

Research Progress of New Water-saving Technology of Surface Irrigation in China

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Keywords: Surface irrigation, Water saving, Irrigation technology, Research progress.

Abstract. The effective way to resolve the shortage of agricultural irrigation water resources is the research and application of new water-saving technology of surface irrigation in China. The aim of this paper is to improve the quality of field irrigation and water use efficiency, introduced two advanced water-saving irrigation technologies which were the improved ground irrigation technology and the precision surface irrigation technology. The improved ground irrigation technology mainly carried out the water-saving border irrigation technology, furrow irrigation technology and surge flow irrigation technology, and the precision surface irrigation technology mainly carried out control technology of the laser controlled land leveling and real feedback control technology of surface irrigation process. Through the promotion and application of the above technologies, improve the level of irrigation management and the quality of surface irrigation, obtain the effect of save water and increase production, promote the development of modern agriculture in China.

Introduction

As an ancient field irrigation technology, surface irrigation is most widely used in the world currently, it is the use of ground ditch, border or separate plots as a water interface, making the water into the field under the action of gravity into the crop farming area soil in order to achieve the purpose of irrigation. Surface irrigation technology has many advantages such as simple field engineering facilities, low investment, low energy consumption, easy implementation and so on[1]. In many areas, surface irrigation is still a suitable irrigation method. At present, more than 90% of the world's irrigated land applying surface irrigation, especially in China, more than 95% of the irrigated area using surface irrigation, it can be expected in a long period of time, surface irrigation will still account for the leading position in China's farmland irrigation[2].

Traditional surface irrigation technology has many shortcomings, such as poor irrigation uniformity, high water consumption, deep percolation and so on. China is an agricultural country, agricultural irrigation water consumption accounted for about 70% of total water consumption, but the water use efficiency is lower, in order to improve the irrigation water use efficiency, an important water saving approach is to improve the surface irrigation technology and increase the field water utilization coefficient[3]. In addition, study the precision surface irrigation technology system relying on the development of modern agricultural science and technology, enhance the developmental level of modern agricultural, improve the performance of surface irrigation systems, achieve the aim of water saving and yield increase. Therefore, it is of great practical significance to study and promote the water-saving surface irrigation technology to alleviate the shortage of water resources in China.

Improved surface irrigation water saving technology

Water-saving border irrigation technology

Border irrigation technology is making field separated into ridge-bordered plots by the soil ridge that the water stream forms a thin layer in the field and flow and infiltration soil under the action of gravity.

In recent years, in order to save water, improve the quality of irrigation and reduce the cost of irrigation, many advanced water-saving border irrigation technologies had been popularized and applied including horizontal border irrigation, small border irrigation, long border phrasing irrigation and so on, and achieved significant effect of water-saving and production[4].

Horizontal Border Irrigation Technology

Horizontal border irrigation is a kind of advanced irrigation technology, which the field slope in both longitudinal and transverse directions is zero, and it has the characteristics of low irrigation technical requirements, small deep leakage, less water and soil loss, convenient field management and suitable for mechanized operations. Jianmin Ren studied the influence of border dimensions and irrigation techniques on irrigation quality and spring wheat yield in Shiyang river basin, concluded that the quality of irrigation and the yield of spring wheat decreased with the increase of vertical slope, meanwhile, with the increase of border length, the irrigation efficiency and irrigation uniformity were reduced, then put forward the technical parameters of horizontal border irrigation as follows: longitudinal slope was 1/3000, discharge per unit width in the range from 6 to 8 L/(s·m), border length was 50 m to 70 m[5]. Aiping Zhang set Shiyang river basin as an example, five commonly used soil infiltration Collis-George models and modified Kostiakov models were established, the results showed that horizontal border irrigation technology has a good irrigation effect[6]. Compared with the traditional border irrigation, horizontal irrigation can save water more than 20%, field irrigation efficiency can reach more than 95% and irrigation uniformity come to 90% or above under the conditions of low soil infiltration rate [7].

Small Border Irrigation Technology

Small border irrigation is widely used in wheat and has better water-saving effect in the northern region, mainly refers to the border irrigation “three changes” technology: border length change long to short, change wide gap to narrow plot, change large plot to small plot. The technical elements of the small border irrigation include the border length, border width and discharge per unit width and so on, the technology mainly improved the water arrangement, the irrigation uniformity, reduced the irrigation quota. According to the results in Shanxi Luohui district that the irrigation quota is reduced by 150~204 m³/hm² when the border length was changed from 100 m to 30 m, it decreased by 150~225 m³/hm² when the border length was varied from 30 m to 100m and discharge per unit from 2.0~4.5 L/(s·m) [8]. In general, the suitable factors for the small border irrigation technology are as follows: surface slope is 0.1% to 0.25%, discharge per unit width is 2.0~4.5 L/(s·m), the irrigation quota is 300~675m³/hm². For the appropriate border length, gravity irrigation district is 30 m~50 m and no exceed 70 m, while water lifting irrigation district is 30 m or so; For the appropriate border width, gravity irrigation area is 2 m~3 m, while water lifting irrigation district is 1m~2 m. The test results showed that small border irrigation has the advantages of saving water, uniform irrigation, high quality irrigation, it also can prevent deep leakage, improve the effective availability of field water, reduce soil erosion, soil nutrient leaching and soil hardening[9].

Long border phrasing irrigation technology

Long border phrasing irrigation technology is a kind of water-saving irrigation method which has been explored in the long term irrigation practice in some district and well irrigation areas in the north of China, it has been widely used in Shandong, Hebei province and in the west of Guanzhong district of Shanxi province. In the case of irrigation, a long border is divided into a number of short borders without transverse borders, with low pressure plastic thin-walled hoses or ground longitudinal transport ditches that transport water to the borders and then irrigate water to short border with bottom-up or top-down section by section until all the short border are irrigated. The border width of long border phrasing irrigation technology are generally 5 m~10 m and border length can come to more than 200 m, but discharge per unit width is not increased. Many results showed that compared with the traditional border irrigation, the irrigation uniformity, field irrigation storage rate and field irrigation efficiency were all more than 80% and can save water 40%~60%, field irrigation efficiency increased about two times under the low irrigation quota of 450 m³/hm²[10].

Water-saving furrow irrigation technology

Furrow irrigation is a kind of water-saving irrigation technology which need digging a ditch between the crops liners, water from the conveyance ditch or furrow into the irrigation ditch wet soil with the role of capillary in the process. Compared with border irrigation, it is a significant advantage in preventing the soil harden, deep seepage, soil evaporation and soil nutrient loss[11]. Furrow irrigation is generally applied in wide row of field crops, such as corn, potatoes, soybeans, etc., it can also be used for fruit trees irrigation. The key technology of furrow irrigation is the reasonable designing of irrigation ditch to determine the length, distance and section space of irrigation ditch.

Ridge and furrow irrigation technology

Ridge and furrow irrigation technique is forming a furrow-ridge according to the crop lines before seeding, which planting two rows crops on the ridge and furrow formation between ridges according to crop spacing requirements, the way the soil is moistened in the roots is mainly through the side irrigation ditch with the capillary force. Ridge and furrow irrigation technology is generally applied to cotton, potato and other crops or wide and narrow lines of intercropping crops, it can both prevent drought and waterlogging. Kecui Sun carried out the technical parameters of spring wheat ridge and furrow irrigation in Minqin county Gansu province, established the optimization model of irrigation technology parameters, the results showed that the yield of wheat was 9142.87 kg/hm², *WUE* was 29.18 kg/(hm²·mm) under the combination of furrow length was 50 m, ridge width was 0.4 m, inflow discharge was 1.5 L/s and slope was 1/1000[12].

Furrow irrigation technology

Furrow irrigation is regard three row crop as a unit, put every three lines in the middle row crops at the site of the soil on both sides of the two lines of the crop root formation of earth, while the middle row crops only to hill around the single plant root, the formation of interline shallow groove for irrigation. Furrow irrigation is mostly applied in maize, the main advantage is that the soil in the root area is moist at the way of lateral infiltration, and root soil loose, moist soil uniform and good soil aeration.

Alternative furrow irrigation technology

Alternate furrow irrigation is a kind of controlled root divided alternative irrigation technology, the principle is that a part of roots in the drought stress when irrigation and produced the root signal-abscisic acid control stomatal aperture, while the other parts of the root supply moisture for leaf to keeping the leaves do not occur water deficit avoid drought to cause injury, beneficial to the growth and development of crops. Alternate control to subject some roots to a certain degree of water stress, improve soil permeability, conduction ability and absorption function[13]. Research showed that alternate furrow irrigation amount more than 30% per ditch compared to flood irrigation, but the total amount of irrigation save more than 30%, and it can save water more than 15% compared to conventional furrow irrigation, and yield was significantly higher than that of conventional irrigation under the same irrigation level, the yield increased 2.85%~3.96% [14].

Surge flow irrigation technology

Surge flow irrigation is an advanced water-saving surface irrigation method which irrigating water intermittently and alternately to border or ditch according to a certain period, until the completion of irrigation. It has the characteristics of water saving, energy saving, labor saving and high irrigation quality compared to traditional surface irrigation method[15]. Yuliang Fu established the intermittent infiltration of surge irrigation model based on the theory of Green-Ampt and Philip infiltration model, the mechanism of intermittent infiltration of surge irrigation is described accurately by the mathematical model of soil volume moisture content increment and cumulative infiltration, which provides a theoretical basis for rational design of surge irrigation technology[16]. Xiulu Sun studied

the spatial distribution and space distribution of soil water and nitrogen in continuous border irrigation and surge flow irrigation, concluded that the distribution of water and nitrate nitrogen in soil was better than continuous irrigation, surge flow irrigation can play a role in water and fertilizer conservation to some extent under the condition of irrigation and fertilization[17]. Surge irrigation technology has the characteristics of energy saving and solve the problem of long furrow irrigation, it is easy to master and apply. Therefore, surge irrigation is very suitable for the existing social, economic and technical status of irrigation areas in China. It is necessary to vigorously promote the surge irrigation for water saving and ease the shortage of water.

Precision surface irrigation technology

From the trend of irrigation development in the world, surface irrigation is still the main irrigation method adopted worldwide for a long time, but irrigation management technology need strengthened. In the process of improved surface irrigation technique, it is necessary to inject some new technology such as laser control technology, GPS and GIS technology, computer simulation technology and automatic control technology to improve the irrigation system performance and effective use of water resources, achieve significant effect of water saving, increasing production and protecting environment[18].

Laser controlled land leveling technology

Laser leveling technology is the most advanced land leveling technology in the world, it has been widely used in developed countries at present, and our country is still in the stage of introduction, demonstration and popularization. Based on laser control technology, global positioning system (GPS) and geographic information system (GIS), realize the achievement of laser control land precision leveling technology. Related research results showed that laser controlled leveling technology can effectively improve the micro topography of the field and the field leveling accuracy, come to effectively use of irrigation water, and achieve precision surface irrigation. In 2006, the application of laser leveling technique in Yellow River irrigation area in Ningxia indicated that the leveling accuracy S_d of paddy field decreased from 4.27 cm to 1.50 cm adopted laser control leveling, the average relative improvement was 64.03%, and S_d of dry land decreased from 7.24 cm to 1.91 cm, the average relative improvement was 71.04%, rice water-saving was 30.71%, and yield increased by 23.41% [19]. In year 2011-2012, laser leveling technologies were popularized in cotton and cumin planting in Jiuquan city, water saving rate was from 26.2%~40.5%, the economic benefits reached from 18.3%~61.3% comparing to the local traditional ground scraping method[20]. At present, the difference of surface elevation is generally in the range of 2 cm after using laser control leveling technology, which has a better effect of leveling land[21]. Laser controlled technique can significantly improve the utilization efficiency of irrigation water, increase economic, social and environmental benefits, and needing vigorously popularization and application in agriculture in future.

Real feedback control technology of precision surface irrigation

The study of real time feedback control technology on surface irrigation is an important aspect of the precision surface irrigation. It is a method of direct or indirect inversion to calculate the effective average soil infiltration parameters and the field roughness coefficients in real time status based on the observed data of surface water flow during a particular irrigation period. At present, the method to estimate the effective average soil parameters is generally divided into two ways: one is directly estimate parameters based on the principle of water balance, the other way is indirectly estimate parameters according to the matching degree between observed and simulated data of surface water flow. In these two methods, Kostiakov empirical formula ($I = k \cdot t^a$ or $I = k \cdot t^a + c$) with two parameters (k, a) or 3 parameters (k, a, c) is usually used to describe soil infiltration characteristics, and the Manning formula ($Q = 1/n \cdot A \cdot R^{2/3} \cdot i^{1/2}$) is used to describe the roughness coefficient (n). Many studies showed that Kostiakov empirical infiltration formula is a widely adopted method at present[22]. The soil characteristic parameters estimated by Kostiakov formula can make the irrigation efficiency of

surface irrigation system under precision land leveling conditions, designed for real-time feedback and control during the process of surface irrigation can reach above 85%, it can effectively improve the design and evaluation method of the surface irrigation system and greatly improve the performance of surface irrigation system[23]. With the development of computing technology, using mathematical model to analyze the whole process of surface irrigation has become an important means of fine surface irrigation technology [24].

Conclusions

Surface irrigation would be the main irrigation methods for a long time in China, however, the traditional surface irrigation cannot adapt to the needs of the development of modern agricultural technology, because it has disadvantages such as lower irrigation uniformity, high irrigation water consumption and so on, so carrying out efficient water-saving surface irrigation technology in future is the main development direction of agricultural irrigation in China. To improve surface irrigation technology and vigorously carry out the precision surface irrigation technology as the representative of the modern surface irrigation technology, and actively promote water-saving border irrigation, furrow irrigation, surge irrigation and other advanced surface irrigation technology, vigorously carry out laser leveling technology and real time feedback control technology to improve surface irrigation field irrigation management level, field irrigation quality and irrigation efficiency, enhance the level of modern agricultural development in China.

Acknowledgements

This work was financially supported by the Central Public-interest Scientific Institution Basal Research Fund (Farmland Irrigation Research Institute, CAAS, Y2017XM08, FIRI2016-23) and the Collaborative innovation project (CAAS-XTCX2016008) .

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