Study on Demonstration of Mulched Drip Irrigation in Maize Field under Surface Water in Mountain Area

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Abstract. In recent years, the technology of water-saving irrigation in agricultural irrigation is strongly supported and promoted. Plastic film mulching cultivation with Chinese characteristics has been widely promoted and applied in plain areas, but also is exploring researched in mountain area. In this paper, according to conditions of complex mountainous topography and elevation changes, mulched drip irrigation in maize field is designed and studied under surface water as water source. The reasonable optimization of design and obtained economic efficiency are also explained.

1. Introduction
China is a large agricultural country. But China is also a country of shortage of water resources [1]. Per capita water resources quantity only accounts for 28% of the world's per capita level.

The distribution of limited water resources is also very uneven in spatial and temporal. In China, there is the dryland of 70 million hm² that completely depend on rain-fed. Therefore, drought and water shortage are currently one of the main factors restricting the development of China's agricultural. Along with the intensification of contradiction between supply and demand of water resources, developing water-saving agriculture is fundamental way to solve the shortage of water for China's agriculture. The utilization of limited water resources is also improved.

The water consumption of agriculture accounted for 63% of the total water consumption in China, where 90% is the irrigation water. The micro-irrigation area in field accounted for about 10% of total micro-irrigation area. According to statistics, the application area of technology of mulched drip irrigation in field in china has reached 5 million mu (1mu=666.7 m²) and is the largest in the world [2]. The technology of mulched drip irrigation is widely promoted and applied in arid area of China’s Northwest [3]. Therefore, China has been in the world’s leading level in aspect of researching this technology.

At present, in Inner Mongolia autonomous region, the technology of mulched drip irrigation in field under surface water is basically used in the projects of effectively water-saving irrigation. But these project area is mostly plain, where the elevation difference has a small change and water-saving irrigation area is also not big in the single project.

Demonstration area of this research is located in small Nanjingwa village, Liujiazi town, Kulun banner, Tongliao city, Inner Mongolia autonomous region. Arable land of demonstration area is
distributed both sides of small Nanjingwa reservoir in Nanjingwa river middle reach that is raising livestock river. The cultivated area in the village is 4800 mu (1 mu=666.66 m²).

Demonstration area is situated in mountain area in south of Tongliao city. The climate is semi-arid temperate continental monsoon climate and the regional rainfall is annual 420 mm. Groundwater resource also is poor and unable to meet irrigation needs. The topography is very complicated, the arable land is relatively concentrated, and the maximum elevation difference reaches 41.7 m.

Small Nanjingwa reservoir is a middle-sized reservoir and has water all year. Only more than 100 mu of arable land near the reservoir in the village are able to pump water for irrigation.

In this paper, by referencing many domestic design and construction methods of mulched drip irrigation in maize field and studying demonstration areas [4-5], the system of mulched drip irrigation is safely and reliably operated under the condition of mountain area, the food production is increased, and the area of efficient water-saving irrigation is also expanded.

2. Engineering Design

2.1. Irrigation Water Capacity

In this design, supply-demand balance analysis is computed only for surface water resources [6]. The irrigation quota is 150 m³/mu and the annual irrigation water volume is 664,100 m³.

2.2. Cultivation Pattern

The design of demonstration area is combined with practical application, and rational close planting is proceed in size-ridge way. Drip tape spacing is 1.2 m, big ridge line spacing of crop is 0.8 m, and small ridge line spacing is 0.4 m. Two rows of crops feature a drip tape and the drip tape is placed in the middle of two rows of crops. That is the cultivation pattern of 1 mulch and 1 tube and 2 rows.

2.3. Design Parameter Determination

That is mainly maize crops of field-grown in demonstration area. Considering the soil texture and drop head flow, and according to the water requirement of crops and the local natural conditions, the percentage wetted area in design is 70% [7].

The locality is the arid area, so the maximum daily water consumption intensity takes the upper limit value 6 mm/d. Under the reasonable irrigation system, the plan moist soil layer depth takes 0.45 m according to local field crops empirical value scope 0.3~0.6 m.

The land of demonstration area is loam. Soil bulk density takes the average 1.55 g/cm³. The upper limit of suitable soil moisture takes θ_{max}=22% and the lower limit takes θ_{min}=17%.

The diameter of drip tape is 16 mm. The emitter is inner labyrinth type. The dripper flow is 2.2 L/h, the dripper spacing is 0.3 m, and the operating pressure-head is 10 m.

3. Reasonable Optimization of Design

In this study, under the conditions of complex mountainous terrain and greatly topography elevation difference, mulched drip irrigation system in maize field is designed using surface water as water source. Optimization scheme of hydraulic calculation, pipe network arrangement, etc. is proposed.

3.1. Pipe Network Optimization

The crops in demonstration area is field crops, so the design and choose of the pipe network [8] need to be considered variously. To facilitate construction, adapt to field operation, and facilitate the calculation and demand of management, the lateral of same diameter should be selected. In the different slope situation and in order to make the pressure difference on both sides of lateral to be same, the length of lateral in downhill is bigger than in the uphill. The diameter of main pipe is calculated by the calculation formula of economic pipe diameter [9], and its arrangement form is similar to the arrangement of lateral. Finally, the adverse nodes are determined and the check calculation is perform in underground pipe network.

The elevation difference of the southwest corner and the northeast corner in demonstration area are more than 40 m. In order to ensure the drip system reasonable, reliable and safe operating, firstly,
based on measuring topographic, the district is developed within suitable range of elevation difference. Then the plots is rationally partitioned and marked in each district. The typical plot is selected and hydraulic calculation is proceed according to related formula of the regulations [6]. According to the calculating results, the design parameters are determined, the pipe network is optimally arranged, and the rotation irrigation area is delineated. 2~4 hydrants that is typically adverse e nodes are selected and marked in given rotation irrigation area. The design flow is inverse deducted to determine whether which meets the design requirements. If it do not meet, then the re-adjusted is need to be done. The opening number of each hydrants is determined and the reasonable pressure that the drip irrigation required is calculated. The pressure in each rotation irrigation area setting by frequency conversion equipment.

In this design, in order to save investment, the manifold and its main pipe are arranged in parallel.

3.2. Equipment and Materials Optimization
The water resource of mulched drip irrigation of field-grown in demonstration area is surface water. The filtering barrier is placed in front-chamber of inlet pool at the edge of the reservoir. The stainless steel mesh is placed in the middle of inlet pool. The filter head is placed at the exit of impounded body. Before entering the underground pipe network, the filter facility of combination of sand filters and 200 mesh screen filters is used in pressure pump house. There are five filtering.

There are new drawing water pump house and pressure pump house in demonstration area. Low-carbon composite centrifugal pumps are used. In drawing water pump house, the main pump in is 90 kw and its installed flow is 586.60 m³/h, and stand-by pump is 45 kw and its installed flow is 92.1 m³/h. In pressure pump house, two pumps supply water and their installed power are both 90 kw, and their installed flow are both 370 m³/h. A reinforced concrete impounded body buried in the underground is build near the pressure pump house and its capacity is 600 m³.

The pump is choose by considering each rotational irrigation group. The flow required by drip irrigation is as design flow and the diameters of all levels of pipes are determined considering the factors of economic pipe diameter. Then the operating points of pump in each rotational irrigation group are checked.

The pump of drip irrigation system uses variable-frequency adjustable-speed squirrel cage induction motor which has many advantages including large frequency range, hard mechanical characteristics, high speed precision, smooth inorganic speed, and so on. In this design of drip irrigation system, the economic adaptability is reasonable analyzed and the appropriate frequency conversion device is choose.

3.3. District Arrangement and Computation Optimization
In order to make the hydraulic design of subunit more conform to the actual conditions of terrain and topography, the arable land of demonstration area is divided into two districts of east and west that respectively provided with irrigation water by two pressure pumps in pressure pump house at central of the demonstration area. In each district, the plots is partitioned and marked according to the crop-ridge and the topographic feature combined with actual situation.

The arable land is larger and the crop-ridge are varied in the demonstration area. Therefore the hydraulic calculation is based on actual topographic slope. After the pipe network is arranged, the hydrants that is typically and adverse are selected in rotation irrigation in marked plots. Then the flow is checked and the irrigation pressure is determined. If it is necessary, the arrangement is adjusted.

3.4. Structure Optimization
The drawing water pump house and the pressure pump house are both semi-underground reinforced concrete structure.

In right abutment of Nanjingwa reservoir, the area in which the conditions of topography and geology are both appropriate is selected as the address of drawing water pump house. The structure of pump house is design considering the effects of design water level of reservoir and the normal impounded water level. The inlet pool of pumping station is the structure of reinforced concrete and caisson of two-chamber. Front-chamber play a role in water diversion and water catchment. Water
enters drawing water pump after it is filtered by stainless steel mesh in the middle of inlet pool. Finally, water is delivered to impounded body.

Pressure pump house is located in central of irrigation area, near impounded body. The water level of supply water is higher than inlet elevation of pressure pump. When pressure centrifugal pump supply water for pipe network, the vacuum pump is need to be matched. The problem of vacuum degree when the centrifugal pump supplies water is solved, and the investment is saved.

4. Comparison of Grain Production

According to the statistics of grain production in demonstration area that is provided by agriculture technology and popularization center of Kulun banner in Tongliao city, the grain production is compared from 2013 to 2018, and the statistics are in the following tables.

Table 1. Comparison of corn production from 2013 to 2018 in demonstration area

| Year | Planting pattern | Breed          | Row spacing (m) | Planting spacing (m) | Representative area (mu) | 100-Seed weight (g) | Theoretical production (kg) | Actual production (kg) |
|------|------------------|----------------|-----------------|----------------------|--------------------------|----------------------|----------------------------|------------------------|
| 2013 | Tradition        | Zheng dan 958  | 0.5             | 0.47                 | 1000                     | 35.5                 | 471.20                     | 400.52                 |
| 2014 | Mulched drip irrigation | Zheng dan 958  | 0.6             | 0.31                 | 4000                     | 38                   | 801.99                     | 681.69                 |
| 2015 | Mulched drip irrigation | Zheng dan 958  | 0.6             | 0.32                 | 4000                     | 38.2                 | 779.64                     | 662.69                 |
| 2016 | Mulched drip irrigation | Zheng dan 958  | 0.6             | 0.30                 | 4000                     | 38.1                 | 787.35                     | 676.58                 |
| 2017 | Mulched drip irrigation | Zheng dan 958  | 0.6             | 0.31                 | 4000                     | 38.4                 | 763.65                     | 679.21                 |
| 2018 | Mulched drip irrigation | Zheng dan 958  | 0.6             | 0.32                 | 4000                     | 37.4                 | 738.69                     | 671.33                 |

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6. References

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