Closing wheat yield gap by optimization of seeding and fertilizer rates based on summer precipitation in dryland

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Introduction

Precipitation has been recognized as the dominant factor for grain yields and the great yield variations. In North China Plain, up to 20% of the yield variation was caused by weather factors, including precipitation and temperature. Yield variation exists not only under different precipitations, but also the similar precipitations. This indicates that it is very important to understand the links of precipitation and other management practices for the purpose to decrease the crop yield variation and increase the harvest.

The present study tried to (1) investigate wheat yield variation under similar precipitation; (2) understand factors controlling the yield variation under similar precipitation (3) propose optimized soil fertility, fertilizer and crop managements for crop yield increase to farmers in dryland of China and other similar areas in the world.

Materials and Methods

Sampling: Wheat and soil samples were collected from 804 farmers' fields in three provinces during the four consecutive years from 2015 to 2018 in the Loess Plateau dryland area of China, with 315 in 2015, 288 in 2016, 108 in 2017 and 132 in 2018.

Measurements： Wheat yield; soil nitrate-N, ammonium-N, available P, available K, pH and organic carbon (SOC); N, P and K concentration of different organs of wheat.

Results

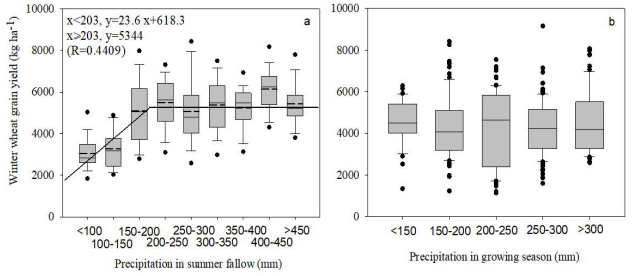

Fig. 1 Relationship between wheat grain yield and precipitation:(a) precipitation in summer fallow, and (b) precipitation in growing season in dryland area of the Loess Plateau.

Based on the liner-plateau model, the observations were categorized into two precipitation groups according to the precipitation in summer fallow: L203 and H203, with their precipitation in summer fallow lower and higher than 203 mm, respectively. Then depending on the yield difference, each group was further divided into three yield groups: Low, Mid and High by equally separating the samples with their yield ordered from low to high.

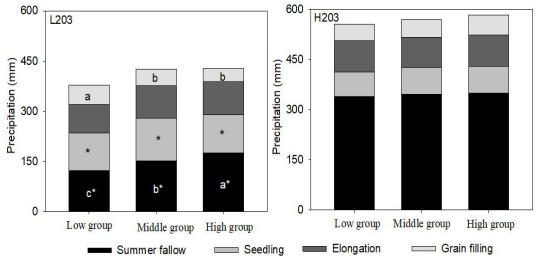

Fig 2. The distribution of precipitation in wheat production under L203 and H203 condition.

Table 1 Wheat biomass, yield, harvest index, yield components and sowing rate in Low, Mid and High groups under L203 and H203 condition.

Groups	L203			H203		
Subgroups	Low	Mid	High	Low	Mid	High
Biomass (t ha^{-1}) *	6.1 c	7.9 b	11.2 a	9.2 c	11.6 b	14.9 a
Yield (kg ha^{-1}) *	2246 c	3372 b	5239 a	3625 c	4289 b	6429 a
Harvest index (%)	36.9 c	43.1 b	46.8 a	40.1 c	41.9 b	43.4 a
Kernel weight (g 1000 grain^{-1})	33.9 c	41.2 b	44.6 a	31.9 a	33.1 a	33.5 a
Kernel number (spike^{-1}) *	23.3 c	25.9 b	34.7 a	34.3 b	36.5 b	41.0 a
Spike number (10^6 ha^{-1}) *	2.86 c	3.24 b	3.44 a	3.58 c	4.26 b	5.03 a
Sowing rate (kg ha^{-1}) *	167.9 c	187.4 b	197.9 a	151.4 a	146.9 a	140.4 a

* represents the significant difference between the same yield subgroup under L203 and H203 condition. Different letters represent the significant difference among Low, Mid and High groups

Table 2 Nutrient input and nutrient uptake (kg ha^{-1}) in aboveground winter wheat

Item	Nutrient Species	Lower than 200 mm			Higher than 200 mm		
		Low	Mid	High	Low	Mid	High
Nutrient input (kg ha^{-1})	N	143.7 a	146.7 a	153.2 a	127.0 c	148.6 b	172.6 a
	P_2O_5*	100.6 b	122.3 a	82.7 c	120.3 a	116.1 a	124.9 a
	K_2O*	51.8 b	61.3 a	28.4 c	22.3 a	21.9 a	21.4 a
Nutrient uptake (kg ha^{-1})	N*	70.6 c	86.3 b	123.5 a	104.6 c	135.2 b	164.9 a
	P_2O_5*	16.7c	21.6 b	32.4 a	27.7 c	35.7 b	47.6 a
	K_2O*	49.0 c	57.9 b	83.1 a	84.7 c	106.8 b	140.7 a
		(9.1)	(13.1)	(19.9)	(15.4)	(20.7)	(27.9)

Table 3 Wheat biomass, yield, harvest index, yield components and sowing rate in Low, Mid and High groups under L203 and H203 condition

Groups	L203			H203		
Subgroups	Low	Mid	High	Low	Mid	High
Biomass (t ha^{-1}) *	6.1 c	7.9 b	11.2 a	9.2 c	11.6 b	14.9 a
Yield (kg ha^{-1}) *	2246 c	3372 b	5239 a	3625 c	4289 b	6429 a
Harvest index (%)	36.9 c	43.1 b	46.8 a	40.1 c	41.9 b	43.4 a
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* represents the significant difference between the same yield subgroup under L203 and H203 condition. Different letters represent the significant difference among Low, Mid and High groups

Table 4 Soil physiochemical properties under L203 and H203 conditions

Item	Lower than 203 mm			Higher than 203 mm		
	Low	Mid	High	Low	Mid	High
SOM (g/kg) *	12.7a[#]	11.3a	11.5a	12.4 a	13.7a	12.2 a
pH	8.4 a	8.3 a	8.3 a	8.4 a	8.4 a	8.3 a
TN (g/kg)	0.7 a	0.7 a	0.8 a	0.8 a	0.8 a	0.8 a
Mineral N (mg/kg)*	9.0 a	10.1 a	9.5 a	16.1 b	23.9 ab	24.4 a
Olsen-P (mg/kg)*	13.1 a	9.3 b	11.1ab	13.0 b	14.8 ab	17.6 a
Available K (mg/kg)	135.9 a	120.9 b	123.8 b	144.4 a	126.0 b	124.3 b

Table 5 Fertilizer rates regulation, economic returns and GHG emissions after precising nutrient management

Items		Plus fertilizer use [a] (kg ha^{-1})			Economic returns ($/ha)			GHG emissions kg CO_2 eq kg^{-1}		
		N	P_2O_5	K_2O	Present [b]	After	Increasing rate (%)	Present	After	Increasing rate (%)
L203	Low	-73.1	-63.1	-42.7	176	343	94.9	2337	1665	-28.8
	Mid	-60.4	-73.7	-48.2	524	701	33.8	2396	1807	-24.6
	High	-29.7	-9.78	-8.5	1241	1281	3.2	2460	2144	-12.8
	Average	-54.4	-48.9	-33.1	647	775	43.9	2389	1872	-22.1
H203	L-to-M	21.6[b]	-66.8	-1.6	683	1149	68.2	2232	2203	-1.4
	M-to-H	24.0	-36.1	6.0	1085	1648	51.9	2381	2469	3.7
	L-to-H	45.6	-48.9	5.6	683	1648	141.3	2232	2469	10.6
	Average	30.4	-50.6	3.3	817	1482	87.1	2282	2379	4.3

[a] The values are calculated from the recommend fertilizer rates and the present rates (recommend fertilizer rates − present rates). N, P and K recommended fertilization rates are based on the method proposed by Cao et al. (2017).
[b] Present, the status of economic returns or GHG emissions under the present management; After, the status of economic returns or GHG emissions after precising nutrient and agriculture management process.

Conclusions

1. wheat grain yield fitted in a liner-plateau model to the precipitation in summer fallow season.

2. Under L203 group, the Low yield subgroup had lower sowing rate, kernel weight, kernel number and spike number than those in the High yield subgroup. Under H203, the differences in kernel and spike number were also observed among the Low, Mid, and High yield subgroups。

3. There was no differences in the soil organic matter (SOM), total N and pH in the three subgroups under L203 and H203, but for soil mineral N, available P and K, significant differences were observed between the three subgroups (except mineral N under L203).

4. The wheat sowing rate and fertilizer input rates can be optimized to close the wheat yield gap, increase the farmers' income and precise the agricultural managements for dryland wheat production.

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