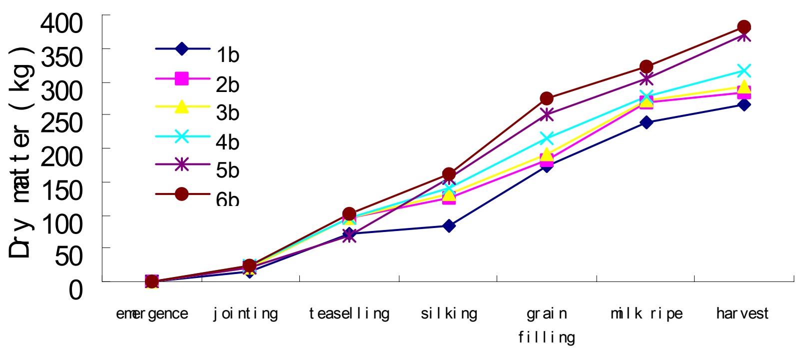

Figure 2. Contrasts on maize dry matter accumulation with ridge plotted field

Since an infrequent drought occurred in Gannan county in 2003 and 2004, maize leaves fell off ahead of schedule, maize plants had no enough leaves for photosynthesis in milk ripe stage, but from figure 3 and 4 mentioned above, we can find that leaf area in more water supplied dispose is bigger regardless with ridge plotted field or not, leaf area with more bed-irrigating is smaller than those with more mending irrigation when water supply grosses are same. This shows that mending irrigation's effects are more marked than bed-irrigating at the two experimentation years. From the effects of ridge plotted field, single plant leaf area of disposals with ridge plotted field increase 173.9cm^2 to those without ridge plotted field, that is ridge plotted field have relative good effects.

3.3 Changes to LAD under different technological measures

The longer plant photosynthetic production accumulation time, the higher plant LAD, and the higher yield correspondingly. From the figure 5, it is obviously that the LAD of the disposals with ridge plotted field are higher than those without ridge plotted field under same amount of water supply; disposals' LAD increase along with the increase of water supply basically under same ridge plotted field conditions.

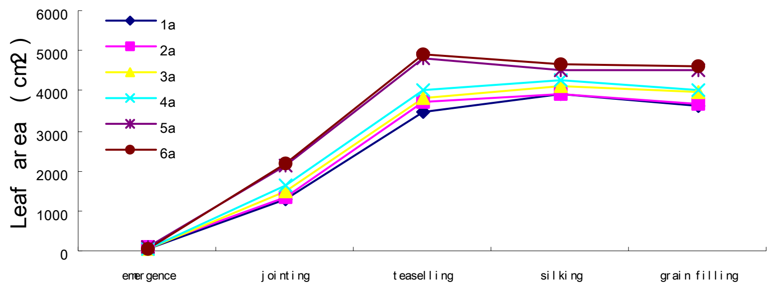

Figure 3. Maize leaf area contrasts of different disposals without ridge plotted field

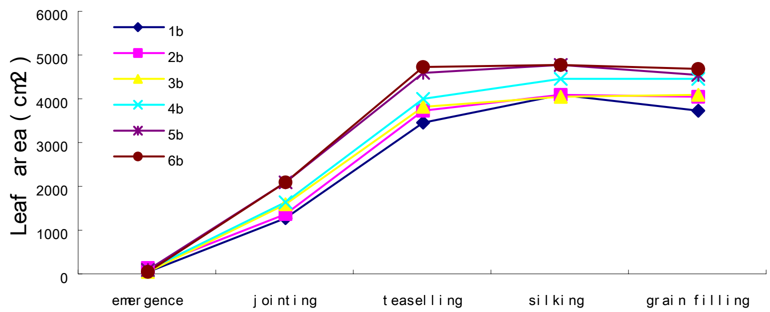

Figure 4. Maize leaf area contrasts of different disposals with ridge plotted field

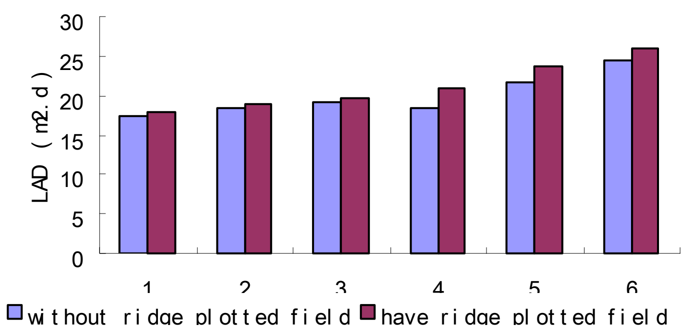

Figure 5. Maize single plant LAD contrasts of difference disposals

3.4 Changes to net assimilation rate under different technological measures

From the whole tendency, changes to net assimilation rate in maize growing period can be divided into 3 stages: rise stage, decline stage and rise again stage.

From the effects of ridge plotted field, the net assimilation rates in the disposals with ridge plotted field increase 6.74% to those without ridge plotted field in average (Figure 6, 7). From the effects of water supply, disposals with more water supply gross have higher net assimilation ratio in each stage basically, and it is obviously that the effects of bed-irritating are rather distinct, prophase net assimilation rates of disposal 2 are relative high regardless with ridge plotted field or not. On the whole, mending irrigation's effects represent more evident.

3.5 Changes to economic coefficient under different technological measures

Economic coefficient is the ratio of economic yield and biological yield, and it reflects the efficiency of biological yield convert into economic yield. From

Figure 8, we can conclude that under same water supply conditions, disposals' economic coefficients with ridge plotted field are higher than those without ridge plotted field, and increase 8.4% in average; under same ridge plotted field conditions, disposals' economic coefficients increase along with the increase of water supply basically.

3.6 Changes to yields under difference technological measures

The disposals' yields can be seen in Table 2. The statistic software—SAS was used in maize yields analyzing, and the regress equations are as follows:

a. Regress equation of maize yields under the condition without ridge plotted field:

$$\hat{y} = 4006.00 + 13.939x_1 + 14.871x_2 + 0.834x_1x_2 - 0.090x_1^2 - 0.073x_2^2$$

b. Regress equation of maize yields under the condition with ridge plotted field:

$$\hat{y} = 4169.33 + 18.389x_1 + 8.055x_2 + 0.081x_1x_2 - 0.119x_1^2 + 0.001x_2^2$$

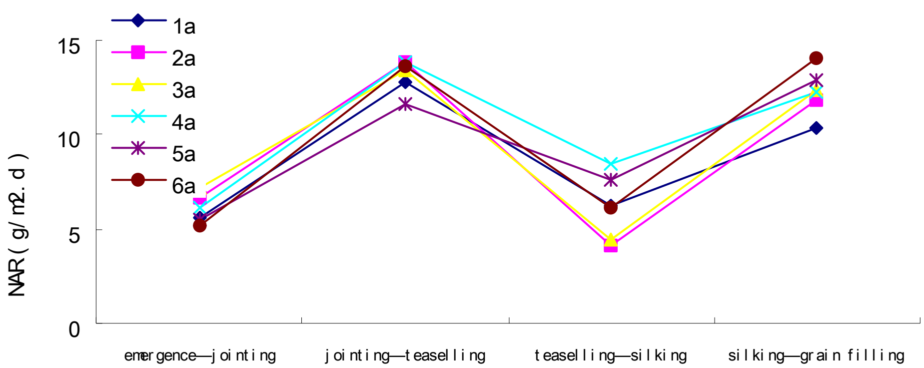

Figure 6. Maize single plant NAR contrasts of different disposals with ridge plotted field

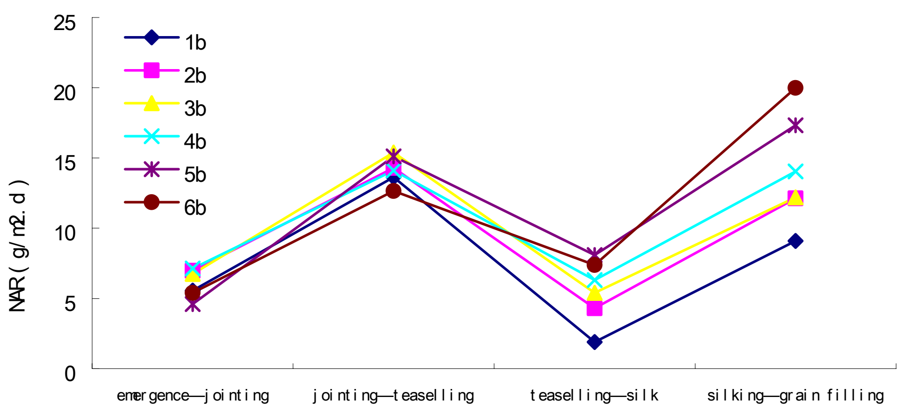

Figure 7. Maize single plant NAR contrasts of different disposals without ridge plotted field

We can conclude that under same water supply conditions, disposals' yields with ridge plotted field are always higher than those without ridge plotted field, and increase 5.8% in average. For getting the optimal amount of water supply for bed-irrigating and mending irrigation respectively, we optimize the equations above, and gain: when we fix a kind of water supply factor to some level, maize yield increase along with the increment of another water supply factor basically regardless with ridge plotted field or not, and the maximal theoretical quantum occurs when bed-irrigating quantum is $120m^3/hm^2$ and mending irrigation quantum is $120m^3/hm^2$.

3.7 Changes to WUE under different technological measures

According to the soil moisture differences in 1m depth under the ground surface between the stages of sowing and harvesting, and the amount of irrigation water and rainfall in the whole growing period, the amount of water consumption in all disposals' in the whole growing period were obtained, and the farmland WUE (kg/m^3) was calculated.

From Table 2 we can conclude: ①the WUE increase along with the increment of limited water supply basically regardless with ridge plotted field or not; ②Under same water supply conditions, WUE of disposals with ridge plotted field are always higher than those without ridge plotted field, the WUE increase range from 16.35% to 39.47%, and 5.8% in average; ③Under same water supply quantum conditions, disposal 3 behaves higher WUE than disposal 2, disposal 6 behaves higher WUE than disposal 5, these show that effects of seedling stage mending irrigation toward maize WUE are better than those of bed-irrigating.

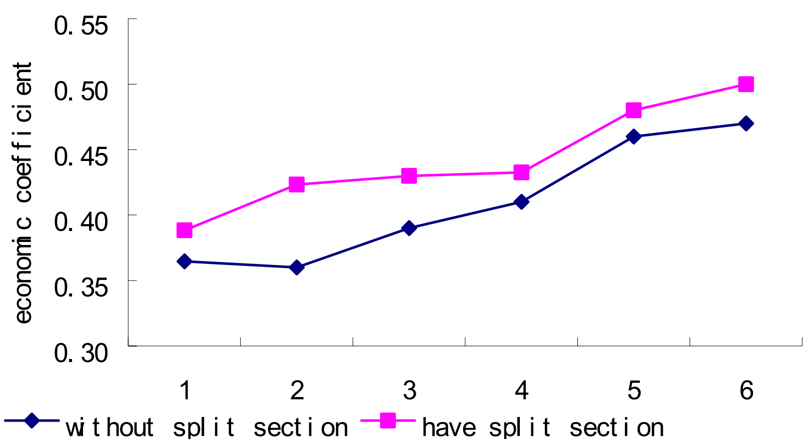

Figure 8. Maize economic coefficient contrasts of different disposals

Table 2. Maize yields and WUE under different disposals conditions

Disposals	Farmland with ridge plotted field.		Farmland without ridge plotted field.		Yields increment (kg/hm²)	WUE increment (%)
	Yields (kg/hm²)	WUE (kg/ m³)	Yields (kg/hm²)	WUE (kg/ m³)		
1	4169	1.32	4006	0.95	163	39.47
2	4660	1.39	4385	1.19	275	16.35
3	5151	1.75	4733	1.27	418	37.72
4	5456	1.67	5298	1.35	158	23.89
5	6163	1.92	5957	1.58	206	21.74
6	6674	1.97	6110	1.59	564	23.65

4 Conclusions

a) The dry matter production of maize for single plant is influenced by the factors of procreation period, leaf area, LAD, and NAR and so on. The analyses of the influences of water-saving and anti-drought combined technological measures on these factors make clear that they have the same tendency with dry matter accumulation: under the same water supply quantum conditions, effects of mending irrigation are better than those of bed-irrigating; from the effects of ridge plotted field, effects of disposals with ridge plotted field are higher than those without ridge plotted field.

b) 4.2 Through statistic analyses, the relations between maize yield and limited water supply and ridge plotted field were obtained, and the optimization analysis were made, from which theoretical extent of the water amount for bed-irrigating and mending irrigation were deduced, and drawing the conclusion that ridge plotted field can increase yield.

c) 4.3 From the analyses of WUE under different technological measures, we can see that ridge plotted field can increase the WUE efficiently under the experimental conditions, and that effects of seedling stage mending irrigation toward maize WUE are better than those of bed-irrigating.

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