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Abstract. From the morphological characteristics of crop growth, the mechanism model of photosynthate distribution based on the dynamic ralationship between root,shoot,leaf and grain is proposed in this paper. And the method of the determining model parameters with the field experiment data is proposed. The root-cap growth equilibrium coefficient, the shoot-leaf growth equilibrium coefficient, the grain-shoot growth equilibrium coefficient, the water stressed coefficient and the nutrient stressed coefficient are obtained by the nonlinear program according to the measured dry matter of the winter wheat root,shoot,leaf and grain in 2008 in the irrigation experiment station of Tianjin argricultutal university and the objective function of the minimum absolute error sum on the simulated and measured dry weight.And they are verified by the the winter wheat measured data in the irrigation experiment station of Tianjin argricultutal university in 2009. The results show that the simulated value and observed data of the dry weight of root, stem, leaf and grain are consistent. The correlation coefficients（R^2）of the comparison between simulated and measured value of the root,shoot, leaf and grain dry weight on every treatments were all over 0.81. It shows that the model on the simulation of the root, shoot, leaf and grain in this paper is reasonable.It provides a theoretical basis on reasonable farmland irrigation and fertilization.

Keywords: photosynthate, mechanism model, winter wheat, dry weight

1 Introduction

The Chinese and foreign scholars have done a lot of work on the tendency of the wheat growth for forties years and proposed many crop growth models. But, the existing wheat growth simulation models also have some shortcomings. Especially, the photosynthate allocation in the existing crop growth models is a empirical model. This has affected the development and application of the crop growth models to a certain extent.It is further studied and developed a mechanistic model. It need to be improved its explanatoriness [1-5].

2.Creation of the model

2.1 Hypothesis of the model

According to the same stretch law of the crop growth, there are several following hypotheses in the establishment of the distribution coefficient model on the winter wheat photosynthate.

（1）Balance hypothesis of the stem-leavf growth

$$Q^{x_1} C^{y_1} W_s = K_{sl} \cdot W_l \quad (1)$$

Where W_l is the dry matter weight of the leaves, kg/hm^2;W_s is the dry matter weight of the stems, kg/hm^2;Q,C are the Nitrate average concentration （g/kg）and the average volumetric moisture content （cm^3/cm^3）in the soil of 0-100cm depth, respectively. x_1 and y_1 are the index. K_{sl} is a proportionate coefficient related to the crop species and the growing period. In this paper, the coefficient of the stem-leave growth balance was defined. It is one of the crop hereditary parameters related to the crop species and the environmental factors.

（2）Balance hypothesis of the seed-stem growth

$$Q^{x_2} C^{y_2} W_e = K_{se} \cdot W_s \quad (2)$$

Where W_e is the dry matter weight of the seed, kg/hm^2; x_2 and y_2 are the index.The remaining symbols are the same meaning as the former.K_{se} is a proportionate coefficient related to the crop species ,the growing period and the environmental factors. In this paper, the coefficient of the seed-stem growth balance was defined. It is one of the crop hereditary parameters.

（3）Balance hypothesis of the root-shoot functions

$$Q^{x_3}C^{y_3}W_r \times S = A\times(W_l + W_s + W_e)\times P_d \qquad (3)$$

Where W_r is the dry matter weight of the roots, S is the absorbing water velocity of the roots, P_d is the canopy photosynthetic rate. x_3 and y_3 are the index.Because the whole crop growth was analysed, the absorbing water velocity of the roots(S) was equal to the actual transpiration rate of the crop (T_a). In this paper, A related to the species , the variety characteristics of the crops and the environmental factors was defined as the coefficient of the root-shoot growth balance. It is one of the genetic parameters of the crops.

(4) The composition of the roots, stems leaves and seeds was not significant difference. The substrate of the growth was transformed the dry matter with the conversion efficiency Y_g. The rest (1-Y_g) was consumed by the respiration [6-9].

Through the one day's accumulation of the photosynthate, the dry matter weight increment of the roots, stems, leaves and seeds(dW_r, dW_s, dW_l, dW_e) were as following

$$dW_r = f_r \cdot P_d \cdot Y_g$$

$$dW_s = f_s \cdot P_d \cdot Y_g$$

$$dW_l = f_l \cdot P_d \cdot Y_g$$

$$dW_e = f_e \cdot P_d \cdot Y_g$$

The dry matter increment of the plant (dW) can be described as

$$dW = dW_r + dW_s + dW_l + dW_e = Y_g \cdot P_d \qquad (4)$$

Where P_d is the total amount of one day photosynthate, Y_g is the conversion efficiency of the photosynthate.

2.2 Deduction of the model

It is supposed that the dry matter weight of the various parts of the plants is W_l, W_s, W_r, W_e in the t time. The canopy photosynthetic rate is P_d, the absorbing water velocity of the roots is S , the plant is in a growth equilibrium state in the t time. It can be described as equation (1), (2) and (3).

In the $t+\Delta t$ time, the various parts of the plant is W_l+dW_l, W_s+dW_s, W_r+dW_r, W_e+dW_e and still in a function equilibrium state. It is described as,

$$Q^{x1}C^{y1}(W_s+dW_s)=(K_{sl}+dK_{sl})\cdot(W_l+dW_l)$$

$$Q^{x2}C^{y2}(W_e+dW_e)=(K_{se}+dK_{se})\cdot(W_s+dW_s)$$

$$Q^{x_3}C^{y_3}(W_r \;\; dW_r)\cdot S=(A+dA)\cdot(W_l+dW_l+W_s+dW_s+W_e+dW_e)\cdot P_d$$

The before-mentioned 3 formulas were arranged and the high-level infinitesimal($dK_{se}\cdot dW_s$, $dK_{sl}\cdot dW_l$, $dA\cdot dW_s$, $dA\cdot dW_l$ and $dA\cdot dW_e$) was omitted. That is obtained,

$$dW_e=[W_s\cdot dK_{se}\cdot Q^{x_1}C^{y_1}+K_{se}\cdot(W_l\cdot dK_{sl}+K_{sl}\cdot dW_l)]/Q^{x_1+x_2}C^{y_1+y_2} \quad (5)$$

$$dW_s=(W_l\cdot dK_{sl}+K_{sl}\cdot dW_l)/Q^{x1}C^{y1} \quad (6)$$

$$dW_r=\frac{A\cdot P_d}{S\cdot Q^{x_1+x_2+x_3}C^{y_1+y_2+y_3}}[W_l\cdot dK_{sl}\cdot Q^{x_2}C^{y_2}+K_{sl}\cdot dW_l\cdot Q^{x_2}C^{y_2}$$

$$+W_s\cdot dK_{se}+K_{se}(W_l\cdot dK_{sl}+K_{sl}\cdot dW_l)]+\frac{(W_e+W_s+W_l)\cdot P_d\cdot dA}{SQ^{x_3}C^{y_3}} \quad (7)$$

Substituted equation (5), (6) and (7) into equation (4) , the distributive mechanism model of the crop photosynthate will be obtained.

The distributive coefficient of the roots was calculated as

$$f_r=\frac{A}{S\cdot Q^{x_1+x_2+x_3}C^{y_1+y_2+y_3}\cdot Y_g}[W_l\cdot dK_{sl}\cdot Q^{x_2}C^{y_2}+K_{sl}\cdot dW_l\cdot Q^{x_2}C^{y_2}$$

$$+W_s\cdot dK_{se}+K_{se}\left(W_l\cdot dK_{sl}+K_{sl}\cdot\frac{Q^{x_1}C^{y_1}W_s-K_{sl}W_l}{dK_{sl}}\right)]+\frac{(W_e+W_s+W_l)\cdot dA}{SQ^{x_3}C^{y_3}\cdot Y_g} \quad (8\text{-}1)$$

The distributive coefficient of the stems was calculated as,

$$f_s=\frac{W_l\cdot dK_{sl}+K_{sl}\cdot\frac{Q^{x_1}C^{y_1}W_s-K_{sl}W_l}{dK_{sl}}}{Q^{x1}C\cdot P_d\cdot Y_g} \quad (8\text{-}2)$$

The distributive coefficient of the leaves was calculated as,

$$f_l=\frac{Q^{x_1}C^{y_1}W_s-K_{sl}W_l}{dK_{sl}\cdot P_d\cdot Y_g} \quad (8\text{-}3)$$

The distributive coefficient of the seeds was calculated as,

$$f_e=\frac{W_s\cdot dK_{se}\cdot Q^{x_1}C^{y_1}+K_{se}\cdot(W_l\cdot dK_{sl}+K_{sl}\cdot\frac{Q^{x_1}C^{y_1}W_s-K_{sl}W_l}{dK_{sl}})}{Q^{x_1+x_2}C^{y_1+y_2}P_d\cdot Y_g} \quad (8\text{-}4)$$

2.3 Determine of the organ quality and economic yield

According to the before-metioned concept of the photosynthate distributive coefficient, the dry matter of the roots, stems, leaves and seeds are calculated as follows,

$$W_{r,i} = W_{r,i-1} + f_{r,i} \cdot P_{d,i} \cdot Y_{g,i} \tag{9-1}$$

$$W_{s,i} = W_{s,i-1} + f_{s,i} \cdot P_{d,i} \cdot Y_{g,i} \tag{9-2}$$

$$W_{l,i} = W_{l,i-1} + f_{l,i} \cdot P_{d,i} \cdot Y_{g,i} \tag{9-3}$$

$$W_{e,i} = W_{e,i-1} + f_{e,i} P_{d,i} \cdot Y_{g,i} \tag{9-4}$$

Where $W_{r,i}$, $W_{s,i,}W_{l,i}$ and $W_{e,i}$ are the dry matter weight of the roots, stems, leaves and seeds on the i day, kg/hm^2. $P_{d,i}$ and $Y_{g,i}$ are the amount of the photosynthate（kg/hm^2）and the transformation efficiency of the photosynthate. $W_{r,i-1}$, $W_{s,i-1}$, $W_{l,i-1}$ and $W_{e,i-1}$ are the dry matters of the roots, stems, leaves and seeds on the $i-1$ day (kg/hm^2). $f_{r,i}$, $f_{s,i}$, $f_{l,i}$ and $f_{e,i}$ are the photosynthate distributive coefficients of the roots, stems, leaves and seeds on the i day.

2.4 Calculation of the water and nutrient stressed coefficients

（1）the water stressed coefficient. Where it is calculated with the power function.

$$FW_I = \left(\frac{T_{ai}}{T_{pi}} \right)^{\sigma} \quad 0 < FW_i \le 1 \tag{10}$$

Where T_{ai} is the crop transpiration on the i day in the water stressed condition(mm/d). T_{pi} is the potential crop transpiration(mm/d). σ is the sensitivity index of the crop growth and yield in the water shortage condition, it also is called the water shortage sensitivity index. The crop transpiration T_{ai} is equal to the water amount of the crop root absorption.

（2）the nutrient stressed coefficient. Where it is also calculated with the power function.

$$FN = \left(R_{tpyN}(t)\right)^{\lambda} \tag{11}$$

Where λ is the sensitivity index of the crop growth and yield in the nutrient shortage condition, it also is called the nutrient shortage sensitivity index.

$$R_{tpyN}(t) = \min\left[1, P_N(t) / P_{crtN}(W)\right] \tag{12}$$

Where P_N *(t)* is the crop Nitrogen content on the *t* time (%). $P_{crtN}(W)$ is the critical crop Nitrogen content, it is also the Nitrogen minimum amount of the crop growth in the no Nitrogen stressed condition (%), it is calculated as follows[10],

$$P_{crtN}(W) = 1.35\left(1 + 3e^{-0.26W^*}\right) \quad (13)$$

Where $W^* = \max[1, W]$, W is the dry matter accumulation on the computed time (t/hm^2).

2.5 Accumulate of the organ dry matter

The crop photosynthate simulation in the water and nutrient stressed condition is calculated as follows. First of all, the potential crop photosynthate is calculated in the no water and nutrient stressed condition, it multiplied by the water and nutrient stressed coefficients then, the crop photosynthate on the *one* day is calculated as follows,

$$P_{di} = P_{dmi} \cdot FW_i \cdot FN_i \quad (14)$$

Where P_{dmi} is the amount of the photosynthate in the no water and nutrient stressed condition on the *i* day（kg/hm^2）. P_{di} is the amount of the photosynthate in the water and nutrient stressed condition on the *i* day（kg/hm^2）.FW_i and FN_i is the water and nutrient stressed coefficient, respectively.

Formulate (14) is calculated the amount of the crop photosynthate on the *i* day, and then it is multiplied by the distribution coefficients of the photosynthate for the organs (the roots, stems, leaves and seeds), the dry weight of the organs are acquired on the *i* day, and then it is added to the the amount of the photosynthate on the previous day, the sum accumulated every day is the final photosynthate cumulative value. The dry weight of the roots, stems, leaves and seeds is calculated as formulate (9).

3. Model Examination

3.1 Experimental Execution

Winter wheat phased draught experiment is performed in the irrigation experiment station of Tianjin Agricultural University. The experiment station is located at

Lat.39° 08′, Long. 116° 57′, sea-level elevation is 5.49m and groundwater level is 3.70-1.06 m. The experimental field covers an area of approximately 1 hm^2. Water for irrigation is groundwater transmitted by plastic hose and is metered. Winter wheat variety 6001 is selected for experiment. Based on local rainfall of the experiment station and water demand of the crop and by referring to previous experimental and research results, it is determined to carry out treatment as per winter wheat water-fertilizer double factorial experiment. Irrigation is divided into 5 levels (240mm, 180mm, 120mm, 60mm and non-irrigation) and is made at wintering, jointing, earing and filling stages. Fertilizer is applied at 4 levels (750kg/hm^2, 450 kg/hm^2, 150 kg/hm^2 and non-fertilizing). Compound fertilizer with total primary nutrient of no less than 54% is used as base fertilizer and is applied to soil with seeding; carbamide with 46% nitrogen content is used as top dressing and is applied along with jointing irrigation, i.e. fertilizer application is immediately followed by irrigation. Considering partial combination of base fertilizer and top dressing, 8 treatments are designed in 2008. A part of treatments are adjusted in 2009 on the basis of experiment in 2008 and number of treatment is increased to 10.

For experiment made in 2008, it is seeded on Sep. 25, 2007 and harvested on Jun. 14, 2008. Precipitation during the experiment is 187.4mm. For experiment made in 2008, it is seeded on Oct. 7, 2008 and harvested on Jun. 15, 2009. Precipitation during the experiment is 84.6mm. Seeding rate is 187.4kg/hm^2 in 2008 and 2009. Seeding is made mechanically with 25cm row spacing and approximately 5cm depth. Neutron survey meter is used to observe soil moisture content at depth 0-180cm by layers, 20cm per layer. Measurement is made at seeding, wintering, regreening, jointing and harvesting stages against each treatment. Generally, measurement is made once every 10 days before jointing and is conducted at the same time with dry weight measurement after jointing. Additional measurement is made before irrigation and after rainfall (daily precipitation more than 30mm).

3.2 Model Examination

Minimizing sum of absolute value of the error between simulated and measured values of dry weight is used as the the objective function. For programming solution to solve indexes of shoot-leaf growth equilibrium coefficient K_{sl}, root-cap growth equilibrium coefficient A and grain-shoot growth equilibrium coefficient K_{se}

x_1=0.3265, y_1=0.1858, x_2=0.0499, y_2=0.01731, x_3=-0.3675, y_3=-0.5639 and solve water and nutrient stressed coefficients λ=0.5695, σ=0.5026 with dry weight of root, shoot, leaf and seed measured by experiment made in winter wheat experimental field at the west capmpus of Tianjin Agricultural University in 2008. Scatter plot of simulated and measured values is drawed with 126 series data of 21 winter wheat zones in 2009. Compared between simulated and measured values of dry weight of root, shoot, leaf and seed in whole growth period of winter wheat is shown in figure 1~4 as medium water medium nutrient. Related coefficients are 0.9998, 0.8142, 0.898 and 0.8726 respectively. It is shown that simulation of organs of winter wheat is reasonable.

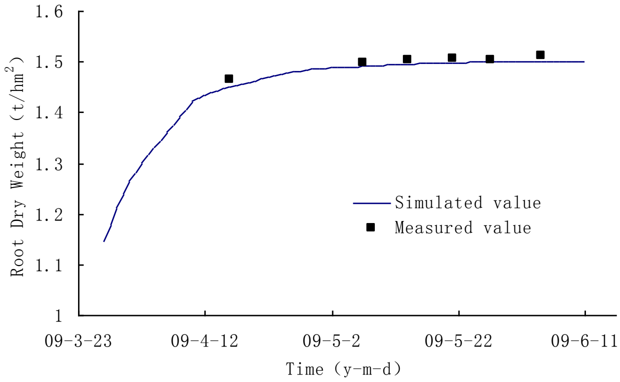

Fig.1 Comparison between simulated and measured value of root dry weight

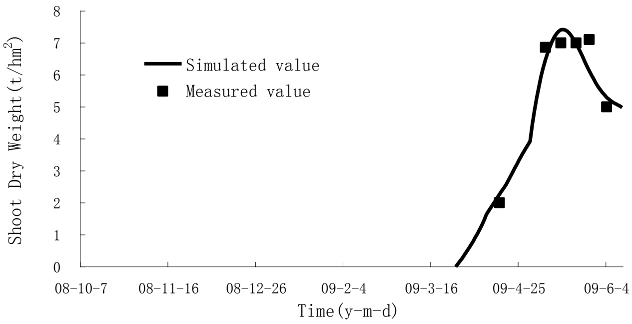

Fig.2 Comparison between simulated and measured value of shoot dry weight

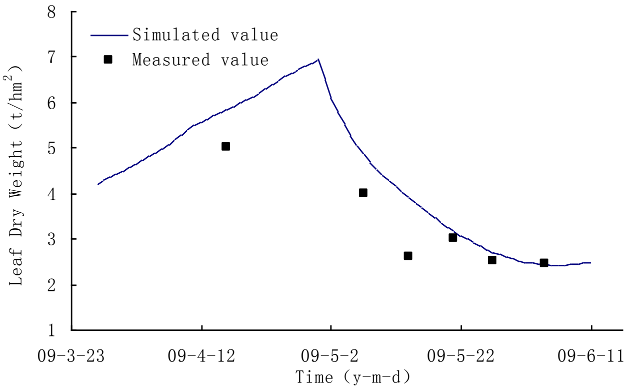

Fig.3 Comparison between simulated and measured value of leaf dry weight

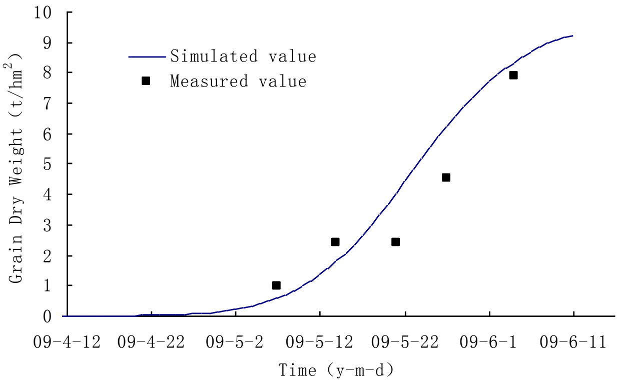

Fig.4 Comparison between simulated and measured value of grain dry weight

4.Conclution

1.Where the time, amount of irrigation and fertilization, influence of photosynthate distribution for the time and amount of irrigation and fertilization in the model of photosynthate distribution are important for formulating controlled measures of the irrigation and fertilization of the winter wheat. This improves the mechanism of the crop growth model.

2.Where the calculation of the water and nutrient stressed coefficients with the power function is simple and beneficial to analysis and calculation of the data of the field experiment. It provides a theoretical basis on the reasonable farmland irrigation and fertilization.

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