PRECISE COMPUTERISED INFORMATION TECHNOLOGY FOR CROP IRRIGATION SCHEDULING AND FERTILISING

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Abstract: Complex scientific basis and software of Information Technology for Crop Irrigation Scheduling and Fertilising are developed and tested on a large scale. New method for soil-crop water status estimating as a whole for the growing season is used. Integrated index L of soil moisture energy levels and crop-stage water susceptibility towards productivity are introduced. Using the Technology, a level L in fields can be created by implementing a specified irrigation schedule obtained in chronological sequence during the season. Equations to calculate the N, P, K-fertilising rates, corresponding to every soil-crop water status created, are developed. Dependencies of crop yield amount and quality on index L are experimentally found out. The Technology application leads to: improved water-fertilisers use efficiency at no current sampling, multi-variant management, and provides new opportunities for both the investigators and the farmers. For sale and putting into practice, please, contact the author, fax: (++3592) 248-937.

Keywords: Scientific basis, irrigation scheduling, fertilising rates, crop yield, new approach.

1 Introduction.

Tremendous financial funds have been invested in agriculture each year to create and keep favourable-to-plants moisture and nutrient status in soils. Further rise in the efficiency of this investment can be achieved by improving the scientific basis, developing a precise estimation of the soil moisture-nutrient impact on crop yield formation, and creating a practical technology for irrigation scheduling and fertilising.

The following scientific achievements are included to develop a new basis necessary to raise the investment efficiency: 1. New integral index and method for specifying the soil-crop moisture status related to the productivity (Christov, 1992); 2. Modern basis of crop water management for creating a specific soil-crop moisture status at a level above the level established by the natural meteorological factors (Christov, 1989; Christov, 1995b); 3. Scientific basis of the mutual impact of both the soil moisture and the nutrient status in soil on the amount of crop yield (offered in the present paper).

These achievements enable to overcome the problems concerning the lack of precise integral estimation of the soil-crop moisture status related to the amount of crop yield. The obtained amount is proportional neither to the mean soil moisture or evapotranspiration sum, neither to the total water receipt (from precipitation, irrigation and underground water), nor to its mentioned components one by one under equal other conditions (Alpatiev, 1963; Delibaltov, 1976; Viets, 1962). It is not taken into account the crop-stage water susceptibility towards yield response, and the variability of total water losses (with surface run-off, soil surface evaporation and deep filtration) during particularized stages of plant growth. This variability exerts influence on the obtained amount of yield in different ways, even when the total losses in different years are the same under equal other conditions. These effects are taken into account in the paper of Christov (1994).

The same achievements enable to solve the problem how to obtain a "planned" amount of crop yield, which was included in the models for calculating the rates of fertilising with nitrogen, phosphorus and potassium (Dinchev & Ikonomova, 1985; Milcheva, 1985; Neikova-Bocheva, 1985). Very often, the actually obtained amount of yield is both considerably lower (it means uneffectively used fertilisers and water) or considerably higher (it means that the soil becomes exhausted) than the "planned", even when the irrigation schedule is the same in different years. To obtain a planned amount of yield, we need both to create a specified soil-crop moisture status during the growing season and to provide the soil with specified amount of fertilisers.

These achievements enable to establish the crop yield dependence on soil moisture status estimated by index L of soil moisture energy levels, and the effects of this status on nutrient content in both the soil (Christov et al., 1991) and the grain production (Christov, 1993). The method for calculating an index P called "rain distribution characteristic for the growing season of a crop", leads to a very strong correlation between P and the amount of crop yield obtained, and can facilitate the determination of the L-index (Christov, 1995a; Christov & Kroumov, 1996).

The aim of the paper is to develop an Information Technology for Irrigation Scheduling and Fertilising (ITCISF), taking into account the mutual impact of soil moisture status and nutrient supply in soil on the amount of crop yield under equal other conditions.

2 New estimation of soil-crop moisture status related to the amount of crop yield.

Every soil-and-crop moisture status for whole growing season can be estimated in terms of an equivalent energy level L_e of the soil moisture, which can be calculated by the equation:

$$L_e = f_1 L_{ec} + f_2 L_c + f_3 L_{i,} \qquad (1)$$

where f_1, f_2 and f_3 are the weighting coefficients for the specified extreme-critical (ec), critical (c), and important (i) stages of crop ontogenesis; L_{ec}, L_c and L_i are the soil moisture energy levels established during the same stages. The L_s-index of a stage is proportional to the lower limit of the soil moisture potential (absolute value) raised to power of 1/2, and occured during the same stage. This index is defined by the values from 1 to 45 $J^{1/2} / kg^{1/2}$ (Christov, 1992). For each stage, the minimum in soil moisture potential is related to the minimum soil moisture.

The dependence of crop yield Y on index L_e should be determined in field experiments and expressed by equation:

$$Y = A - BL_e, \qquad (2)$$

where A and B are the constants characterizing the crop under climatic conditions of the region.

3 Modified model for nitrogen fertilising.

Proceeding from the equation of nitrogen balance (Dinchev & Ikonomova, 1985) and expressing the planned amount of yield with equation (2), we obtained the equation for calculating the nitrogen rate N:

$$N = n_1 (A - BL_e) + N_l - (N_b + N_m \pm N_h - N_{er} - N_s), \qquad (3)$$

where: L_e is the equivalent energy level of soil moisture to be created by implementing the special irrigation schedule obtained in chronological sequence by the technology, based on the theory of Christov (1989), n_1 is the amount of nitrogen taken out by unity of the plant production; N_l is the loss of nitrogen from soil and fertiliser added; N_b is the amount of nitrogen symbiotically fixed by leguminous plants or left behind them; N_m is the nitrogen amount entered the soil from the manure added; N_h is the amount of nitrogen related to humus content and soil texture; N_{er} is the nitrogen loss during the erosion processes; N_s is the additional amount of nitrogen necessary for the single cropping of cereals.

4 Modified model for phosphorus fertilising.

For determining the phosphorus rates of fertilising, we modified the model described in publication of Neikova-Bocheva (1985). The corrected annual rate F, corresponding to the level L_e of soil moisture, can be calculated using the obtained equation:

$$F = K_a [F_{nc} + f(A - BL_e)], \quad (4)$$

where: F_{nc} is the uncorrected annual phosphorus rate which equals to the total rate necessary to create a specified phosphate level, divided by the number of years needed to establish this level; f is the amount of phosphorus removed by unity of the plant production; K_a is the “ageing” coefficient of phosphates.

5 Practical application of the Technology.

To put into practice, we need information about: the agriculture of the region, irrigation possibilities, crops, soils, communication facilities, current meteorological observations in the region, computers available. The Technology functioning, adapting and control, have to be organised for the geographical region.

The Technology application takes into account the current meteorological, soil-physical, crop biological and agrochemical data, and the fundamental laws and regularities governing the main processes of crop yield formation. Using the Technology, we obtain a special irrigation schedule in chronological sequence during the growing season of every crop. Implementing this schedule specified for each field, we create a chosen energy level L_e of the soil moisture, which enables to obtain the planned amount of crop yield. The rates of fertilising are calculated to correspond to the L_e-value and applied to supply the plants with regard to this amount of yield.

The choice of the energy level L_e must be based on reliable information about the climatic, soil and crop conditions of the region, resources available for the farmer, agricultural and technical potential of the farm, and profit and loss account.

The computer technology is applied following the procedure steps: 1. Preparing the field files-name, area, crop, planting date; 2. Receiving the past-one-day (or past-three-days) current meteorological data by E-mail, telefax or telephone from the irrigation region; 3. Implementing the up-dating calculations of: the soil moisture deficiency in the increasing root zone, the expected date and rate of watering for each crop and field; 4. Sending the messages to the region operators to irrigate in due time, and receiving the back information about the implementation and control.

6 Results from the Technology application.

Some results obtained can be very briefly summarized in the following.

Field experimental data of many years with different fertilising rates prove (with correlation coefficient 0.935) that the yield Y, t/ha, of maize grain depends on the energy level index L_e, $J^{1/2} / kg^{1/2}$, as follows:

$$Y = 18.33 - 0.46L_e. \quad (5)$$

The same dependence is slightly changed when the data Y^*, obtained at appropriate N, P, K-fertilising rates, are used. The new correlation coefficient is 0.973 and the equation is:

$$Y^* = 19.21 - 0.52L_{e.} \quad (6)$$

The nitrogen content in grain of maize increases on average from 1.226 to 1.540%, i.e. by 25.6% of the minimum when changing the index L_e from 5 to 26 $J^{1/2} / kg^{1/2}$. The best rates of fertilising to accumulate protein in the grain are found out under the considered conditions.

The soil moisture levels with L_e = 15 to 17 $J^{1/2} / kg^{1/2}$ (at the best rates of fertilising) appeared to be the best for accumulation of phosphorus in grain of maize under soil and climatic conditions of the region.

The zinc content in grain of maize depends significantly on index L_e: it decreases 1.5 to 2.2 times when L_e-index increases from 5 to 26 $J^{1/2} / kg^{1/2}$, i.e. with the lowering of soil moisture levels and depending on N, P, K-fertilising rates.

Using the Technology, we established that crop water susceptibility towards the maize productivity during the extreme-critical, critical and important stages of ontogenesis is 52.6, 28.0 and 19.9% respectively.

7 Conclusion.

The offered Information Technology for Irrigation Scheduling and Fertilising is an innovation in soil physics, plant science and agricultural practices. Its application in different geographical regions leads to improved water and fertilisers use efficiency, multivariant management and provides new opportunities for both the investigators and the farmers.

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