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OBTAINING THE SCIENTIFICALLY PLANNED CROP YIELDS THROUGH APPLYING AGROPHYSICAL AND AGROCHEMICAL SCIENTIFIC BASE

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ABSTRACT

The paper deals with the application of recent top scientific attainments, which allow purposeful obtaining both the maximum and the reasonable crop yields. Maximum possible yield is necessary in plant genetic research to determine the yield genetically set in the new plant variety or hybrid. Practically reasonable crop yield is economically acceptable to be obtained in agricultural practices.

For the first time, both new ecotechnology for monitoring, estimating and managing the water status (EMEMWS) and new scientific bridge between water and nutrient statuses (SBWNS) enable us to estimate and create appropriate conditions for different crops in each field. The EMEMWS is a Decision Support System (DSS) for precise management in agriculture. Its version for scientific research was checked. The version for friendly and easy application by farmers can be created as market tool product.

Both scientific (EMEMWS and SBWNS) attainments are verified under field conditions. These are managing tools for obtaining planned amount and quality of crop yield in each agricultural field. Using it, the farmer saves energy (electrical, from fuel, etc.), irrigation water, nutrients for plant, and human labour in agricultural practices. This way, the farmer minimises or completely removes the losses of soluble

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substances, which pollute the surface and underground water and soil. The EMEMWS substitutes the periodical sampling for soil moisture determination and the use of other methods for local (point) measuring.

Keywords: crop, maximum yield, planned yield, water status, energy level of soil moisture, nutrient needed for fixed level of water status.

AIMS AND BACKGROUND

Increase in the efficacy of investments can be attained through practical application of the examined (during a period of 30 years) computerised ecotechnology for monitoring, estimating and managing the water status (EMEMWS). Creating the new varieties and hybrids requires exact determination of their maximum amount of yield and quality indices. For reaching this purpose, we need:

(a) the exact estimate of biologically optimum soil water status and its establishment in each field for the whole growing season of each year[1–3];

(b) the nutrient (nitrogen, phosphorus, potassium, microelements) supplies in soil, which are necessary to correspond and keep the growth at this biological optimum[4–6];

(c) the ecotechnology for current monitoring, estimating and managing the water status (EMEMWS), taking into account the various plant stage susceptibilities[7,8]. Using EMEMWS and appropriate irrigation equipment in the field, we can create the specific water status needed (applying minimum irrigation water) during the growing season[9–13];

(d) the appropriate irrigation equipment, water resources and executive human team[14].

The paper is aimed at revealing some great economic and ecological possibilities of the modern ecotechnology for monitoring, estimating and managing the agroecosystem water-nutrient status, including the creation of exact conditions needed for obtaining the genetically-possible and practically-reasonable crop yields.

RESULTS AND DISCUSSION

Genetically-possible crop yield. The both top scientific achievements (EMEMWS and SBWNS) enable us to estimate and create appropriate agroecosystem statuses for different crops in each field. Moreover, using these scientific tools, we can create the biologically optimum water and nutrient statuses under the changing meteorological conditions in different fields and regions. This way, we are able to determine and obtain the genetically-possible crop yield (GPCY) in field.

This complex ecotechnology is necessary in plant genetic research to determine the maximum yield genetically set in the new plant variety or hybrid. GPCY can be obtained under biologically-optimum conditions in field. Moreover, the ecotechnology is necessary to be applied in the seed production.

For the first time, the ecotechnology gives scientifically based decision how to create the recommended energy level $L = 5\ J^{1/2}/kg^{1/2}$ from the Class of Biological Optimum[2] in field during the growing season of crops each year, and to determine this genetic feature of the existing and new crop varieties or hybrids and produce their seeds under this water status.

Experimental data of 30-year period show that the maximum genetically-possible grain yield of H 708 maize grown on Calcareous Chernozem soil in north-western Bulgaria is on average 16.21 t/ha (Table 1).

Table 1. Soil-moisture energy levels (L, $J^{1/2}/kg^{1/2}$) recommended to be created in fields for the maize H 708, and the corresponding minimum allowed values of soil moisture potential (ψ_{min}, J/kg) at each stage of crop growing

Class number	Class name	L ($J^{1/2}/kg^{1/2}$)	ψ_{min} (J/kg)	Maize grain yield (t/ha)
I	Class of biological optimum	5	–50	16.21 (e) 16.69 (c)
III	Class of slightly lowered levels	15	–225	11.91 (e) 11.18 (c)

The values of grain yield (both maximum genetically-possible amount at $L = 5\ J^{1/2}/kg^{1/2}$ and reasonable one at $L = 15\ J^{1/2}/kg^{1/2}$) are experimentally (e) obtained in field and calculated (c) using the regression equations based on numerous experimental data[2].

Table 2 shows some detailed data on the H 708 maize yield, soil-moisture energy levels and fertilisation rates for different years.

Practically-reasonable crop yield. This ecotechnology offers the practical opportunity to create an agroecosystem water-nutrient status, which is scientifically-based and necessary to obtain reasonable amount and quality of crop yield and saves energy, fuel, organic and mineral nutrients, and human labour in agricultural practices, which is also for the first time.

Table 1 shows the recommended soil-moisture energy levels both $L = 5$ and 15 $J^{1/2}/kg^{1/2}$, which are necessary to obtain the both maximum genetically-possible amount of yield and the practically-reasonable one, respectively. Under the mentioned soil and regional conditions, the reasonable yield amount of grain is on average equal to 11.91 t/ha for the H 708 maize hybrid, creating the plant density of 65 000 plants per ha. All amounts of yield are calculated for 14% of standard grain moisture. The farmer should take into account the losses due to a reduced plant density and other factors in agricultural field, and those during harvesting and transport of the grain.

Table 2. Yield (t/ha) of the H 708 maize grain depending on L ($J^{1/2}/kg^{1/2}$) of water status of Calcareous Chernozem soil in the Complex Experimental Station, near the town of Lom, Bulgaria, which is obtained experimentally under different rates (kg/ha) of fertilisation

Year	Created energy levels ($J^{1/2}/kg^{1/2}$) of water status				
	under appropriate irrigation schedule			no irrigation	
	$L = 5$	$L = 10$	$L = 15$	$L_e = 22$	$L_e = 26$
			Nutrient rates: N_{340} P_{450} (3) K_{160}		
1986	16.36	14.24	13.72	9.90	–
1987	16.22	14.70	12.48	–	5.58*
1988	16.07	14.91	12.68	–	6.17*
Mean	16.21	14.61	12.96	9.90	5.87*
			Nutrient rates: N_{280} P_{320} (3) K_{120}		
1986	15.85	13.39	12.96	9.71	–
1987	16.09	13.77	11.07	–	5.44*
1988	14.95	13.98	11.71	–	5.76*
Mean	15.63	13.71	11.91	9.71	5.60*
			Nutrient rates: $N_{220}P_{230}$ (3) K_{80}		
1986	15.54	13.12	12.79	8.70	–
1987	14.55	10.86	9.52	–	7.33
1988	14.93	13.71	12.07	–	6.21
Mean	15.00	12.56	11.46	8.70	6.77
			No nutrients added: N_0P_0 (3) K_0		
1986	12.95	10.25	9.81	7.54	–
1987	12.14	10.38	9.62	–	6.52
1988	11.15	9.48	8.95	–	5.42
Mean	12.08	10.03	9.46	7.54	5.97

The yield values marked with asterisk (*) show that the maize plants have been depressed by an water status of energy level, which is lower than the necessary one for the two high rates ($N_{340}P_{450}$ (3) K_{160} and $N_{280}P_{320}$ (3) K_{120}). The phosphorus P (3) is supplied in soil for three years[13].

The farm, which is well furnished with agricultural and irrigation equipment, is able to reach the reasonable amount of yield, creating the necessary water status with the energy level L = 15 $J^{1/2}/kg^{1/2}$ of soil moisture, and the nutrient status corresponding to this level. This can be done using the offered ecotechnology for monitoring and estimating, creating the necessary schedule for irrigation and executing it. The application of this ecotechnology will save energy and fuels, water and nutrients, and human labour. Moreover, the exact execution of the schedules using appropriate irrigation equipment by the farmers will minimize or stop the pollution of surface and underground water.

Protection of environment and benefits. The offered ecotechnology for monitoring, estimating and managing the water status (EMEMWS) creates modern information possibilities for farmers to take precise decisions for accomplishing their activities concerning the regulation of water-and-nutrient status in soil for each crop grown in different fields. This is a great scientific tool to put into the agricultural practices the ecological principles and requirements, and to help the development of sustainable agriculture and to produce the safety products. Application of EMEMWS gives possibilities:

– to determine the necessary amounts of irrigation water and the exact days during the growing season for correcting the soil water status in order to create the appropriate energy level L of soil moisture to obtain the crop yield of planned amount and quality;

– to minimise or avoid the deep filtration under the soil root layer, which is a transport of water and solved substances polluting the underground water, and losses of water and nutrients for plants. All these need information on: (a) precise scheduling using the offered ecotechnology; (b) appropriate equipment for watering; (c) filtration properties of soil profile, and (d) realising of suitable parts of watering norm;

– to minimise or remove the surface water runoff and the linked soil erosion with it, which is a process of losses for plants of water, nutrients and soil solid phase, polluting the rivers, lakes and dams located near the agricultural fields. This protects the surface layer of soil;

– to obtain the reasonably planned crop yield, for which the farmer ensures the necessary nutrients in soil;

– to avoid the processes of impoverishment or overloading the soil with nutrients. Both processes lower the soil fertility, depress the growth and development of plants, reduce the amount of yield, and worsen its quality.

Creating water status with $L = 5\ J^{1/2}/kg^{1/2}$. The ecotechnology gives the scientifically based decision how to create an energy level from the Class of Biological Optimum (CBO) in field during the growing season of crops to determine the maximum genetically possible yield obtained from new crop variety or hybrid (Fig. 1) for the first time in agricultural science. It should be put into these practices for the first time.

In traditional agriculture, the fixed design of crop watering schedule at 90% ensuring the permanent total irrigation norm is not related to the biological water optimum of agroecosystem[15].

The great variety of natural agroecosystem water status (under no irrigation) was estimated with the new index L_e of equivalent energy levels of soil moisture and through the amount of yield obtained in different years.

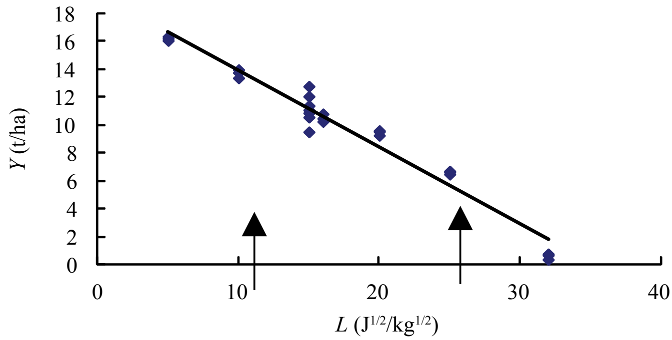

Fig. 1. Yield amount (*Y*, t/ha) of maize grain (H 708) obtained in experimental field under conditions of appropriate nutrient (N, P and K) status as a function of water status of Calcareous Chernozem soil (Lom, Bulgaria), which is estimated through the integral *L* index and created: by means of sprinkling irrigation in the 1982–1985 period; by furrow irrigation in the 1986–1988 period, and under no irrigation, during the growing season[2,13]

Table 3 shows the irrigation schedules developed through the EMEMWS and actually created in the maize agroecosystem to establish the soil-moisture energy level with $L = 5$ $J^{1/2}/kg^{1/2}$ during the growing season of 1981–1988 period[2,13]. Number of watering, which is necessary to create this energy level with $L = 5$ $J^{1/2}/kg^{1/2}$ in the different years considered, increases from 5 in 1982 to 11 in 1985. The total irrigation norm enlarges from 2400 m^3/ha in 1982 to 5330 m^3/ha in 1985. For the same period, the mean number of watering is equal to 7.75, and the average total irrigation norm is 3792 m^3/ha.

Creating water status with $L = 15$ $J^{1/2}/kg^{1/2}$. For irrigation practices, Zahariev et al.[15] recommended the fixed design of maize watering schedule in the considered region, as follows: 6 times of watering with 600 m^3/ha (total norm of 3600 m^3/ha) for the considered Lom region each year, as follows: first and third decades of June; each decade of July; and second decade of August.

Table 4 shows the irrigation schedules developed through the offered ecotechnology and actually created by irrigation in the maize agroecosystem to establish the soil-moisture energy level with $L = 15$ $J^{1/2}/kg^{1/2}$ during the same growing seasons[2,13].

Table 3. Irrigation schedules developed through the ecotechnology and actually executed in the field to establish the energy level with $L = 5$ J$^{1/2}$/kg$^{1/2}$ during the growing seasons of 1981–1988 period

Year and L_e (J$^{1/2}$/kg$^{1/2}$)	Dates and gross watering norms (m^3/ha)				Total number of watering	Total irrigation norm (m^3/ha)
	May	June	July	August		
1981 (19)	–	2 June 320; 14 June 390	2 July 460; 12 July 540; 22 July 600	7 Aug 640; 21 Aug 620	7	3570
1982 (16)	–	13 June 350; 21 June 440; 30 June 480	7 July 490	13 Aug 640	5	2400
1983 (20)	14 May 250	1 June 310	19 July 560; 31 July 620	10 Aug 650; 18 Aug 640	6	3030
1984 (25)	26 May 200	8 June 290; 22 June 380; 30 June 420	7 July 470; 18 July 550; 28 July 590	8 Aug 650; 20 Aug 640	9	4190
1985 (32)	24 May 250	7 June 320; 15 June 370; 23 June 440	1 July 450; 7 July 480; 17 July 550; 26 July 580	2 Aug 650; 11 Aug 630; 22 Aug 620	11	5330
1986 (22)	–	4 June 280; 26 June 410	25 July 570	5 Aug 650; 16 Aug 630; 26 Aug 640	6	3180
1987 (26)	–	11 June 340; 22 June 450	4 July 470; 17 July 540; 27 July 630	6 Aug 620; 18 Aug 600; 29 Aug 610	8	4260
1988 (26)	20 May 200; 31 May 230	20 June 340	6 July 440; 13 July 450; 22 July 510	1Aug 560; 10Aug 580; 19Aug 540; 28Aug 540	10	4380
Mean number over 8 years	0.625	2.125	2.5	2.5	7.75	3792

In the first column are presented the equivalent energy levels L_e, J$^{1/2}$/kg$^{1/2}$ of natural water status.

Table 4. Irrigation schedules developed through the ecotechnology for monitoring, estimating and managing and actually executed in the maize agroecosystem to establish the soil-moisture energy level with $L = 15\ J^{1/2}/kg^{1/2}$ (from Class of Slightly Lowered Levels) during the growing season of 1981–1988 period

Year and L_e ($J^{1/2}/kg^{1/2}$)	Dates and gross watering norms (m^3/ha)				Total number of watering	Total irrigation norm (m^3/ha)
	May	June	July	August		
1981 (19)	–	16 June 750	10 July 1100	3 Aug 1200	3	3050
1982 (16)	–	24 June 790	24 July 1140	–	2	1930
1983 (20)	–	2 June 600	–	2 Aug 17 Aug 1180 410	3	2190
1984 (25)	–	27 June 780	15 July 1000	4 Aug 1220	3	3000
1985 (32)	–	10 June 28 June 650 850	14 July 30 July 1030 1200	13 Aug 1200	5	4930
1986 (22)	–	–	–	6 Aug 27 Aug 1230 300	2	1530
1987 (26)	–	24 June 820	27 July 1190	25 Aug 420	3	2430
1988 (26)	–	16 June 700	15 July 31 July 970 1120	18 Aug 380	4	3170
Mean number over 8 years	0	1	1	1.125	3.125	2779

In the first column are presented the equivalent energy levels L_e, $J^{1/2}/kg^{1/2}$ of natural water status (no irrigation) for the years considered.

For obtaining on average 11.91 t/ha (Fig. 1), the number of watering, which is necessary to create this energy level with $L = 15\ J^{1/2}/kg^{1/2}$ in the different years, increases from 2 in 1982 and 1986 to 5 in 1985. The total irrigation norm enlarges from 1530 m^3/ha in 1986 to 4930 m^3/ha in 1985. For the same period, the mean number of watering is equal to 3.1, and the average total irrigation norm is 2779 m^3/ha.

Obviously, the farmer has to perform not 6 (six) times of watering, but on average only 3.1 times. He has to use for irrigation not 3600 m^3/ha, but on average 2779 m^3/ha for the period considered.

Using the fixed design of maize watering schedule[15], the farmer should perform almost 2 times higher number of watering, applying 1.3 times more amount of water than actually needed amount, both established by us through the application of the offered ecotechnology. This means that the irrigation practices, in which the farmers use the fixed design of watering schedule, are not economically effective and cause great pollution of surface and underground water of the region considered.

We have to emphasise a very important inference. To keep the same energy level of soil moisture and obtain fixed yield, the farmers have to perform the specified schedule of irrigation during each growing season, which strongly differs by: (a) number of watering; (b) date of watering; (c) rate of watering, and (d) total irrigation norm, for the same crop and soil in the region.

The creation of agroecosystem universal water status at the energy level $L = 15$ $J^{1/2}/kg^{1/2}$ is accessible for crops grown on all soils under conditions of good irrigation equipment, available water resources, and put-into-practice computerised Ecotechnology for Monitoring, Estimating and Managing the Water Status. We must emphasise that this energy level correspond to different pre-watering moisture for diverse soil varieties.

Traditional agriculture and modern technology for managing. Zahariev et al.[15] suggested a scheme of Bulgarian regions with fixed design of crop watering schedule at 90% ensuring the permanent total irrigation norm. The scheme is based on a very rough approach using mean day-and-night air temperature sums averaged over many years.

All designs of crop watering schedule do not take into account: (a) the four other meteorological factors strongly influencing the agroecosystem water status; (b) the specific course of soil moisture change in the root layer of crop during the actual growing season; (c) the different crop stage susceptibility related to available soil moisture for plants, etc.

Start of drought and degree of its development. The knowledge obtained in agrarian sciences and practices (soil physics, plant growing, hydro-amelioration), agroecology and biology up to now did not permit to define precisely the terms: start of drought and degree of drought thoroughness. The introduction of integral index of energy levels L of soil moisture and method for their determination[2], as well the development of Ecotechnology for Monitoring, Estimating and Managing (EMEM) the agroecosystem water status[13], allowed to determine the first day-and-night, on which the drought started for crops to be used in agricultural practices. We define the start of drought on the day when the energy level $L = 15$ $J^{1/2}/kg^{1/2}$ is reached in the field. This corresponds to a decrease in the soil moisture potential down to the value of –225 J/kg averaged over the soil root layer. The degree of drought thoroughness depends not only on the five basic meteorological factors, but also on both the properties of soil in each field and the crop biological features. This degree for each soil and crop can be estimated using the offered equations[2].

CONCLUSIONS

The formation of amount and quality of yield due to water status depends on both the energy limitation on supplying the plants with soil moisture and the degree of irreversible biological changes in plant organism caused by the variable water deficit at the different crop-development stages. The improvement of soil moisture status adding the necessary water on time implementing the decisions obtained through the offered ecotechnology for monitoring, estimating and managing is a good agricultural practice for the farmer to save energy, fuel, organic and mineral fertilisers, and human labour, reaching economically high-effective crop production. Moreover, this ecotechnology is a powerful control tool to protect the environment.

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