CROP WATER STRESS AND DROUGHT IN THE CENTRAL HUANG-HUAI-HAI PLAIN

An Shunqing* Zhu Zixi** Wu Naiyuan*** Jiao Yizhen*

(*Research Center for Agricultural Meteorology CAMS)

(**Agrometeorological Experiment Station, Henan Meteorological Bureau)

(***Taian Agrometeorological Experiment Station, Shandong)

ABSTRACT

Experimental data related to various types of soil water treatment for winter wheat and summer maize carried out in Gongxian, Henan Province and Taian, Shandong Province were used to expound on the relationship between crops, soil and atmosphere and on the behavior of water consumption by means of a defined optimal water consumption and water stress indices. An optimal irrigation scheme for winter wheat from the viewpoint of improving water use efficiency and economic benefit was proposed. It is found that this scheme is successful and of great significance for the problem of alleviating water resource deficiencies in this region.

Key words: water stress, water consumption, optimal irrigation scheme

The central region of the Huang- Huai- Hai Plain belongs to the semihumid climate zone with precipitation inadequate in spring, great precipitation variability in summer and frequent drought occurrence. Shortage of water resources has a severe influence on agriculture. The agricultural water consumption amounts to 80% of the total water consumption in the region. Wastage of water in over-irrigation is common.

In order to solve the problems we have carried out a 4- year experimental study. Some problems related to conserving irrigation water were analysed and wheat optimal irrigation schedules were presented from the viewpoint of raising water use efficiency (WUE) and economic benefit.

I EXPERIMENTAL METHOD

The experiments were carried out from September 1983 to December 1987, with artificial control of the soil moisture, in plots, with <40%, 40-55%, 55-80%, and >80% of the field capacity. A plot subject to natural precipitation was the control. The testing double cropping system was winter wheat and summer maize. The water treatments were made during periods of jointing to heading and heading to maturing. A large movable rainshelter was set up on the site to rule out the input of rainfall to soil and water proof walls were built round the treatment plots to prevent horizontal water exchange. Irrigation quantities were measured with water-gauges. Soil moisture, growth and development states, physiological and ecological features (stomatal resistance, transpiration rate, photosynthesis rate, leaf water content, dry matter weight, leaf area and milking rate) and meteorological elements were measured.

II RESULTS AND ANALYSIS

The relation between water consumption and crop yield is parabolic. The relationship indicates that yield increases linearly with water

consumption when the yield level is low and then increases slowly, and even decreases when water consumption increases to a certain level. However, the water consumption corresponding to the maximum yield is not the optimal water consumption. The optimal water must be determined from the viewpoint of raising WUE and economic benefit. From a comprehensive assessment of grain yields, stalk yields, WUE and irrigation costs for various water treatments, the optimal water consumption can be evaluated. The result of a comprehensive assessment is such that the economic benefit of the control sample is the highest: a yield of 5281.5 kg/ha with water consumption of 351 mm.

The optimal water consumption level from viewpoint of raising WUE can also be obtained by application of the optimal segmentation method.

The water consumption of winter wheat of the highest WUE is found to be 330 mm in Gongxian, the corresponding yield and WUE being 5145 kg/ha and 1.04 kg/mm, respectively. Optimal water consumption for winter wheat is taken as 340 mm by averaging the results (350 mm and 330 mm) obtained with the two methods used. The optimal water consumption for summer maize was calculated by the same method.

Results of optimal water consumption in Gongxian and Taian were combined to obtain the optimal water consumption for winter wheat and summer maize for the region as 340-370 mm and 330-350 mm respectively, the yields corresponding to the optimal consumptions are respectively 4500-5250 kg/ha and 5250-6000 kg/ha.

Water consumption at different growth stages shows significant difference. For both winter wheat and summer maize, optimal water consumption at different growth stages are listed in Tables 1 and 2.

Table 1. Optimal water consumption at different growth stages of winter wheat (mm)

growth stage	before wintering	wintering	return green --jointing	jointing --heading	heading --maturing
water consumption	66.3--72.2	13.3--14.4	57.5--62.5	88.4--96.2	114.6--124.7

Table 2. Optimal water consumption at different growth stages of summer maize (mm)

growth stage	sowing-seven leaves	seven leaves ---jointing	jointing --tassel	tassel --maturing
water consumption	28.4---30.1	74.8---79.3	90.2---95.7	131.6--144.9

As shown in Tables 1 and 2, for both winter wheat and summer maize, the maximum water consumption phase occurs in the jointing to maturing stage. Water consumption in this phase in the percentage of the seasonal total is large, amounting to 60% or so for winter wheat and about 80% for summer maize. Water shortage in this phase will damage crop growth and development.

The optimal water consumption estimates are used to determine crop the amount of water shortage and irrigation application, though it can not be used to determine adequate irrigation times. For irrigation timing, it is necessary to develop indices of soil moisture stress and

adequate soil moisture. The soil moisture stress indices for both winter wheat and summer maize were calculated with the data of stomatal resistance, transpiration, photosynthesis, milk-filling rate and yield elements under different water treatments.

On the basis of the percentage reduction of the yield for the different water treatments in Taian, these indices for both winter wheat and summer maize were calculated as well.

The results in Gongxian and Taian were combined to estimate the regional indices of soil moisture stress of different ranks for winter wheat and summer maize (Table 3).

Table 3. Soil moisture stress indices for winter wheat and summer maize (w, mass soil water content, %)

soil moisture stress rank	extreme stress		severe stress	
	w	% field capacity	w	% field capacity
winter wheat	<7.5	<34.0	7.6-9.0	34.1-40.0
summer maize	<8.5	<40.0	8.6-12.5	40.1-55.0

soil moisture stress rank	mild stress		adequate moisture	
	w	% field capacity	w	% field capacity
winter wheat	9.1-- 12.6	40.1---55.0	12.7--- 17.5	55.1---80.0
summer maize	12.6-- 15.0	55.1---70.0	15.1--- 18.0	70.1---85.0

Under natural conditions, the seasonal variation of soil moisture is great in this region, with the maximum being in the last ten days of September. A moist layer took place at 130-180 cm in-depth, which is commonly called the "soil water reservoir". It is a very important water supply for winter wheat growth in the spring of the next year. The minimum occurs in the first and middle ten days of June, with a dry layer at 50-120 cm in-depth, the average water content being 6.8%, not far from the wilting point, May-June is the key water demand period for wheat and the water supply should be ensured.

Under natural conditions the soil moisture for winter wheat during growth period is mainly governed by three factors: initial soil moisture at sowing time, effective precipitation during the period and water consumption conditions. These factors are the function of time. A dynamic equation of non-stress soil moisture for wheat fields in Gongxian is expressed as

$$W_t = W_0 + \sum_{i=1}^{t-1} P_i - 330 \int_0^{t-1} P_e(t) dt \quad (1)$$

where W_t is the non-stressed soil moisture content at t -th day, W_0 is the initial soil water content at sowing time, P_i is effective

precipitation at i -th day, $P_e(t)$ is ratio of water consumption at t -th day to that of the whole growth period. Equation (1) can be used to determine both length and the intensity of soil moisture stress. Analysis indicates that the soil moisture of wheat field drops to the value of the soil moisture stress index in Gongxian in early May. There is a shortage of 60 mm from early May to maturing, requiring of $600\text{m}^3/\text{ha}$ of irrigation water. The water shortage of 76 mm of winter wheat in Taian for the same period was calculated by a dynamic soil water balance model. The results in Gongxian and Taian indicate that under normal climatic conditions with sufficient soil moisture at sowing time, application of irrigation ($600\text{--}750\text{ m}^3/\text{ha}$ for loam soil) just once in early May can lead to higher wheat yield in the region.

III POPULARIZATION

Because of severe water shortages in the central Huang-Huai-Hai region, popularization of the proposed optimal irrigation scheme is of importance for alleviating the status of water resource shortages. The irrigation scheme has been arranged in a "major popularization plan of science and technology research achievements" in 1989. So far it has been popularized and used in more than 666.7 thousand ha. of wheat fields in Henan, Shandong and Hebei.

Results of this popularization indicate that the application of the optimal irrigation scheme can save $2250\text{ m}^3/\text{ha}$ of water, 225 kwh/ha of electric power, and 22.5 labors/ha, cost of 300 Yuan/ha.

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