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Review

The modern water-saving agricultural technology: Progress and focus

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Based on the analysis of water-saving agricultural technology development status and trends in China, and in combination with the development and the needs of modern water-saving agricultural technology, we have put forward a future research emphasis and developing direction of modern water-saving agricultural technology, which include modern biological water-saving technology, unconventional high-efficient and safe-water using technology, water-saving irrigation technology and equipment, dry high-efficient water using technology and new materials regional high-efficient water-saving agriculture comprehensive technology.

Key words: Biological water-saving technology, unconventional water resource, water-saving irrigation, dry-land water high-efficient agriculture, technical integration, biotechnology.

INTRODUCTION

It is known to all that the past 20th century has been the fastest 100-year in human history, in which the world population has increased by 4 times and the gross value of industrial production has increased by 50 times. However, water consumption has increased 100 times. The development models have gained rapid economic growth by excessive consumption of resources, and this has lead to global water consumption and to the greatest potential water resources exploration. How to relieve the worsening global water crisis has becomes a major common-concerned strategic issue in the 21st century (Wu and Feng, 2003; Shi and Lu, 2001). After the 21st century, with increasing drought and water shortage, population growth rapidly developed as well as urbanization And socio-economic, and water conflicts became increasingly acute. Agricultural industry has the largest water-saving potential in China. It has been a consensus that developing modern water-saving agriculture is an important strategic measure to ensure food, water and ecological security in China (Shi and Lu, 2001; Gong et al., 2003; Liu, 2001). By analyzing the developing status and technological needs of modern water-saving agriculture, we found that the development of modern water-saving agriculture is at a critical period with the traditional technology upgrading intertwined with the hightech development (Rural Water Conservancy Division of Water Resources Ministry,2001). How to determine the research emphasis and develop direction of modern water-saving agricultural technology in the critical period is significant for modern water-saving agriculture in China, as well as to ensure strategic water, ecological and food security in China. Based on the analysis of water-saving agricultural technology development status and trends in China, this paper have put forward the future research emphasis of modern water-saving agricultural technology together with the development and needs for modern water-saving agri-

Abbreviations: WUE, Water use efficiency; **R & D,** research and development; **RDI,** regulated deficit irrigation; **ARDI,** alternative root-divided irrigation; **PRD,** part root drying; **PAM,** polyacrylamide; **PE,** polyethylene.

cultural technology.

THE DEVELOPMENT STATUS OF WATER-SAVING AGRICULTURE TECHNOLOGIES IN CHINA

China started vigorously with the development of water resources, developed farmland irrigation since the 1950s according to the status of the increasingly acute contraction between water supply and demand, serious agricultural water waste and great water-saving potential, and have made remarkable achievements. The development of water-saving agricultural technology has entered a new era, especially in the 1990s. During the "Ninth Five-Year" period, the water-saving agricultural technology research and demonstration was classified as a national scientific and technological project. Deep and comprehensive study was carried out in the aspects of new water-saving irrigation technologies, rational utilization of water resource, water-saving irrigation system for mainly crops and water-saving irrigation equipments. During the "Tenth Five-Year" period, the significant tech-nology project, "system of modern water-saving agricultural technology and research and exploitation of new products" was implemented by the Ministry of Sci-ence and Technology, Ministry of Water Resources and Ministry of Agriculture after the approval of the State Leading Group for Science and Education in 2002, and was listed in the national 863 high-tech development plan, with emphasis on break-through for the "bottleneck" problem of water-saving agricultural technology develop-ment in China (Kang et al., 2004; Xu et al., 2003; Xu et al., 2004). The completion of the above-mentioned projects played an important role in increasing the level of water-saving agriculture fundamental research in China, developing new water-saving agriculture products and materials and achieving industrialization. It enhanced the progress of water-saving technology in agriculture, and promoted the organic integration of national water-saving goals and farmers' income target. This made tremendous contributions in creating a modern water-saving agricultural technology system with independent intellectual property rights and solving water shortage in China.

Most aspects of water-saving agriculture application foundation and its forefront as well as key technologies and innovation, water, nutrient migration theory, regulation of soil-plant-atmosphere continuum, deficit irrigation theory and model of crops were revealed more systematically, especially major breakthroughs made in the fields of crops' water transformation rule, root information transmission and signal oscillations, dynamic simulation of moisture and nutrients transfer, crop water requirement and calculation model as well as the drought-resistance water-saving mechanism, which provided strong technical reserves and support for water-saving agricultural technology development in China (Shan et al., 2004). A series of achievements have been gained in non-technology of water-saving products, which produced significant water-saving benefits (Wu and Feng, 2005). The laser rapid research platform of water-saving products was firstly established internationally.

It cuts the single cycle period of micro-irrigation products from 90- 150 to 3 - 5 days, the cost from 30,000 - 50,000 to 2,000 Yuans, work efficiency was improved by 30 times, and the cost was decreased by 20 times. The yield of the new selected drought-resistant water-saving variety increased by 10% more than control yield in the middle drought conditions, and water use efficiency (WUE) increased by 20 - 40%. The establishment of the laser controlling ground automatic operation technology made the land leveling precision reach 2 – 3 cm, and the utilization ratio of irrigation water increase by 20 - 30%. The controlling split-root alternating irrigation technology was put forward based on crop water requirement signal, with its WUE up to 2 kg/m^3. The strength of a new type of soil stabilizer for rainfall collecting material was 68% higher than cement soil, and the efficiency of collection was up to 85 - 91% with investment of only 3 or 4 Yuans per square meter. The developed plant-growing nutrient conditioner could cut biological-collecting surface shield time from 3 years to 30 days, making 0.5cm thick water stay six hours with-out leakage, and the runoff increased by 30% more than that of the controlled.

Significant results have been got in the aspects of key devices such as major product of research and development (R & D) and industrialization of water-saving agriculture, green house micro-irrigation system devices, walking multi-function moisture conservation devices, new types of pipe fittings; also, water measuring and distributing devices, self-propelled sprinkler irrigation unit, new multi-function water retaining agent and degradative water conservancy sheeting were exploited. A series of water-saving products and complete sets of equipments were initially formed with Chinese characteristics and independent intellectual property rights, which promoted the rapid development of water-saving leading enterprises like Xinjiang Tianye, Fujian Yatong and so on (Qian et al., 2002; Wu, 2004). Drip irrigation tubes producing line were established, which made the cost of drip irrigation tubes drop from 1.2 to 0.25 Yuan/m, with drip irrigation line dropping from 0.15 - 0.2 Yuan/m down to the 0.08 Yuan/m, and greenhouse micro-irrigation system dropping from 600 -3000 to 350 - 1000 Yuans/mu, with a reduction of more than 50%. A series of high water-absorbent composite like water retaining agent with high fluid absorption rate, strong security and good salt resistance was created by using layered silicate minerals and complex co-polymer technology, whose price reduced from 20,000 to about 9,000 Yuans/ton. The degradative water conservancy sheeting with a thickness of 20 micrometer was created with the use of magnetic oscillation blown technology, and it will totally degrade in one year, and can replace the existing plastic sheeting in technical performance.

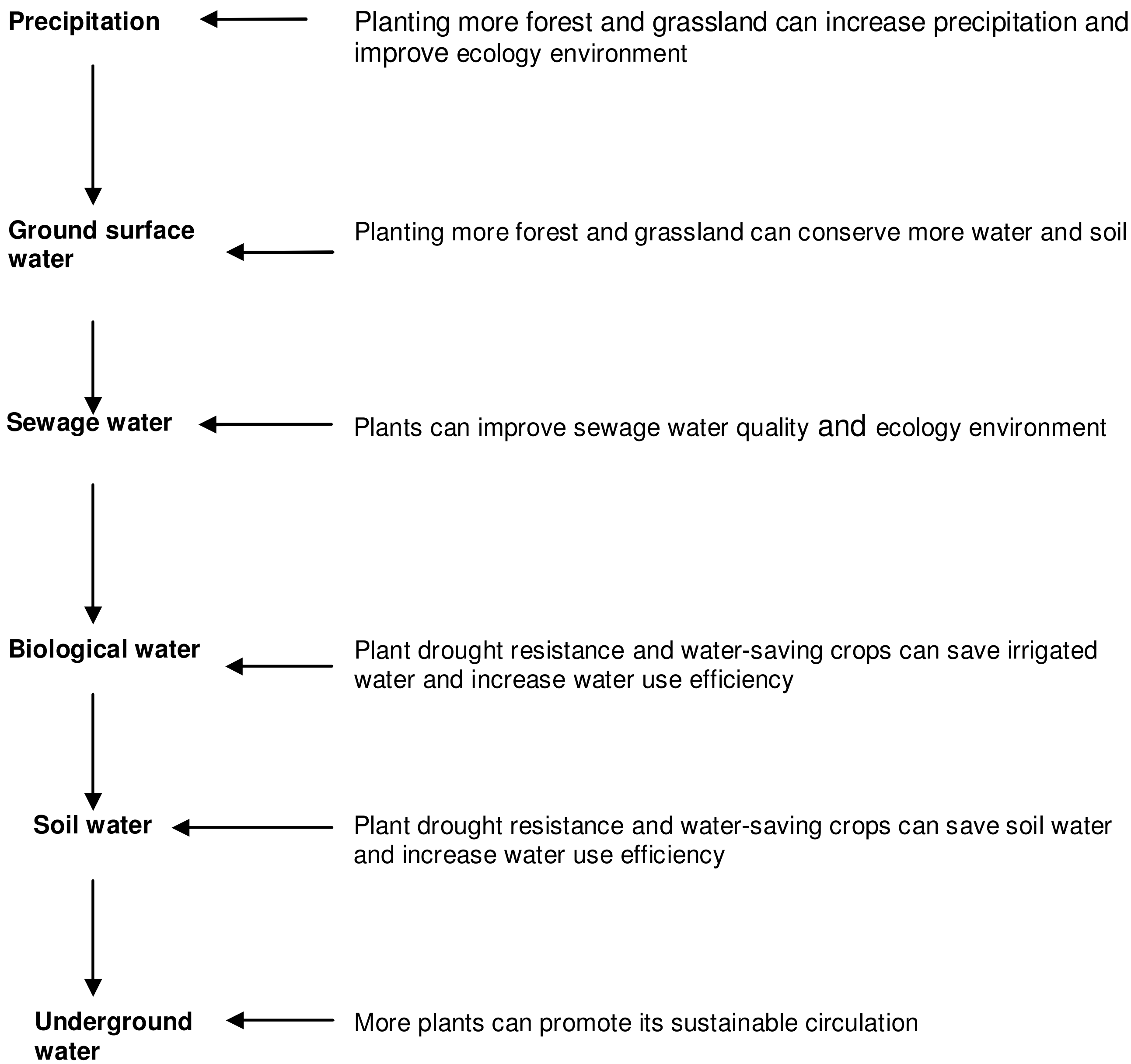

Figure 1. Bio-water saving and water conservation (Zhang et al., 2009).

In water-saving agricultural technology system integration and demonstration, we have initially set up a developing pattern of modern water-saving agricultural technology development for China's national conditions and different regional characteristics. We have put forward 9 regional modern water-saving agricultural development patterns that suit the northern arid inland river irrigation area, semi-arid plains well irrigation areas, semi-arid plains channel irrigation area, semi-arid plains drought-resistant irrigation area, semi-arid plains supplementary irrigation area with harvested sub-humid wells-channels irrigation area, semi-arid vegetation construction area, semi-arid urban greenland irrigation area and southern seasonally dry areas. Thus, 17 demonstration areas have been established according to this model in China's northwest, North China, northeast, East China and south seasonally dry areas; the total area was up to 25 hectares. The technology radiated 367.6 hectares, promoted 2 million mu, and saved about 2.4 billion m^3. The crop production increased by 2.5 billion kilograms and increased the economic output by 4.8 billion. In addition, the applied area of China's field cotton drip irrigation under plastic film has reached 500 million mu, while the applied area of harvested rainwater technology reached more than 3000

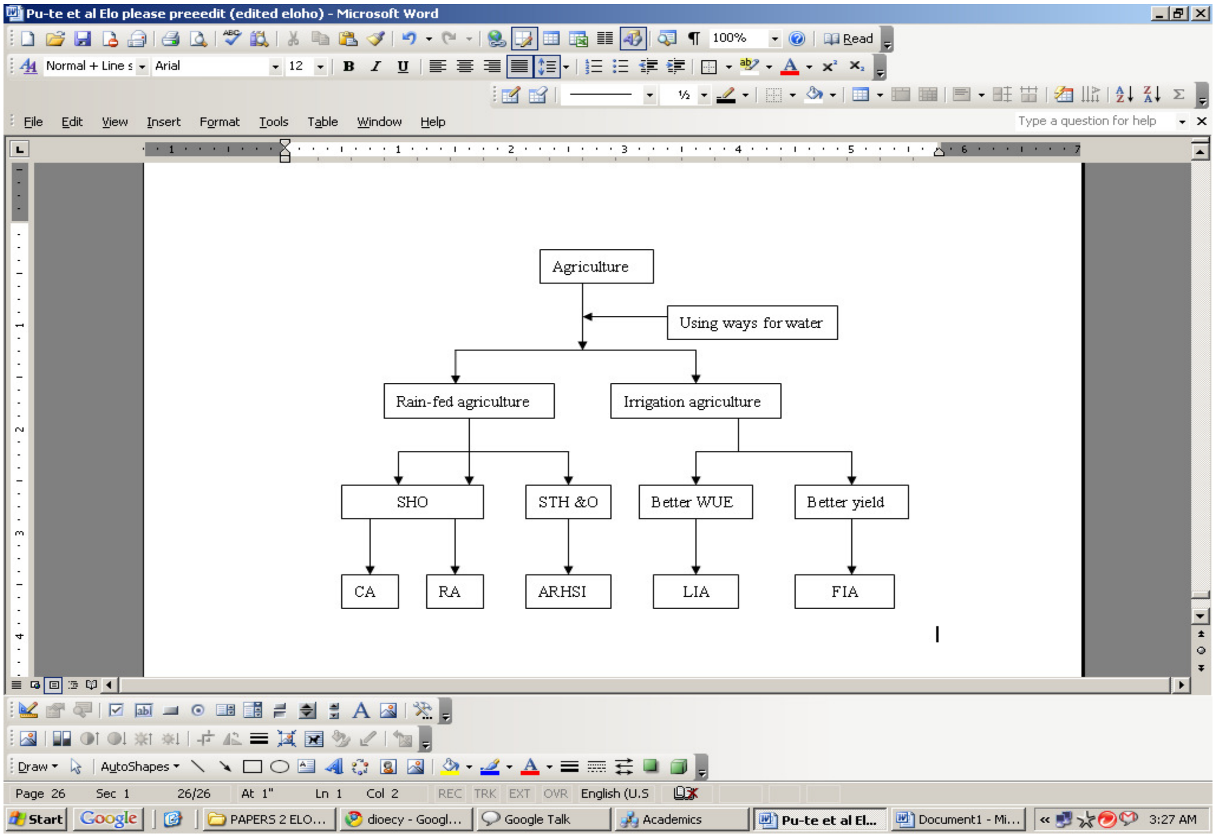

Figure 2. A schematic diagram for agricultural development based on agricultural utilization of water. SHO, Spatial harvesting and overlapping; STH & O, spatial-temporal harvesting & overlapping; WUE, water use efficiency; CA, conservation agriculture; RA, runoff agriculture; RHRA, agriculture of rainwater harvesting for supplemental irrigation; LIA, limited-irrigation agriculture; FIA, full-irrigation agriculture (Zhao et al., 2009).

hectares, and both are in forefront of the world (Li et al., 2004).

Although water-saving agricultural techniques in China has a degree of basis accumulation and has gained several innovative scientific achievements that play an important role in practical production, there are still a number of important technical bottlenecks, which could not provide a strong technical support to build a modern water-saving and efficient agriculture. These are as follows: Lack of basal data accumulation for water-saving agricultural development and effective monitoring and control of agricultural water usage; basic research from a pure basis to the application level is still short; standardized, quantitative and integrated water-saving agricultural technology system and application mode are still defective; the function of water-saving equipment and products aresingle and lack instability with poor durability, materials and the technology research is still lagging behind; the exploration and utilization of crops' drought-resistance germplasm resources are not enough, we are short of efficient evaluation methods and indicators that can rapidly identify drought-resistance performance of plant; application level of information technology is lower. Also, the information collection and transmission reliability of water management are poor (Jing and Li, 2004; Peng et al., 2004). The related concept and proposed technology steps can be references to Figures 1 and 2.

DEVELOPING TENDENCY OF MODERN WATER-SAVING AGRICULTURAL TECHNOLOGY

Excavation of the own water-saving potential using biotechnology

The biological water-saving technology that uses crop physiology control and modern breeding techniques to increase production and water use efficiency from crops' own enginery is a hot topic, and also a key technology for achieving modern water-saving high-yield and quality type from traditional water-abundance high-yield type (Shan et al., 2004). Countries with developed technology attach great importance to fostering water-saving and drought-resistance crop varieties using transgenic technology, such as the Australian wheat varieties, American cotton varieties, Canadian forage species, as well as

Israel fruits varieties (Theiveyanathan et al., 2004; Bustan et al., 2004). These varieties are not only water-saving and drought-resistance, but also have stable yield traits and excellent quality characteristics. Chinese Academy of Agricultural Sciences, China Agricultural University, Northwest Agriculture and Forestry University of Science and Technology and other units have researched the physiological mechanism and control technology of high-efficient crops' water using the application of gene mapping, molecular markers, gene cloning and genetic improvement of transgenic technology. A strong operational methods and index system for screening identify techniques, and nurturing a group of new crops varieties with water-saving and drought-resistance was initially established.

The deficit irrigation technology based on physiological water requirement control can significantly increase crop water use efficiency, such technologies are regulated deficit irrigation (RDI), alternative root-divided irrigation (ARDI) and part root drying (PRD) technology. These technologies are commonly used in Australia, Israel, Portugal, Morocco and other countries as well as some regions of China. Compared to traditional irrigation methods, the deficit irrigation technology can reduce total irrigation water quantity, and decrease transpiration with no yield-reduction. Northwest Agriculture and Forestry University of Science and Technology, China Agricultural University and Chinese Academy of Agricultural Irrigation Research Institute, and other organization have done a lot of research in this field, they have proposed and perfected the theory of deficit irrigation theory and crop controlling root-divided irrigation technology. The essence of biological water-saving should be the high-efficient use of water through biological ways, namely the "utilization and exploitation of physiological and genetic potentials of organisms so as to acquire more agricultural output and better economic and ecological benefits by utilizing smaller or same amounts of water or poor quality water". Biological water-saving should not only be applied with priority in crop production, but also in other aspects of agriculture and industries such as husbandry, aquaculture, landscaping, sewage water management, water and soil environmental conservations. Therefore, water-saving potential using bio-technology represents the human effort in the construction of a resource-saving and environmental-friendly society (Zhang et al., 2009).

Utilizing technology of non-traditional water resources as the hotspot in this field

The utilization of non-traditional water resources like rainfall, wastewater and brackish water has become a new way of solving water-usage crisis in many countries and regions. It has also become one of the concerned emphasis content in the field of modern water-saving agriculture.

Great achievements have been made in calculating model of crop water demand and consumption under the conditions of wastewater irrigation, as well as influence of wastewater irrigation on plants, soil and groundwater, and initial formation of the irrigation optimization pattern that controls the irrigation volume according to the evapotranspiration intensity. 45 States of the US carries wastewater back to agriculture; the total amount of recycling wastewater was about 94 × 108 m^3/year, of which 60% was used for irrigation; Israel has established more than 200 wastewater recycling projects with utilization rate of 70% and about 2/3 is use for irrigation. This accounts for 1/5 of total irrigation water. Tunisia's reclaimed water irrigation has reached 125 million m^3; India since the 80's, the annual irrigation water accounts for the volume of urban sewage of more than 50%; Mexico City, 90% of urban wastewater is reuse for irrigation (Juanico and Milstein, 2004; Jimenez et al., 2003). Zhejiang University, Hohai University and Wuhan University carried out the process of wastewater utilization of harmful substances in the soil, as well as the cumulative effect of crop research, the sewage irrigation methods and theories, but the gap between advanced countries was large.

About the utilization of brackish water, Spain and other countries have studied the brackish water irrigation technologies and theories with brackish water irrigation stations. Israeli scientists have discovered that the fruits of tomatoes, watermelon and other crops will be sweeter and longer persevered after the drip irrigation of brackish water at the concentration of 0.45. In Arizona of United States, scientists have also discovered that the production of cotton, barley, beet, and other crops will not decrease or even increased after the brackish water irrigation (Ceballos et al., 2003). Nanjing Agricultural University and China Agricultural University have mainly studied the influences brackish water has on crop quality and soil by using modern control technology, and have put forward the utilizing technology and models of brackish water. However, the experimental study of brackish water irrigation in our country started late, and the technology has not matured enough.

About the rainwater using technology, international rainwater utilization was transformed from concluding the past experience to a modern high-tech and industrial applications, such as the industrial mass production and application of Germany plastic cellar body, while Israel, India, Japan, Australia and so on were studying utilizing theory and methods of the rain resources by using GIS technology (Machiwal et al., 2004). Water-saving irrigation of Yangling National Engineering Research Center, Chinese Academy of Sciences, Shijiazhuang Institute of Agricultural Modernization have proposed a wide range of chemical, biological and soil stabilizer catchment materials and new technologies. They have also created new rain storage cellar structure and materials, and established intelligent decision-making system of rain utilization. At present, the high-efficient utilization technology of farmland rain with independent intellectual property rights in China is in forefront of the world, and has formed a relatively mature technology systems and technical standards. The application area is up to 30 million mu across the country, which made our country to become the country with the most application area of this technology in the world.

Information technology, intelligent technology and 3S technology promote high-efficient modernization of water-saving management

A variety of sensing technology and transmission technology that support agricultural information real-time collection like crop water monitoring and information collection, decision-making simulation of crop growth, has aroused extensive concern. Computer management system enables the management of irrigation water change from static to dynamic usage. Water management has been transformed to comprehensive decision-making that combines the database, model base, knowledge base and geographic information systems.

The United States has researched on the relationship between crop water consumption and meteorological factors according to crop water evaporation, and has identified changes of soil moisture and the appropriate amount of irrigation water (Belder et al., 2004). Ground-based infrared thermometer was widely used to measure the temperatures of crop canopy, the leaf surface and the ambient air to determine the crop water requirement. At the same time, aircraft for aerial survey and satellite for remote sensing were used to monitor them. Heat-pulse technique was largely used in Australia to measure the sap flow and transpiration of crop stem, which are used to monitor crop water, and has put forward the theory and methods of soil moisture monitoring and prediction (Battam and Michael, 2003).

Real-time irrigation forecasting research based on soil and crop water status has developed rapidly, and a number of representative water-saving irrigation predicttion models have been made (Sporre-Money et al., 2004; Aydin et al., 2005). Irrigation water management in developed countries are developing towards information technology, automation and intelligence. Especially in recent years, the 3S technology has provided basement for maximum optimization of agricultural inputs and full exploitation of production potential that are implicit in the differences of water and fertilizer conditions. Chinese Academy of Agricultural Sciences, Xinxiang Irrigation Research Institute, Northwest Agriculture and Forestry University of Science and Technology, China Water Conservancy and Hydroelectric Power Research Institute have been engaged in the research of crop water monitoring and information collection techniques, and concepts and ideas of digital water-saving were proposed. A series of water-saving irrigation integrated decision-making system have been developed, which has certain benefits in practice, but still has a large gap with regards to developed countries.

Technologies of advanced manufacturing and new material promoted the development and upgrading of water-saving products

Multi-function, low power consumption, environmental protection, and intelligent control are the new trends of water-saving irrigation product development. Developed countries speed up the progress of water-saving product development and improved product performance using advanced manufacturing technology and new materials. For example, the application of fast advanced manufacturing technology in water-saving irrigation techniques makes the product development cycle to be significantly shortened.

Information technology and monitoring technology are the main drive used to enhance the accuracy of irrigation and fertilization using bio-technology. Israel, the United States, and the Netherlands have been studying the irrigation systems and special liquid fertilizer of different crops for 20-30 years, and have gained a wealth of information which has resulted in developed experts management system for water and fertilizer high-efficient utilization of various cash crops (Hutton et al., 2003; Abbasi et al., 2003). High-precision rapid prototyping equipment is becoming the hotspot for studies in rapid development platform technologies of water-saving irrigation products. In China, Yangling National Engineering Research Center, Xi'an Jiaotong University, and Huazhong University of Science and Technology researches on water-saving irrigation products using advanced manufacturing technology of laser rapid prototyping have put forward development ideas for new type of low-pressure drip irrigation system, and developed a series of irrigation control systems and equipments. Xinhua Irrigation and Drainage Company developed a large-diameter high-strength reinforced plastic water pipe using new materials and technologies. With water-saving agriculture input increment of each country, technology progress and upgrading of water-saving equipment have rapidly developed. Serialized water-saving spray micro-irrigation equipment was developed by American RAINBIRD and Israel NETAFIM, PLASTRO and China's Xinjiang Tianye Group and Shandong Laiwu Plastic Factory with reliable perfor-mance and longer service life. With regards to the field cotton drip irrigation system under films, its application area in arid inland river irrigation area has reached 500 million mu, which made our country one with the largest field drip application area in the world.

Chemical water retaining agent and plastic film water are ideal materials for water-saving irrigation (Herwitz et al., 2004). Foreign countries extracted a water retaining agent from coal and had excellent water absorption. Mulching is an important agricultural yield increase technology, but it also had a serious "white pollution", which can be solved by developing biodegradable plastic film. Foreign countries discovered a degradable plastic film synthesized by polystyrene, whose surface is a graft polymer. New manufacturing technology can accurately control the drug to degrade film, and it will be widely used with flexible and adjustable raw materials formula. In recent years, drought-resistant water-saving products developed by the United States, Japan and other countries have been widely used for cash crops, and have made good yield benefits (Begovich, 2003). The United States sprayed polyacrylamide (PAM) on soil surface, which plays obvious effects in inhibiting field water evaporation, preventing soil erosion and improving soil structure. The United States has successfully synthesized biological high-absorbent material using desert plants and starch, and has achieved significant water-obtaining effects (Inman-Bamber and Smith, 2005; Greven et al., 2005). China has preliminary solved the swelling and cross-linking technology of straw fiber in water-saving preparation and materials research, which greatly enhanced the salt-tolerance of products. A great innovation was achieved in non-ionic polymer oligomer graft technology and chelating agent processing technology, which made the saline absorption rate of products to rise up to 40 times. Studies on degradation of plastic films made a major break-through in raw materials preparation and production technology of micronized starch.

Focus on water-saving agriculture technology integration and selection of appropriate water-saving development modes

During the development of water-saving agriculture, every country emphasized the organic combination and integration of engineering, agronomic, biological and management water-saving techniques, paid attention to the comprehensive benefits of water-saving agriculture, and developed water-saving agricultural technology model that adapt to the level of the national economy and water resource. Less developed countries like Egypt, Pakistan, India mainly used the mode that are based mainly on channel anti-seepage and ground irrigation technology together with agronomic methods and rainfall resources utilization because of the restrictions of economic conditions and technological level (Amin et al., 2004; Perry C, 2004). However, developed countries like Israel, the United States, and Australia always used the mode that are mainly on high-standard curing channels and pipe transmission technology, sprinkler irrigation, micro-irrigation technology as well as improved ground irrigation technology. For instance, Israel basically relied on full pipeline water transmission, and total microspray irrigation; the area of sprinkler irrigation and micro-irrigation accounts for 30% of total irrigated area in the United States (Leib et al., 2003; Tognetti, et al., 2003).

FUTURE EMPHASIS FOR MODERN WATER-SAVING AGRICULTURE IN CHINA

According to the development status and demand of

water-saving agriculture technology in China, together with modern water-saving agricultural technology development trends, our research and development of modern water-saving agricultural technology focus on five aspects, and take modern biotechnology water-saving as forefront technical reserves. This is because modern biological research is still at the experimental stage and is not appropriate to be applied in large scale.

Modern biology water-saving technologies

Modern biology water-saving technologies focus on main crops and grass to carry out identification and evaluation on fields or indoor drought-resistance of germplasm resources, select outstanding water-saving and drought-resistant resources, and establish evaluating index system and methods for crops' water-saving and drought-resistance identification. These technologies help to establish simple and effective drought-resistant and water-saving germplasm improvement and breeding techniques using molecular marker-assisted selection, and trans-genic and gene polymer technology. They also create new materials with drought-resistant, water-saving and high-efficient water-using, and breed new varieties that are drought-resistant and water-saving. They create an exogenous substance that can control transpiration, study crops' eco-physiological response to exogenous substances and the compound technology between exogenous substances and nutrient. They study plant transpiration inhibitor using integrated application of chemical synthesis and sequestration technologies by developing a multi-functional seed coating agent with drought-resistance and water-saving, preventing pesticides, enhancing environmental protection and high-efficient dry-land and deficit irrigation. The technologies also study the deficit irrigation mode under limited water and water production function of the main crop in different regions, main indicators systems and irrigation model of regulated deficit irrigation, as well as local water controlling irrigation techniques and methods of the main crops.

High-efficient and safe using technology of unconventional water resource

High-efficient and safe using technology of unconventional water resource focus on the R&D of new high-efficient engineering, biology rainwater harvesting form and new harvesting materials with low-cost, high-efficient and environmentally-friendly that adjusts to the dry-land. Study on the structure of new harvesting facilities and on-site molding technology, has put forward system design engineering software for rainwater harvesting and high-efficient utilization; harvesting the established regional rainwater utilization technology system, optimum development model and intelligent decision-making system software; study on the effects of reclaimed water irrigation for soil, groundwater and quality of crops. It has also put forward the indicators system for safety irrigation, established an irrigation system under different reclaimed water irrigating patterns by using different irrigation methods, applied technologies for mixed irrigation or rotation irrigation of reclaimed water. Studies on the utilizing technology and equipment of brackish water with low-cost, energy-efficiency, and the controlling indicators systems and crop irrigation systems under brackish water irrigation, as well as salt moving laws and regulation technology under brackish water irrigation and patterns of mixed or rotation irrigation, have put forward a set of brackish water utilization that could improve the regional ecological environment.

Technologies and equipments of water-saving irrigation

We had to research the technology of soil precise-flat standard and laser controlled leveling, develop the China-made equipment of smoothing ground and carry-scraper by the control of laser and the corresponding control of the hydraulic lift system, study its matching field irrigation and drainage engineering system model; research surface irrigation techniques to control parameters, develop the field surge irrigation control equipment and field porous gate-pipe pipe irrigation systems and automatic control equipment; research alternate partial rootzone irrigation technology elements and the corresponding field equipment and establish the technical system of the moisture-retaining irrigation; structure the digital design and quick shaping platform of spray and micro-irrigation products; manufacture the special energy-saving sprinkler nozzle and light sprinkling of small mobile units and low-pressure pipe for a new type of sprinkler irrigation systems unit; develop the micro-pressure drip irrigation with ultra-thin wall, anti-blocking, durable, low-cost micro-irrigation emitter, automatic backwash filters, precision fertilizer injection device, pressure regulator, precision micro-irrigation control valves and automatic control systems.

We also used nanotechnology to improve the performance of impermeable material; develop the new composite materials and fillers geomembrane material; study expansive and saline soil and other special soil type channels impermeable material and application-specific technologies; develop the new type of thermal insulation composite material and environment-friendly composite reinforced concrete and new materials; develop the large-diameter pipe and pipe fittings and corollary equipment for piping water using the polymer composite; exploit the standardization and serialization of the new type of metal pipe and pipe fittings; and develop the reinforced high-density polyethylene (PE) moving sprinkler pipe and fittings.

High-efficient water using technology and new material for dry-land regions

The basic relationship model between the water demands and water resource protection of major crops should be established, and the main regional water-saving and production-stable crops planting structures put forward. We should establish rain appropriate planting parameters in coordination with water resource, put forward water-saving and efficient intercropping and rotation cropping patterns, no or less tillage moisture conservation technology, optimal and design software for regional water-saving farming systems which can adapt to the regional characteristics; study the structure and the main components performance parameters of walking multi-function drought-resistant planter , moisture conservation farming machinery and equipment based on the principle of mechanical bionics, micro-machines for water lifting and local water irrigation systems that suit small water resource; develop new water retaining agent with moderate magnification, high water availability, low cost and long validity period, biomass-based water-absorbent polymer resin and high-efficient multi-purpose soil conditioner by taking biological materials (algae, fiber, desert plants, etc.) or chemical materials as matrix; develop a whole bio-degradable plastic using natural materials and modified materials (focus on plant fiber and starch), research the film forming technology and related equipment for field biological material; exploit multi-functional liquid covered material with temperature increments , moisture production, production-increments, no residual, modify and create the new liquid film.

Comprehensive technologies for regional high-efficient water-saving agriculture

We should research on regional crop water signal monitoring technology and diagnise indicator system, as well as rapid determination and forecasting techniques of soil moisture. We should also study intelligent precise control-ling crop irrigation systems with the functions of monitoring, transmission, diagnosis, decision-making by using artificial neural network technology and data communications technology based on soil moisture forecast, crop moisture dynamic monitoring and crop growth information integration. Research on the technologies of dynamic management information collection, transmission and analysis of irrigation area, computer identification for irrigation system, simulation of irrigation water distribution and real-time control of water flow based on network technology should be combined with 3S technology.

Research on the water resources optimal distribution and management model under joint use of multiple water resources as well as support systems for regional multi-resources optimal distribution and intelligent management decision-making, should be explored using virtual irrigation realization technology. Technologies of biological water-saving, water-saving irrigation, agronomic water-saving and water management should be assembled by agricultural high-tech water-saving technology and products application to form modern water-saving agricultural technology systems and models with each feature in demonstration zone. The demonstrative management mechanism and mode mainly on the farmer water use association should be probed, and diversified investment mechanism for demonstration zone construction that are conducive to arouse the enthusiasm of scientific research, business, irrigation areas and farmers, etc should be explored.

CONCLUSION AND SUGGESTIONS

The development of modern water-saving agriculture is at a critical period with the traditional technology upgrading intertwined with the high-tech development. At the same time, emphasis on the traditional technology application and upgrading depend on high-technology. Great attention should be paid to the research and exploitation of modern water-saving technology, using information technology, biotechnology and other high-tech and new materials.

Secondly, modern biology water-saving technology, an important direction for future water-saving agriculture development, is also a hotspot and emphasis for current research. However, its research is still in the reserve phase, the time for large-scale application is not ripe.

Also, water-saving irrigation technology, non-traditional water resources, exploitation technology, and dry-land water efficient technology are the keys to recent research of modern water-saving agriculture technology. The main elements of its research should be focused to solving difficult problems of technology applications process, which is also an emphasis that we should strongly support and increase investment starting from now.

Finally, technical system integration and demonstration is the key stage for technology into production application, but also a weak link of water-saving agricultural technology development in China. To strengthen research and development of this work, it is conducive to transform technology and large-area applications, therefore it is also a current key research content that should be supported.

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