ECOLOGICAL AND ECONOMICALLY EFFECTIVE AGRICULTURE THROUGH CREATING ENERGY LEVELS OF SOIL MOISTURE IN FIELDS

Prof. Ilia Christov, Ph.D. and D.Sc.
Poushkarov Institute for Soil Science, Agrotechnology and Plant Protection, Sofia, Bulgaria
E-mail: ichristow@gmail.com

Abstract. *The report deals with the perspectives for developing ecologically based biological agriculture in Bulgaria, the European Union and the other countries. Innovative technology (for computerized monitoring the soil water deficit and scheduling the irrigation) replaces the periodical local (point) measurements of soil moisture. Its application helps to be taken into account the physiological features of crop, creating appropriate energy level of soil moisture through ecologically accepted watering technique in each agricultural crop field. It ensures to be obtained the scientifically planned amount and quality of crop yield, saving on average 30 % of irrigation water and one third of nutrients added for plants.*

New universal estimation of crop water status, current computerized monitoring of the water deficit in root zone of soil, and exact management of productivity are possible to be accomplished.

Data were obtained under field conditions over 30-year research period. Fundamental physical laws and recent Bulgarian and foreign world-top scientific achievements were aggregated and applied to be created the new scientific basis of the technology.

The obtained results showed the successful applications of: (a) the new hydro-physical index and the method for its determination under both non-irrigation and irrigation conditions and (b) the Technology for Monitoring, Estimating and Managing (TMEM) of the water status of this layer in irrigation rural activities, taking into account the European ecological requirements. The technology is easily applied as Decision Support System (DSS) in irrigation agriculture.

KEY WORDS*: SOIL WATER STATUS, ENERGY LEVEL OF MOISTURE, PHYSIOLOGICAL IRREVERSIBLE PROCESS.*

1. Introduction

For the first time in the world agricultural science and practice, we can practically control the physiological processes in cultural plants. These processes concern the water and nutrients uptake by plants. New biophysical index (L) of soil moisture energy levels, method for its determination and new scientific basis and ecological technology are recently developed [1, 2, 3]. Applying the offered Decision Support Ecotechnology (in research version) during a period of 8 years, the precise schedules include 3.125 times of watering on average less with total irrigation norm equal to on average 2780 m^3/ha (or 29.5 % less amount of water) than tradition [4, 5, 6, 7]. We obtained 12 ± 0.5 t/ha of grain under appropriate N, P and K nutrition for each year (Table 1). We recommend L = 15 $(J/kg)^{½}$ to be realized in agricultural practices [8].

2. Problem discussion

Enormous losses of energy, fuels, water, fertilizers and human labour are due to the lack of current representative monitoring and integrated scientific management of farmer activities in each agricultural field under irrigation. We offer a new scientific tool to solve these cardinal problems in the world agricultural practices. Moreover, this tool will help the modern research for creating and examining new sorts and hybrids. ***It will significantly reduce or completely remove the pollution caused by the agricultural activities in each field under irrigation around the world.***

The recent achievements in biophysics of plant populations and the application of biophysical approach contributed to be created the Computerized Decision Support Ecotechnology (CDSE). It is possible to be created a version of this universal Computerized Decision Support Ecotechnology (CDSE) for Monitoring, New Estimating and Managing Agroecosystem Water Status as a market product friendly for farmers and agrarian associations. Its application will ensure economically-efficient crop production and environmental protection.

3. Objective and research methodologies

The aim is to overcome the risk coming from the influence of the most important water factor during growing season on agroecosystem productivity. This risk can be completely removed applying the ecotechnology under conditions of ecologically-acceptable irrigation technical facilities and available water resources. The minimum total needed amount of water and its precise distribution during each growing season to obtain a planned crop yield can be reached using the offered Computerized Decision Support Ecotechnology (CDSE). This ecotechnology is recommended for farmers, who can organize good technical implementation of the agricultural activities in their crop fields.

The offered ecotechnology ensures the amount of planned crop yield to be obtained and helps the exact determination of nutrient rates necessary for the formation of planned crop yield. *It ensures significant increase of yield and great reducing of irrigation water, human labour, and other costs* [8]. The ecotechnology is based on new complete scientific biophysical basis, which includes: 7 current daily meteorological indices twice a week; physical characteristics of the soil profile; biological function for each crop; fundamental (physical and biological) laws and established regularities of the soil-crop-atmosphere processes [1, 8]. We established the maize susceptibility of each stage of ontogenesis and we included it in the scientific basis of the ecotechnology (Fig. 1).

A stage	B stage	C stage	D stage
Germination, formation of first and second roots and five leaves 50 % Extreme-critical (ec)	Extending cone of growth and formation of new leaves 20 % Important (i)	Flowering, insemination and maize-cob formation 50 % Extreme-critical (ec)	Active phases of filling the grain 30 % Critical (c)

Fig. 1. *Scheme of ontogenesis stages based on the maize susceptibility to decrease the amount of grain yield when reducing the soil moisture. The percentages show the decrease of yield amount at lowering ΔL_{ec} = 30 $J^{1/2}/kg^{1/2}$ of the energy level of soil moisture only at the corresponding stage and keeping the genetically optimal level at all other stages. The yield losses at the separate stages are irreversible damage that accumulates till the end of growing season. The experimental data are obtained and verified during a period of 30 years*

4. Results and Discussion

In some agricultural practices for example, the farmers plan 10 t/ha maize-grain amount of yield. They calculate the fertilizer (N, P, K, microelements) rates and bring these nutrients in soil. In fact, they obtain 6.5-7.0 t/ha. That means 30-35 % losses of fertilizers, which are not used for plant nutrition. Those losses pollute the environment (water in rivers, lakes, dams, etc. and underground water). Applying the new offered ecological technology, the farmers significantly reduce or completely remove these losses and protect the environment.

The ecotechnology currently takes into account the following physical and biological characteristics:

1. Momentary and marginal (allowed by the chosen energy level) water deficit in the root zone; 2. Reference and real evapotranspiration; 3. Dew point temperature; 4. Daily solar radiation; 5. Average 24 hours wind speed; 6. Crop biological function; 7. Current increase of root zone depth; 8. Participation of underground water in the process of evapotranspiration; 9. Periodical estimation of expected date and и norm of watering for keeping the chosen energy level of soil moisture; 10. Efficiency of irrigation (net-norm/loss of water); 11. New indices of drought degree; etc.

Based on precise field experiments over a period of 30 years, we established the dependence of maize grain yield (Y, t/ha) on the energy level L (J/kg)$^{1/2}$ (Figs. 2 and 3). The equation for yield mass (obtained without irrigation and under irrigation schedule currently determined by us using the ecotechnology) is:

(1) $Y = 19.45 – 0.55\ L.$

The general form of this equation is: $Y = A – B\ L$, where A и B are the coefficients characterizing the crop physiological features. The correlation coefficient is equal to R = –0.980.

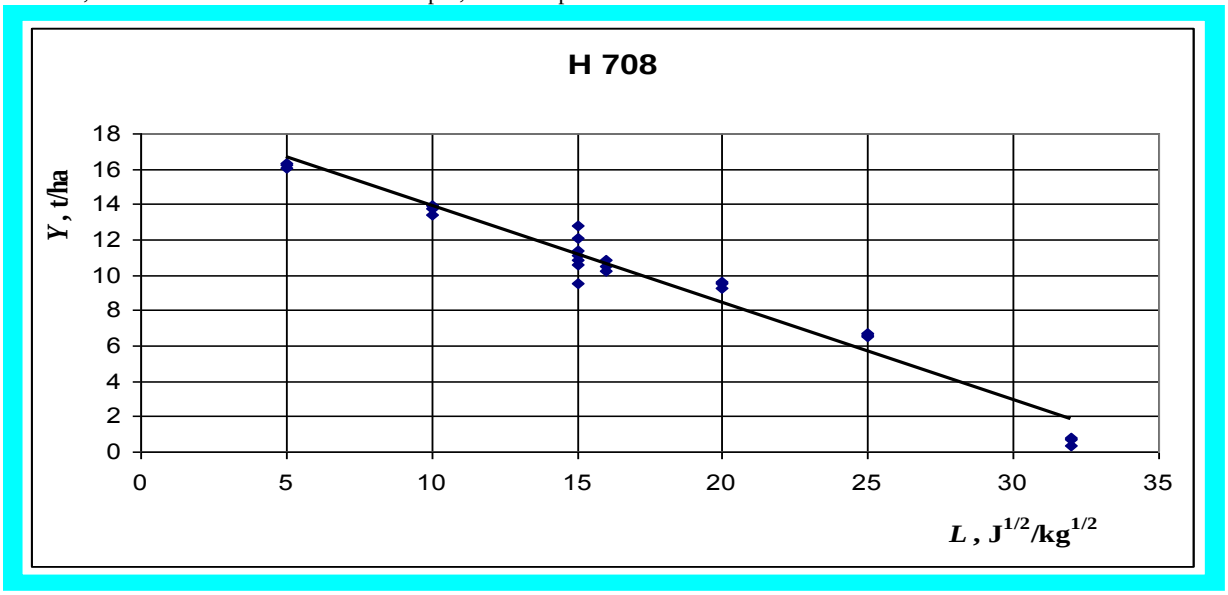

Fig. 2*. Dependence of maize (H 708 hybrid) grain yield (Y, t/ha) obtained at appropriate N, P and K rates on the energy level L (J/kg)*$^{1/2}$*. Correlation coefficient is equal to R = –0.98*

The crop physiological features are as follows.

● Gradual reduction of the water supply in the soil root layer from the field capacity (FC) to the wilting point (WP) causes *irreversible physiological processes* with increasing intensity in the plant organism. The cardinal problem related to these processes can be solved, applying the ecotechnology.

● The degree of plant irreversible damage is different at the various mentioned stages under conditions of one and the same moisture reduction of the same soil (Fig. 1).

● The plant irreversible damages caused at all stages are accumulated during the growing season. These damages irreversibly limit the amount and quality of crop yield,

irrespective of the increase in soil moisture caused by subsequent irrigation or rainfall.

● The irreversible physiological defeat depends on the energetic status of moisture in soil. This energetic status corresponds to different moisture contents in soils of diverse mechanical composition.

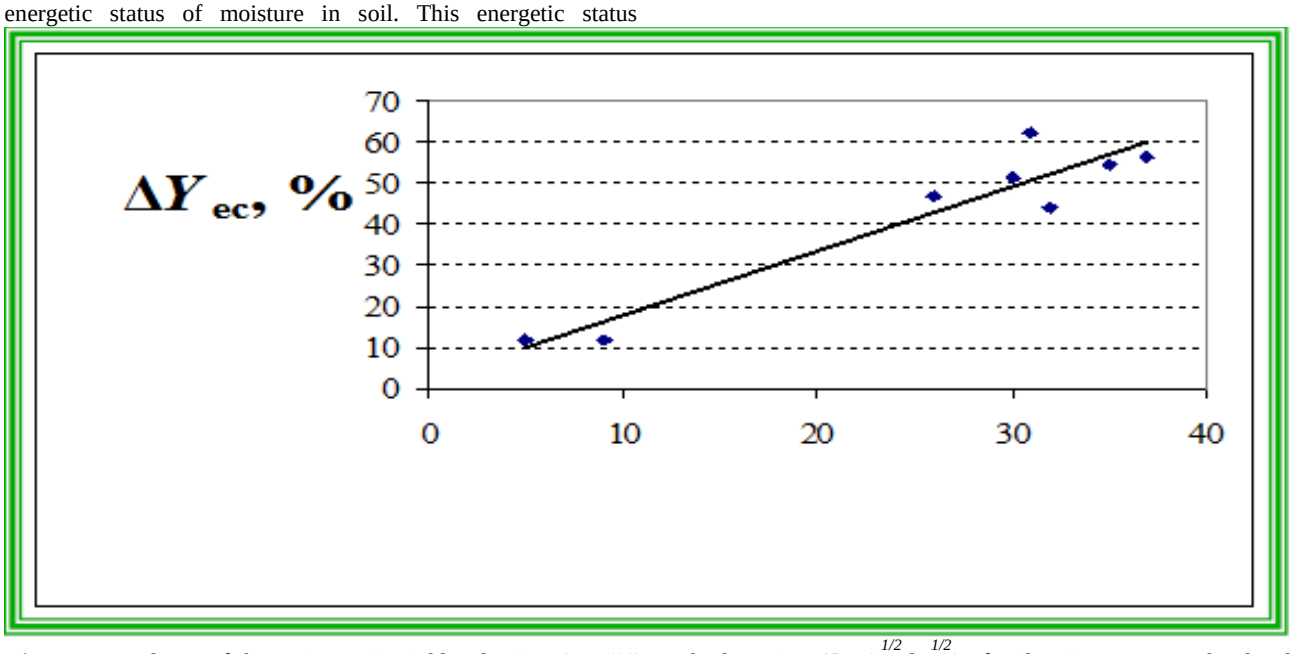

Fig. 3. *Dependence of the maize-grain yield reduction ΔY_{ec} (%) on the lowering ΔL_{ec} ($J^{1/2}/kg^{1/2}$) of soil-moisture energy level only at the extreme-critical C stage of plant*

Table 1. Average amounts of maize (H-708) grain yield (t/ha) obtained under different rates of fertilizing, depending on the energy level L (J/kg) **1/2** of soil water status (Lom, Bulgaria)

Rate of fertilizing	**Levels L of soil water status**				
	L = 5	L = 10	**L = 15**	L = 22	L = 26
$N_{34}\ P_{45}(3)\ K_{16}$	**16.21 Genetically put in hybrid**	14.61	12.96	9.90	5.87
$N_{28}\ P_{32}(3)\ K_{12}$	15.63	13.71	**11.91 Recommended yield for practice**	9.71	5.60
$N_{22}\ P_{23}(3)\ K_{8}$	15.00	12.56	11.46	8.70	6.77
$N_{0}\ P_{0}(3)\ K_{0}$	12.08	10.03	9.46	7.54	5.97

5. Conclusions

Applying the Decision Support Ecotechnology, we are precisely establishing the needed irrigation schedule currently during growing season each year to create the necessary universal energy level L = 15 $(J/kg)^{1/2}$ of soil moisture through its implementing. This level is recommended by us for all soils and crops in the agricultural practices.

The level L = 5 $(J/kg)^{1/2}$ of soil moisture belongs to the Biological Optimum of Plant Soil Water Comfort. We recommend it to be created in field using the offered ecotechnology in order to obtain the crop yield, which is genetically possible for new sorts and hybrids. This study provides information for the practice of competency-based management.

Dependence of the maize yield on the introduced universal estimate is established for the first time in agricultural

sciences and practices. The application of DSS (research version) showed higher efficiency compared to the traditional irrigation regime. The maize grain yield increased on average more than 70 %, implementing the DSS schedules to maintain the energy level $L = 15\ J^{1/2}/kg^{1/2}$ of water status, which took into account the meteorological features of each year and saved on average (over eight years) 29.5 % of irrigation water in comparison with the traditional irrigation regime for considered crop and region.

The research version of ecotechnology was tested in field experiments over 30 years. The complex scientific base and many results are accepted by scientists working at the University of California (USA); University of Moscow (Russia); Land Reclamation Institute of Sindos (Thessaloniki, Greece); University of Beijing (China); Aegean University of Izmir (Turkey); Institute of Water Problems and National Institute of Meteorology & Hydrology, both at Bulgarian Academy of Sciences, Sofia (Bulgaria); and Poushkarov Institute for Soil Science, Agrotechnology and Plant Protection, Sofia (Bulgaria).

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