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Influences of climate change on dry matter accumulating velocity of spring wheat and numerical simulation in arid and semi-arid regions

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Abstract— The influences of climate change on the velocity of dry matter accumulation of spring wheat and numerical simulation in arid and semi-arid regions under the condition of rainfalled agriculture or irrigated agriculture were quantitatively analysed by using the field experimental data. The results showed that the velocity of dry matter accumulation of spring wheat was declined with the temperature rising. The accumulating velocity would be declined 4.9–14.0% in irrigated agriculture area when air temperature rose in 0.5–4.0℃; but in rainfalled agriculture regions, the velocity of dry matter accumulation would be increased with the soil moisture increasing when air temperature rose in 0.5–1.0℃ and decreased when the air temperature rose in 3.0–4.0℃.

Keywords: climate change; velocity of dry matter accumulation; rainfalled agriculture; irrigation agriculture.

INTRODUCTION

With the human being coming into the industrial society, the mineral fuel consumption increased quickly. Then, it is presented that the contents of atmospheric CO_2 and other trace gases successive increase. These trace gases are all presented greenhouse effect, especially for CO_2. In the past 10 years, it was pointed out that the contents of atmospheric CO_2 would be doubled before the year 2100 and then the global mean temperature would rise several degrees by the study results of many numerical simulation in overseas. Under normal emission situation, the global mean temperature would rise in 1 ℃ before the year 2025 and 3 ℃ at the end of next century estimated by the IPCC WGI in June 1990.

The earth warming would make the great influences on agricultural ecology sys-

tem. The advantage side would be existed to the influences of agricultural produces. The effective accumulated temperature and growth periods would be increased with the yearly mean temperature rise (Gao, 1990). The cultivated boundary would be moved to north. The multiple cultivated areas would be increased. But the disadvantage side would be also existed. Because of the temperature rising, the evaporativity would be great, the soil water consumption would be more than that in the present. It would be more serious for arid and semi-arid regions. In recent 2 years, some studies were made about the impacts of greenhouse effects on agricultural produce in domestic (Gao, 1990). But, most studies were analysis of the impacts of contents of atmospheric CO_2 doubling on cultivated system, agriculture and stock-raising boundary, crop yields in macroscopic were studied. The quantitative analysis was not reported in using fine experimental data to analyse the influences of climate change on crop growth and development. In the paper, the influences of climate change on the velocity of dry matter accumulation of spring wheat in arid and semi-arid regions were quantitatively analysed and numerical simulation by using field experimental data. The results showed that the velocity of dry matter accumulation of spring wheat was declined with the temperature rising in arid and semi-arid regions, the moisture factors were more important in non-irrigated regions.

EXPERIMENTAL METHODS

The methods combined sowing by stages with geographical sowing. The experimental sites were in Yongning and Guyuan counties, Ningxia Province. The annual mean temperature was 8.6 and 6.2 ℃, respectively, the difference was 2.4 ℃. The precipitation was about 200 mm in Yongning County. But it was irrigated, slight loam and the high fertility level. Generally, the yield was 5250−6000 kg per hectare. The annual mean precipitation was 480 mm but no irrigation in Guyuan County. It is dry land cultivation region, sandy soil. The performance of preserve moisture and fertility was short, the soil was barren, generally, the yield was 1200−1500 kg per hectare.

The sowings by stages were presented in two experimental sites. The interval between sowing was 15 days. The sowing time in Yongning in the year 1989 was 10/3, 25/3, 9/4 (Table 1); In Guyuan was 30/3, 4/4, 19/4 (Table was omitted). In 1990, on the basis of 1989, the sowing times were increased (it was 24/4 in Guyuan, otherwise in Yongning experimental site, the second sowing stage was postponed to 30/3 because of the rainfall).

The areas of experimental field was 8.40−9.45 m^2, repeated three times. The varieties for experimental were No. 4 Yongliang (Yongning) and Hongwangmai (Guyuan). The dry matter weight, fresh matter weight, stalk weight, leaf weight, ear weight, grain weight and the green leaf areas of individual plant in main growth

Table 1 The daily mean temperature in different development stages in every sowing (Yongning, 1989)

Sowing time	Development stage: Three leaves-jointing	Jointing-boot	Boot-blossom	Blossom-milk maturity	Milk maturity-mature	Mature Period
1st sowing (10/3)	14.0	15.6	19.3	20.8	22.5	15.0
2nd sowing (25/3)	14.4	16.7	19.5	21.2	21.5	16.5
3rd sowing (9/4)	16.4	19.4	19.9	21.9	23.0	18.0

stages (three leaves, tillering, jointing, boot, blossom, milk maturity, mature period) were measured. The meterological data in every growth stages were in Yongning and Guyuan meteorological stations. The water contents of layer 0 – 50 cm was measured in every growth stages (The soil water contents before every irrigation were determined in Yongning).

THE METEOROLOGICAL FACTORS AND CHARACTERISTIC VALUE OF SPRING WHEAT GROWTH

The results of quantitative analysis according to the experimental data showed that the influences of meteorological factors on living beings characteristic value in different growth stages were differences. The differences for velocity of dry matter accumulation among different development stages were markable, the correlation with meteorological factors were very closely. The guiding factors which influences the velocity of dry matter accumulation were also differences. In the following, the relations between the meteorological factors and velocity of dry matter accumulation according to development stages were discussed.

Three leaves-jointing stage

In this period, the accumulation of dry matter was slow. The experimental results showed that the velocity of dry matter accumulation was 0.0075 – 0.0184 g/plant per day. The differences between moisture area (Yongning, irrigation) and dry land cultivation region (Guyuan, non-irrigation) were great disparity.

The velocity of dry matter accumulation in moisture areas was increased with the soil moisture (before first irrigation), daily mean temperature and effective radiation successive increasing. In the dry land cultivation region, moisture and temperature were the guiding factors.

The accumulation of dry matter in this period was mainly used to grow leaf, tillering and root. So, the velocity of leaf dry matter accumulation was faster and restricted mainly by moisture and temperature.

Jointing-boot stage

With the leaf spread, the stalk stretched, the accumulation of dry matter was increased quickly. The velocity was 0.0093 – 0.0649 g/plant per day. The negative correlation was presented between the velocity of dry matter accumulation and temperature. Under high temperature, the leaves spread faster, colony light transmisivity became weaken, the jointing growth was restricted and even death. So the accumulation of dry matter was decreased. The moisture factors were the guiding elements for the wheat dry matter accumulation at the dry land cultivation regions in the period. The growth center from jointing stage to boot stage was turned to stalk and baby ear. So, the stalk dry matter was increased quickly. If the water supply was enough, the green leaves areas would be increased continuously, and reached the greatest value in whole growth periods.

Boot-blossom stage

In this period, the accumulation of dry matter was continue increasing, the accumulating velocity was 0.0166 – 0.0718 g/plant per day. It was the period that the velocity of dry matter accumulation was fastest. The velocity of dry matter accumulation was increased with the temperature raise.

Blossom-milk maturity stage

Since the blossom, the wheat was turned to reproduction growth. The assimilation products were turned to grain. The velocity of dry matter accumulation was declined to 0.0043 – 0.0523 g/plant per day. The high temperature and moisture lack would restrict the assimilation products transport to grain. Then the weight of grain declined. The temperature was guiding factor for the velocity of dry matter accumulation in this period. The second was moisture factor, it was the same in moisture area and dry land cultivation region.

Milk maturity-mature stage

The accumulation of dry matter was slow down continuously till stop. The accumulation velocity declined to 0.0034 – 0.0434 g/plant per day. The velocity of dry matter accumulation was restricted by temperature whether it in moisture area or in dry land cultivation region.

THE NUMERICAL SIMULATION OF INFLUENCES OF CLIMATE CHANGE ON THE VELOCITY OF DRY MATTER ACCUMULATION OF SPRING WHEAT

The influences of meteorological factors on velocity of dry matter accumulation in different development stages were quantitatively analysed according to the experimental data of sowing by stages and geographical sowing in the year 1989 and 1990. The model (omitted) of meteorology-velocity of dry matter accumulation was set up. On the basis of this work, the models of climate (temperature, moisture) change on the velocity of dry matter accumulation in different development stages were built. Three simulation schemes were given as following by according to the different meteorological factors.

1. Under present produce level, the assumption that the water contents in the soil and physiological radiation was not change. The numerical simulation of the influences on velocity of dry matter accumulation was given if the daily mean temperature rise in 0.5, 1.0, 2.0, 3.0 and 4.0 ℃ .

2. The assumption that the temperature and sunshine was not change and the soil moisture change ±1%, ±4%, ±7%, ±10%, ±15%, ±20% (the water contents in the soil was presented by using the percentage of capacity). The simulation value of influences on the velocity of dry matter accumulation was made.

3. The synthesized influences of temperature and moisture on the velocity of dry matter accumulation were simulated at each development stages. The last results were gotten by weighted average.

THE ANALYSIS OF SIMULATION RESULTS

The influences of temperature on the velocity of dry matter accumulation

The correlation between temperature and velocity of dry matter accumulation are given in Fig. 1 and Table 2. It is seen from the Fig. 1, the influences of temperature on the velocity of dry matter accumulation were different in the moisture area and dry land cultivation region. The velocity of dry matter accumulation was declined as the index function form with the temperature rising (Fig. 1a). When the temperature rose in 0.5 ℃ , the accumulating velocity was declined 4.9%. When the temperature rose in 1−2 ℃ , the accumulating velocity was declined 8.1−12.2%. When the temperature rose in 3−4 ℃ , the accumulating velocity was declined 13.7−14.0%.

The differences of respond in each development stages to temperature were markable. The accumulating velocity was declined with the temperature rising from jointing stage to boot stage and from blossom to mature stage. The other stages were

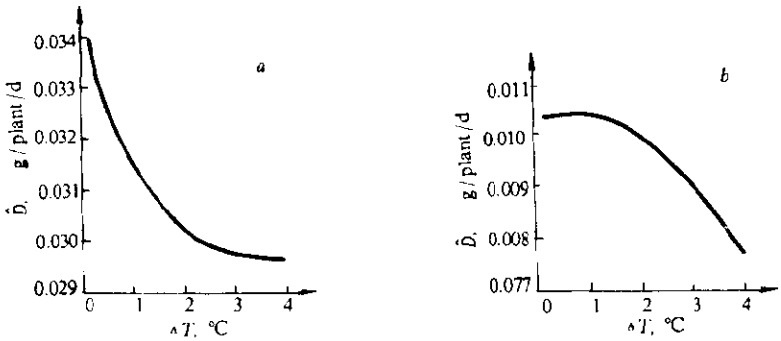

Fig. 1 The influences of temperature change on velocity of dry matter accumulation of spring wheat
a. moisture region (Yongning) *b.* dry land region (Guyuan)

Table 2 The climate models for velocity of dry matter accumulation in mainly spring wheat development stages

	Yongning (moisture region)	Guyuan (dry land cultivation region)
Three leaves-jointing	$\hat{D}_{1j}=(-0.244+0.007336\ M_1-0.0000378\ M_1^2)\cdot e^{26.0407/T_1}$	$\hat{D}_{1j}=(1.9550074+0.2783T_1-0.00869T_1^2)\cdot e^{1103.6/M_1+15.6103/Q_1}$
Jointing-boot stage	$\hat{D}_{2j}=0.3117e^{(0.393/D_{20}+51.2905/N_2)}$	$\hat{D}_{2j}=0.369e^{14.626/T_2-7.8179/Q_2}$
Boot-blossom stage	$\hat{D}_{3j}=0.435e^{(0.0.1323/D_{30}+18.4981/M_3)}$	$\hat{D}_{3j}=1.0993e^{57.4140/T_3}$
Blossom-milk maturity stage	$\hat{D}_{4j}=(-4.82863+0.5283T_4-0.01421T_4^2)\cdot e^{1.5175/D_{40}}$	$\hat{D}_{4j}=(0.00041+0.56866M_4-39.7933M_4^2)\cdot e^{63.1762/T_4}$
Milk maturity-mature stage	$\hat{D}_{5j}=0.000469e^{94.3127/T_5}$	$\hat{D}_{5j}-113\times10^{-9}e^{288.0332/T_5}$

Note: D_i—the weight of dry matter (g/plant per day) in the development stage. No. i, M_i, T_i, Q_i were the moisture contents in the soil 0—50 cm (it was presented by using the percentage of capacity), daily mean temperature and physiological radiation in the development stage No.e, respectively.

contrasted. Especially, the responds to tempeature were most sensitive from milk maturity to mature stage. When the temperature rise in 0.5 ℃, the accumulating velocity

were declined 15.5%. The temperature rise in 1 – 2 ℃ and 3 – 4 ℃, the accumulating velocity were declined 26.7 – 43.2% and 54.0 – 61.2%, respectively.

From Fig. 1*b*, the parabola form was presented between the velocity of dry matter accumulation and temperature in dry land cultivation region. When the temperature rose in 0.5 – 2.0 ℃, the accumulating velocity was almost not change. The temperature rose in 2 – 4 ℃, the velocity of dry matter accumulation was decreased 3.9 – 26.9%.

The influences of soil moisture on the velocity of dry matter accumulation

The influences of soil moisture change on the velocity of dry matter accumulation is given in Fig. 2.

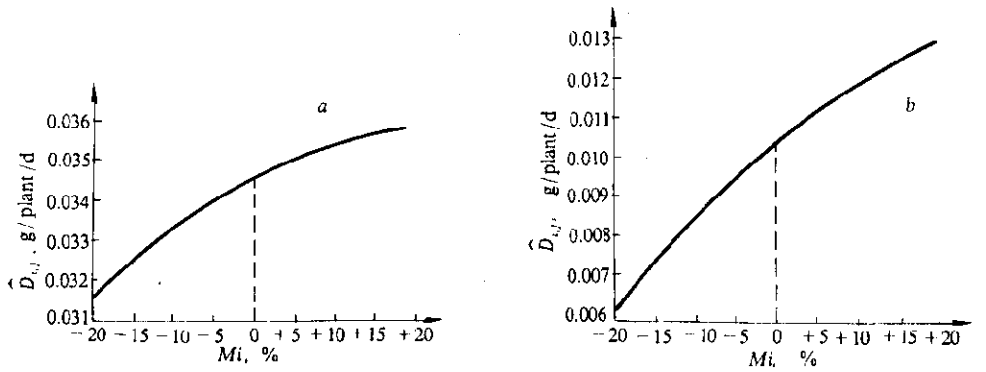

Fig. 2 The influences of soil moisture change on the velocity of dry matter accumulation of spring wheat (*a*. *b* are the same as Fig. 1)

The velocity of dry matter accumulation of spring wheat was increased with the soil mositure increasing in moisture area. When the soil moisture increased or decreased 1 – 10%, the accumulating velocity was increased 0.3 – 2.6% or decreased 0.3 – 3.5%, respectively. The soil moisture increased or decreased 15 – 20%, the velocity of dry matter accumulation was increased 3.5 – 4.1% or decreased 5.5 – 7.8%, respectively.

The responds velocity of dry matter accumulation on soil moisture was more sensitive at dry land cultivation region. The accumulating velocity was increased as index function form with the soil moisture increasing. When the soil moisture increased or decreased 1 – 4%, 7 – 10%, 15 – 20%, the velocity of dry matter accumulation were increased 1.0 – 5.8%, 9.6 – 13.5%, 19.2 – 24.0% or decreased 1.9 – 6.7%, 12.5 – 18.3%, 28.8 – 40.4%, respectively. So, the impacts of moisture factors at dry land cultivation regions were greater than that at the moisture area.

The influences of temperature and soil moisture on velocity of dry matter accumulation

The synthesize impacts of temperature and moisture on the velocity of dry matter accumulation of spring wheat are shown in Fig. 3.

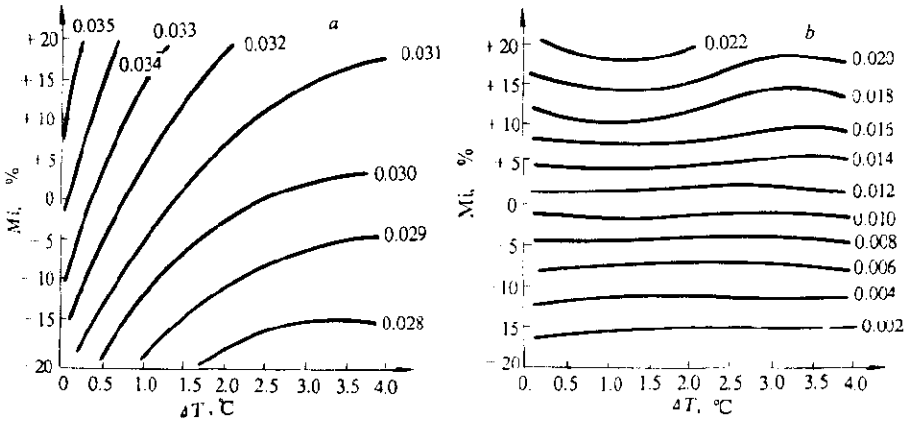

Fig. 3 The influences of temperature and soil moisture on velocity of dry matter accumulation of spring wheat
(*a*. *b* are the same as that in Fig. 1)

The velocity of dry matter accumulation of spring wheat in moisture area was increased with the temperature rose and decreased with the soil moisture declined. The velocity of dry matter accumulation, under present temperature, made the maximum value when the soil moisture increased 20%. The minimum value was respond the high temperature and low soil moisture.

There were great differences between the dry land cultivation region and moisture area. The velocity of dry matter accumulation was increased with the soil moisture increasing if the soil moisture was from the present level to increased 20% and the temperature rose in 0.5—1.0 ℃. If the temperature rise exceeded 1 ℃, the increased value was small. This is because that the evaporation would be increased and the soil moisture contents would be declined when the temperature rise. The result was that the temperature effect was counteracted by the soil moisture effect. When the soil moisture changes ranged from 1—15%, the velocity of dry matter accumulation present declined tendency with the temperature rise, but the differences were small.

CONCLUSION

The numerical simulation results of influences of climate change on velocity of

dry matter accumulation showed that the important influences of climate change on the accumulation process of dry matter of spring wheat were engendered. If the mean temperature rise in 0.5－4.0 ℃, the velocity of dry matter accumulation within whole spring wheat development periods in moisture area is declined 4.9－14.0%. From blossom to mature stage is the sensitivity period of temperature respond. The advantage side of climate warm is that it can advanced the accumulating velocity of green leaves. But, because of the increasing of the velocity of dry matter accumulation in stalk, the assimilated products transport to grain is restricted and the useful rate of assimilated products is declined. The velocity of dry matter accumulation is increased (or decreased) with the soil moisture increases (or decreases). The respond range is greater in dry land cultivation region than that in moisture area.

The velocity of dry matter accumulation is declined with the temperature rises and soil moisture decreases in moisture area. It is different between dry land cultivation region and moisture area, when the temperature rises in 0.5－1.0 ℃, the velocity of dry matter accumulation would be increased with the soil moisture increasing. When the temperature rises in 3－4 ℃, the accumulating velocity would be declined.

In this paper, the influences of climate warm of velocity of dry matter accumulation were numerical simulated under present produce level. The impacts of agricultural factors (fertilizer level, plant densities and so on) were not considered.

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