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Soil K supplying capacity and crops responses to K fertilizer in rice-oilseed rape rotation system

稻-油轮作体系土壤供钾能力及作物对钾肥的响应

Xiaokun Li 李小坤 and Jianwei Lu 鲁剑巍

Huazhong Agricultural University

华中农业大学

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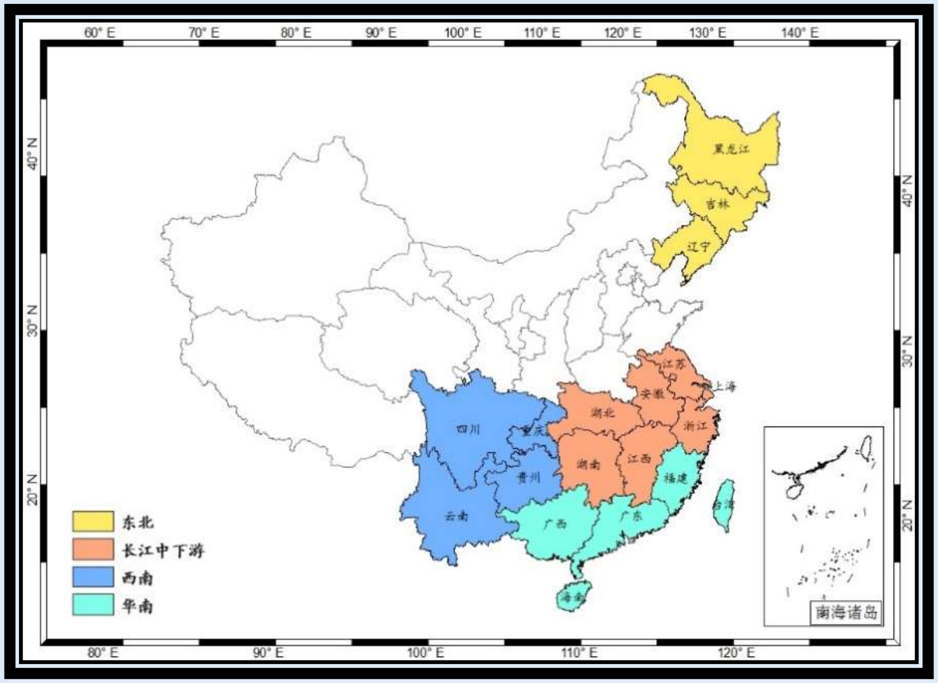
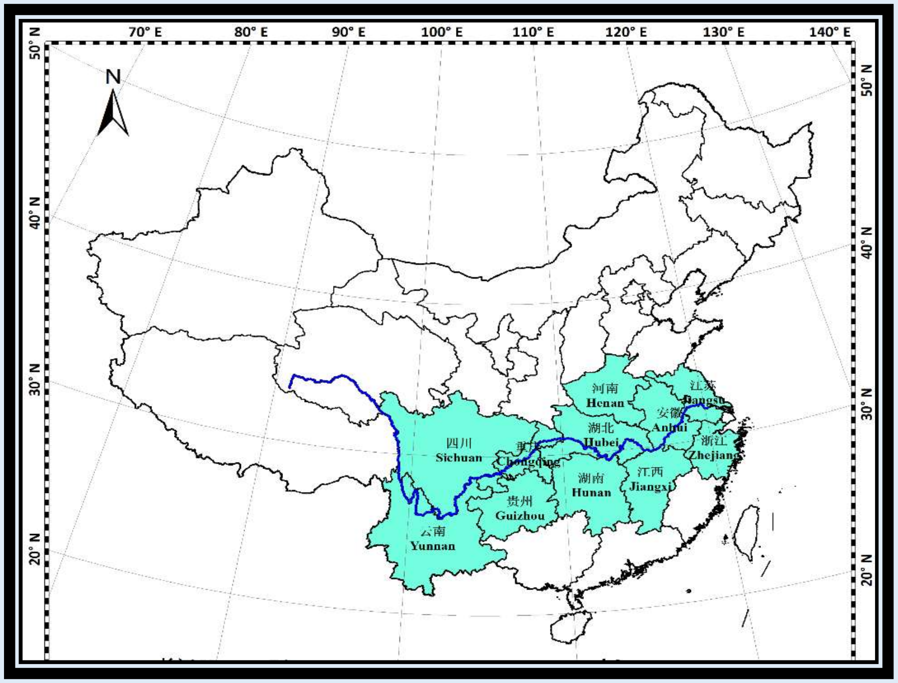
Main producing area of rice



Rice: one of the most important food crops in China

Main production area: Northeast, Middle and lower reaches of the Yangtze River, Southwest, South China

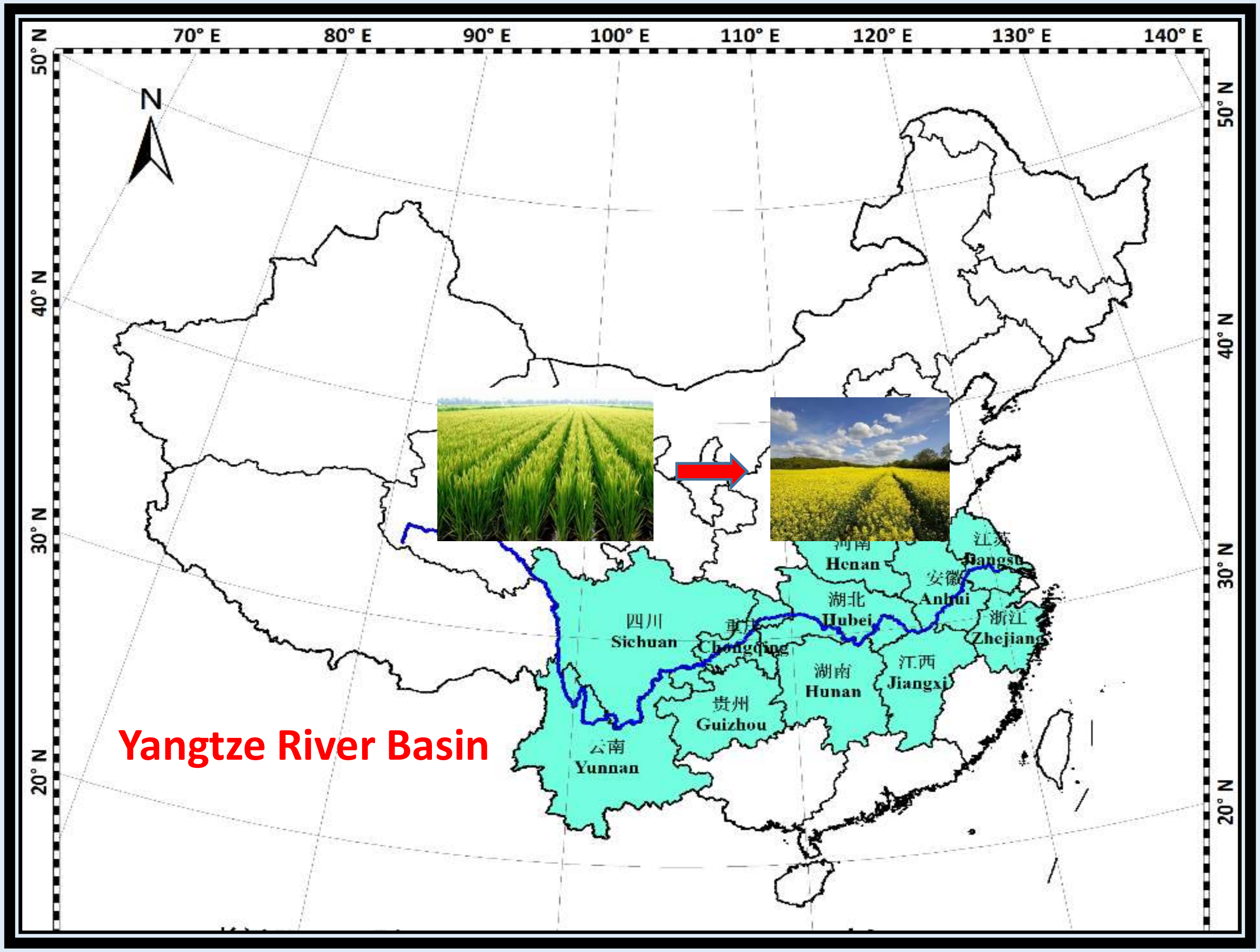
Main producing area of oilseed rape



Oilseed rape: the largest oil crop in the planting area

Main production area: Yangtze River Basin (YRB)

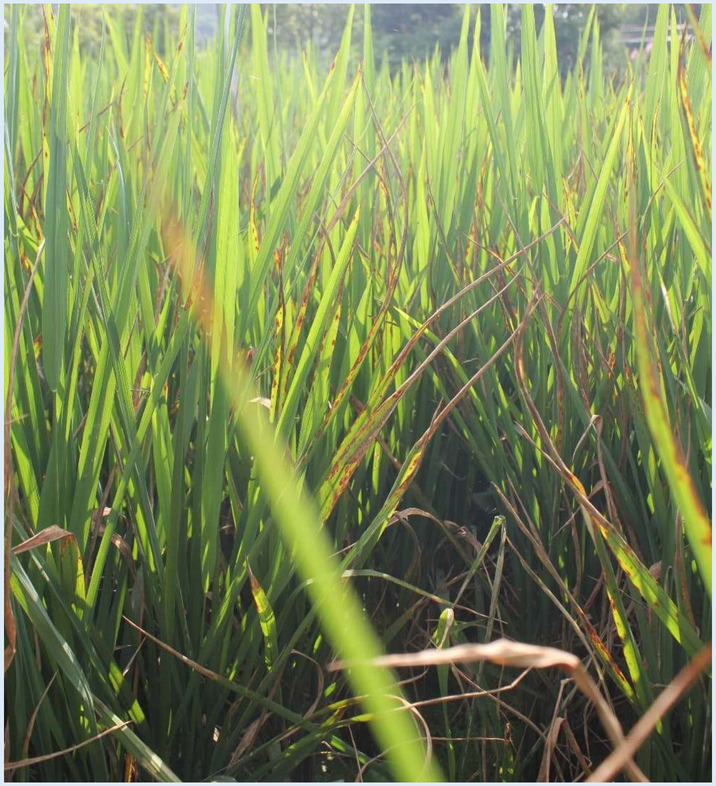
Rice-oilseed rape rotation



Important role: Ensuring grain and edible oil security

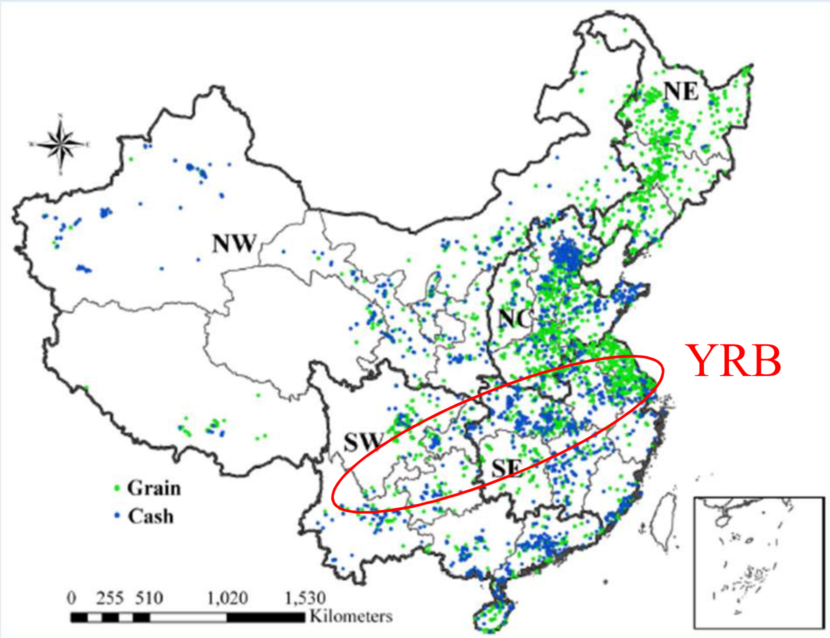
1 Temporal changes of soil K supplying capacity

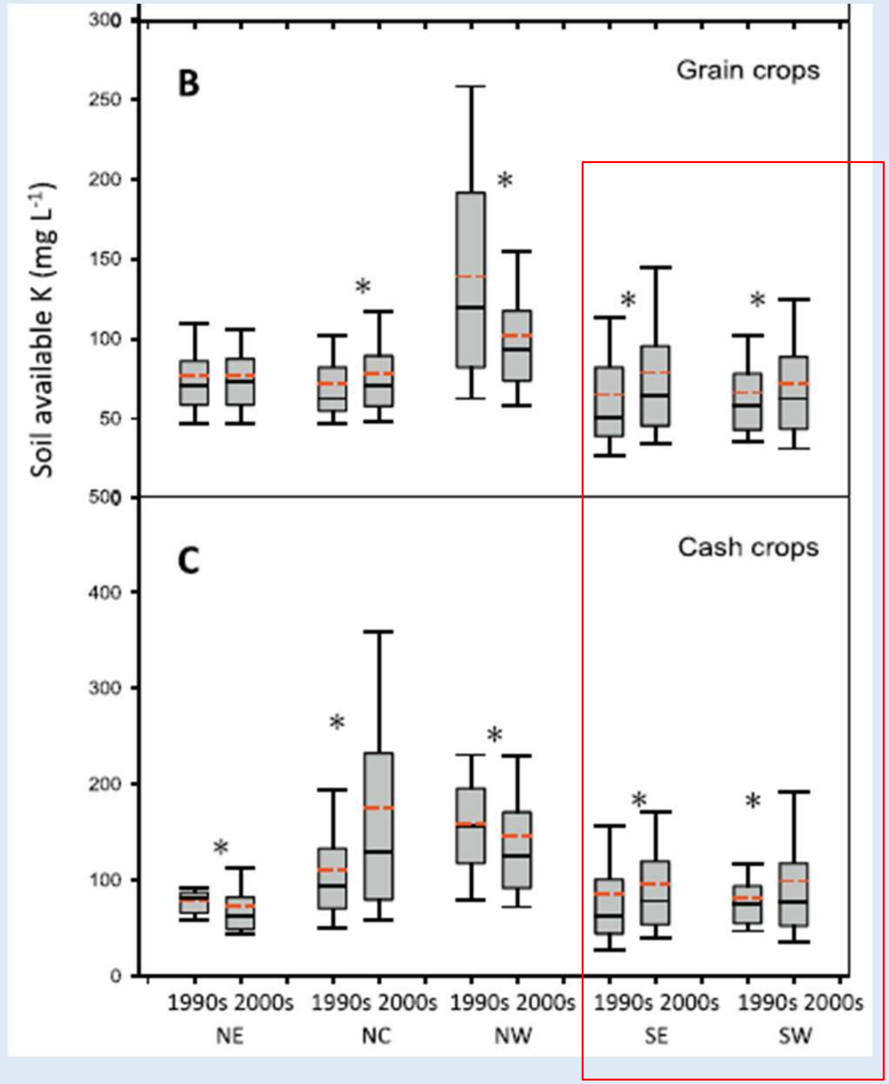
20-30 years ago,



- K deficiency in rice and oilseed rape was very common in the Yangtze River basin
- Why?

Lower soil K supplying capacity

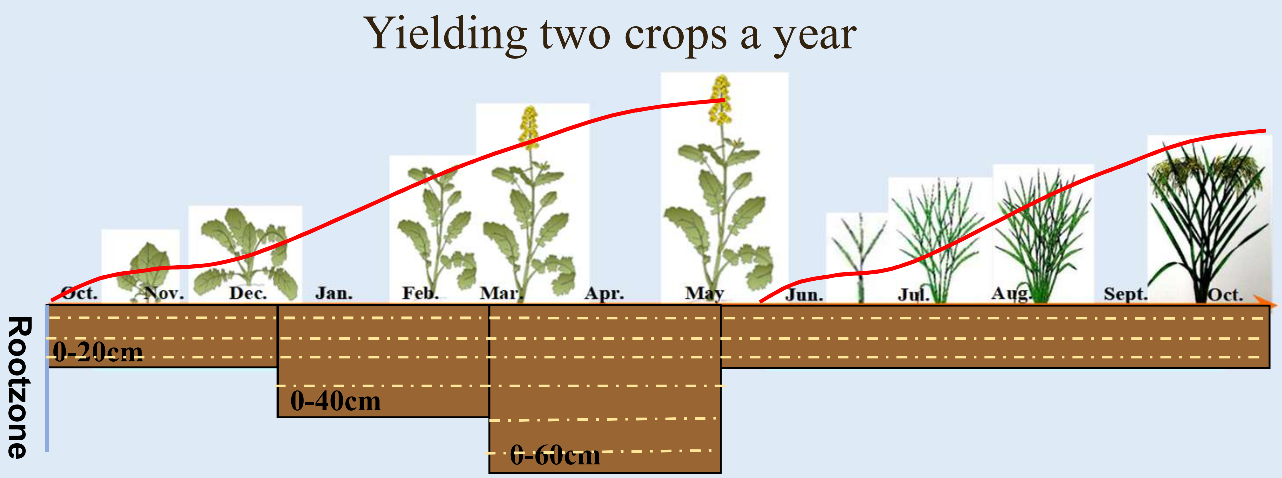


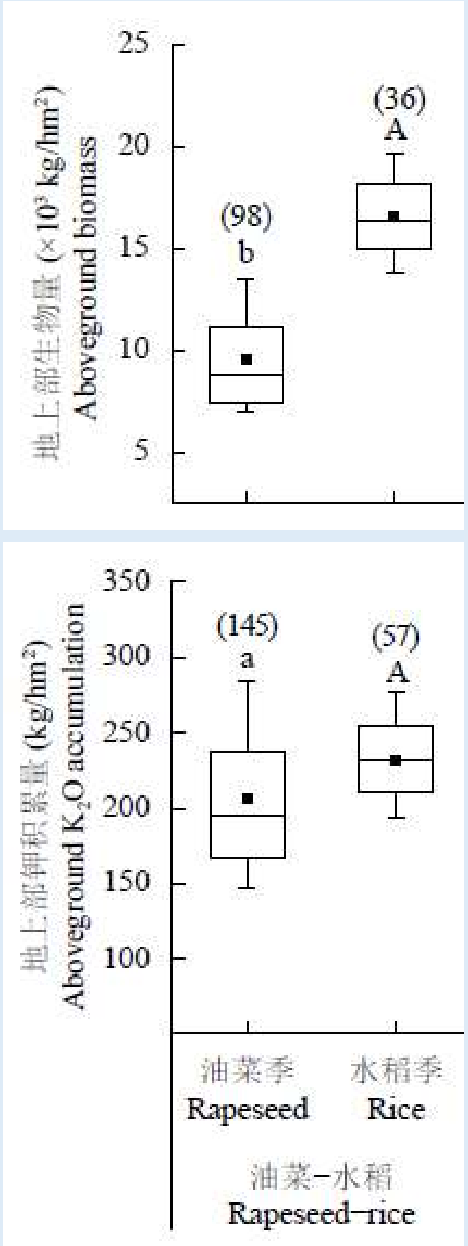


From 1990s to 2000s, average soil available K was changed from 71.5 to 84.3 mg L^{-1} and from 68.8 to 82.7 mg L^{-1}, for SE and SW (YRB), respectively.

(He, et al., 2015)

Reason 1: crops harvest took away mass K





- **Aboveground biomass**

  9525 kg/hm^2 for oilseed rape; 16606 kg/hm^2 for rice

- **K uptakes**

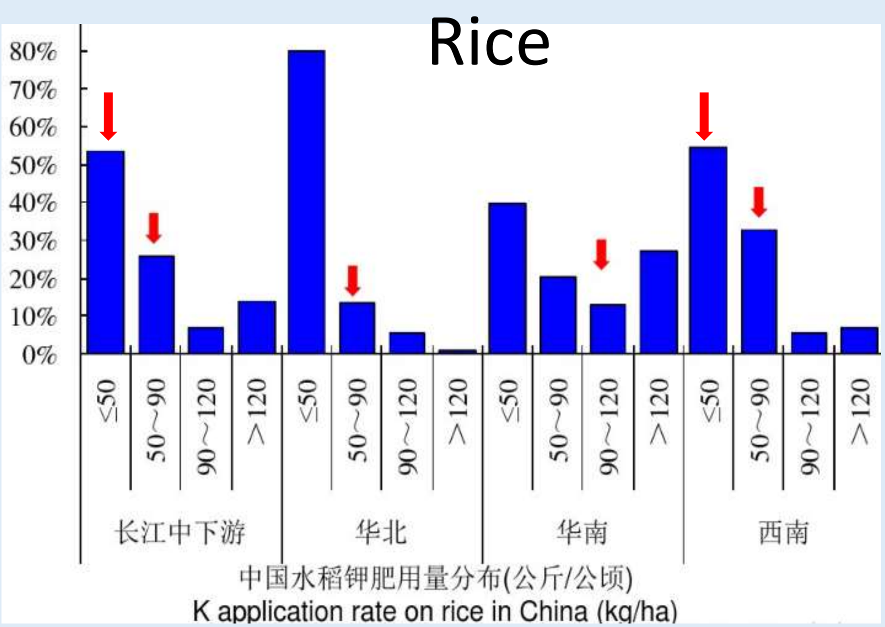
  206 kg/hm^2 for oilseed rape; 232 kg/hm^2 for rice

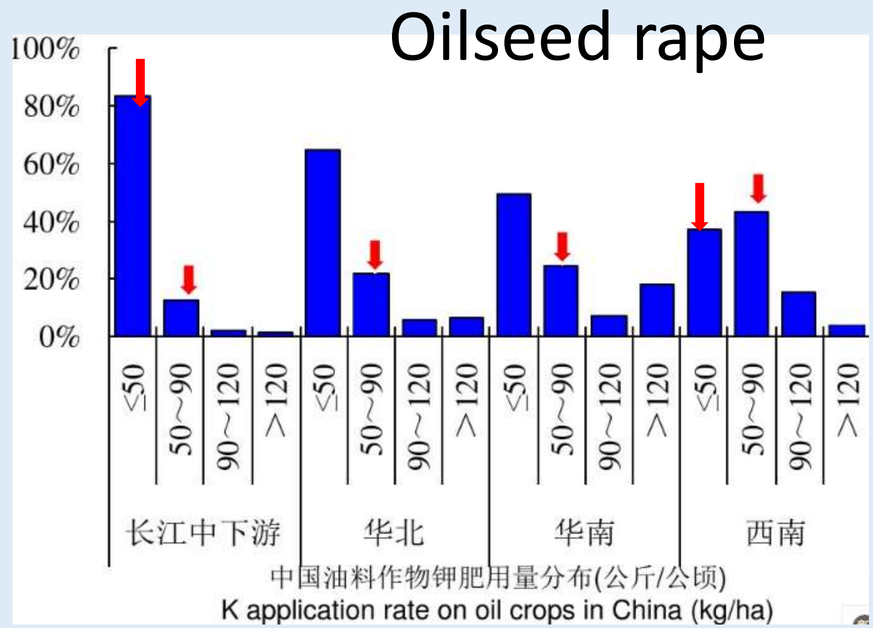
朱芸等，植物营养与肥料学报，2019

Especially for Straw: moved away for another use

- As fuel like firewood
- As livestock feed, bed down the livestock (used for livestock)
- Used for compost fertilizer...

Reason 2: almost no K addition





- Rice

  percentage of <50 kg/ha: 55%

- Oilseed rape

  almost no K addition

(张卫峰等， 2018)

Potash played an important role in rice-oilseed rape rotation system 20-30 years ago.

↑

Lower soil K supplying capacity

↑ ↑

crops harvest took away mass K

almost no K addition

↑ ↑

Mass application of N and P fertilizer,
Breeding of varieties with large K uptake,
Straw removed,
……

Lack of knowledge,
Unobtainable (no potash),
Expensive,
……

From 2005 to the present, *Government Action 1*

Soil testing and fertilizer recommendation

Covering the country

Straight fertilizer

↓

Compound fertilizer

↓

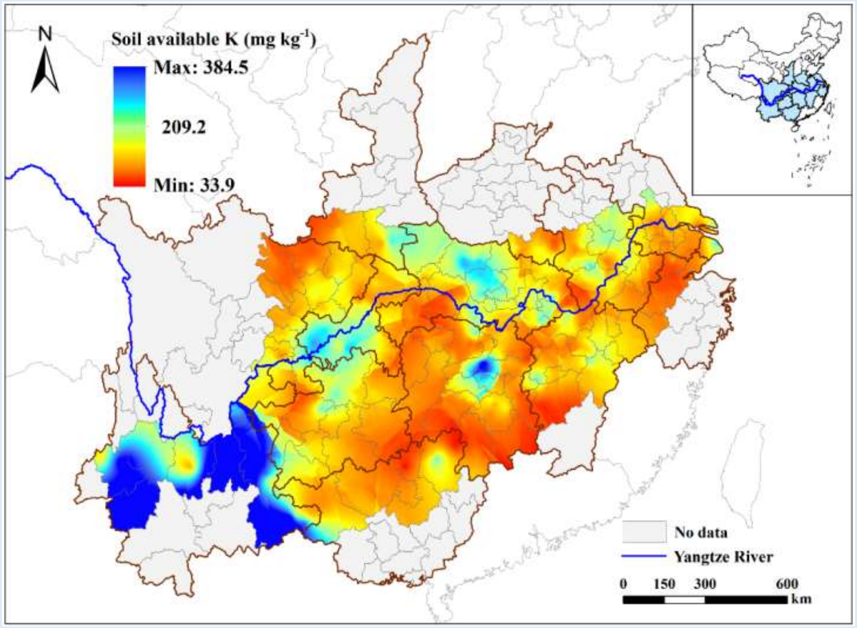
Increased the application amount of potash

Government Action 2

Straw return to field

Reduced the amount of K removed by harvest

Higher soil K supplying capacity



有效钾 **Soil available K** （**mg/kg**）	长江 上游 **UYR**	长江 中游 **MYR**	长江 下游 **LYR**	长江 流域 **YRB**
平均值**Mean**	140.1	127.7	129.1	131.1
标准差**SD**	94.8	73.6	70.5	77.5
最小值**Min**	16.0	36.0	42.0	16.0
下四分位数**UP**	76.0	79.7	67.2	77.0
中值**MD**	106.0	107.6	110.0	105.0
上四分位数**LP**	176.0	156.6	172.0	165.7
最大值**Max**	504.0	374.0	372.8	504.0

- Sampled, tested and analyzed soil available K in the Yangtze River Basin
- Average soil available K was 131.1 mg/kg

Guo, et al., 2018, unpublished data

2 Crops responses to K fertilization (1)

- Four experimental sites
- Five K levels
- Straw removed

Hubei province, China

Yield

Crops yield affected by K levels under rice-oilseed rape rotation systems

	Treat.	Wuxue†-1		Qichun-1		Chibi-2		Jingzhou-4	
		Rice	Oilseed rape	Rice	Oilseed rape	Rice	Oilseed rape	Rice	Oilseed rape
Yield ($t\ ha^{-1}\ year^{-1}$)	K0	8.9b‡	3.1b	8.5b	1.5b	8.5c	2.0c	6.8c	2.4c
	K1	-	-	8.9ab	1.7a	8.9b	2.2b	7.1b	2.6b
	K2	9.4a	3.4a	9.1a	1.8a	9.0ab	2.3ab	7.3a	2.7a
	K3	9.5a	3.4a	9.2a	1.8a	9.1a	2.3ab	7.3a	2.7a
	K4	9.5a	3.4a	9.3a	1.8a	9.1a	2.4a	7.3a	2.7a
Increase rate (%)	K0	-	**-**	-	**-**	-	**-**	-	**-**
	K1	-	**-**	4.7	**13.3**	4.7	**10.0**	4.4	**8.3**
	K2	5.6	**9.7**	7.1	**20.0**	5.9	**15.0**	7.4	**12.5**
	K3	6.7	**9.7**	8.2	**20.0**	7.1	**15.1**	7.4	**12.5**
	K4	6.7	**9.7**	9.4	**20.0**	7.1	**20.0**	7.4	**12.5**

† Values in Wuxue and Qichun site were means of four replicates in 1 rotation period, while it were the average of two rotation period in Chibi and four rotation period in Jingzhou, respectively.
‡ Means with different letters are significantly different between treatments (LSD test, P<0.05).

- The yields of rice were higher than that of oilseed rape
- However, the effects of K fertilizer on oilseed rape were obviously better than that on rice

Yield at Jingzhou experimental site (4 rotation period)

Effects of K fertilizer application on crops yield (t ha^{-1}) from the 1st to the 4th rotation cycle at Jingzhou site under rice-oilseed rape rotation systems

Treatment	1st rotation		2nd rotation		3rd rotation		4th rotation	
	Rice	Oilseed rape	Rice	Oilseed rape	Rice	Oilseed rape	Rice	Oilseed rape
K0	6.9 a†	2.7 b	7.6 a	2.6 b	6.7 b	2.3 b	6.0 c	2.0 b
K1	7.1 a	2.9 ab	7.7 a	2.8 ab	7.1 ab	2.5 a	6.3 b	2.2 a
K2	7.1 a	2.9 ab	7.9 a	2.9 a	7.4 a	2.6 a	6.7 ab	2.3 a
K3	7.1 a	3.0 a	7.9 a	2.9 a	7.4 a	2.6 a	6.8 a	2.3 a
K4	7.1 a	3.0 a	7.9 a	3.0 a	7.5 a	2.6 a	6.8 a	2.3 a

†Means with different letters are significantly different between treatments (LSD test, $P<0.05$).Values are means of four replicates.

- K application had no significant effects on rice yield from the 1st to the 2nd cycle, while significantly increased rice yield (5.5%-14.3%) from the 3rd to the 4th rotation cycle

Apparent K balance (AKB)

K fertilization significantly decreased the negative AKB

		Wuxue	Qichun	Chibi	Jingzhou
K uptake	K0	303.0 †	183.0	332.9	235.2
	K1	-	266.5	371.1	291.1
	K2	393.5	316.2	404.0	332.2
	K3	450.1	379.6	424.4	356.3
	K4	496.2	411.2	438.9	381.4
K applied	K0	0	0	0	0
	K1	-	122.0	87.2	74.7
	K2	174.3	174.3	161.9	149.4
	K3	249.0	226.6	236.6	224.1
	K4	323.6	278.9	311.3	298.8
Apparent K balance	K0	-303.0	-183.0	-332.9	-235.2
	K1	-	-144.5	-283.9	-216.4
	K2	-219.2	-141.9	-242.1	-182.8
	K3	-201.1	-153.0	-187.8	-132.2
	K4	-172.6	-132.3	-127.6	-82.6

† Values in Wuxue and Qichun were means of 4 replicates, while it was the average of 2 years in Chibi and 4 years in Jingzhou, respectively.

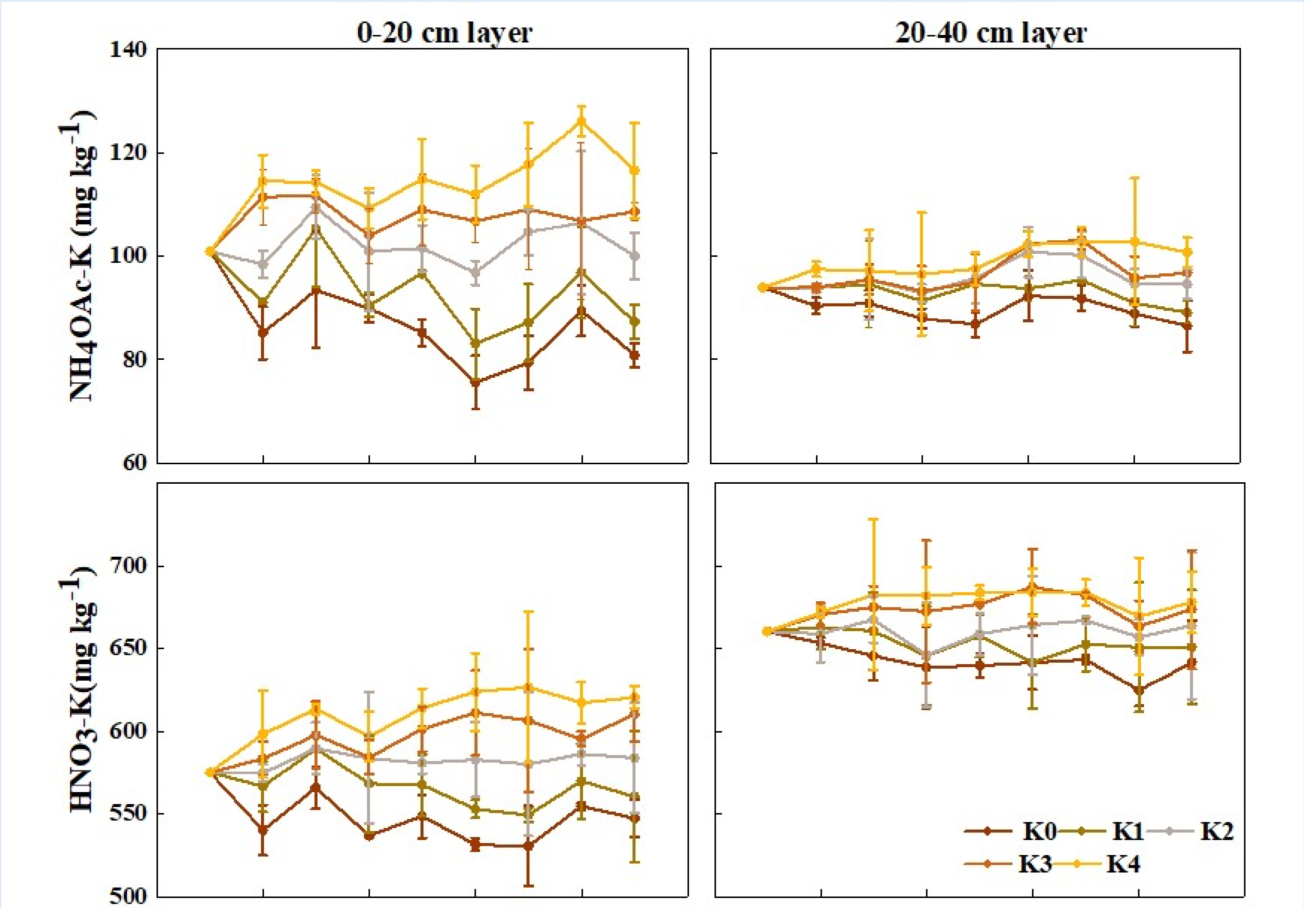
Temporal and Spatial Soil Test K

Effects of K levels on soil test NH_4OAc-K (mg kg^{-1}) and boiling HNO_3-K (mg kg^{-1}) at 0-20 cm and 20-40 cm depths after the last rotation crops harvested.

		Wuxue†		Qichun		Chibi		Jingzhou	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
Initial value		**84.3**	**74.3**	**63.9**	**45.1**	**70.4**	**44.4**	**100.9**	**93.9**
NH_4OAc-K (mg kg-1)	K0	60.1 c‡	-	47.3 b	40.3 c	52.3 c	40.4 c	80.8 c	86.4 c
	K1	-	-	55.1 b	47.9 b	52.9 c	42.1 c	87.3 c	89.1 c
	K2	71.9 b	-	65.0 a	48.8 b	65.1 b	46.3 b	99.9 b	94.6 bc
	K3	100.3 a	-	66.0 a	50.0 ab	74.4 a	49.6 ab	108.6 ab	96.8 ab
	K4	111.3 a	-	67.2 a	53.1 a	75.3 a	51.2 a	116.5 a	100.7 a
Initial value		**405.8**	**361.3**	**308.6**	**276.3**	**373.4**	**406.0**	**474.2**	**566.5**
Boiling HNO_3-K (mg kg-1)	K0	379.0 c	-	290.0 b	260.4 b	351.4 b	381.2 b	466.6 b	555.4 a
	K1	-	-	289.2 b	271.4 b	361.5 b	390.2 b	473.2 b	561.8 a
	K2	385.9 b	-	324.0 a	283.2 ab	365.6 ab	401.9 ab	484.0 ab	569.2 a
	K3	424.3 a	-	334.6 a	286.2 ab	383.0 a	417.0 a	501.7 a	577.0 a
	K4	428.7 a	-	326.8 a	295.1 a	384.8 a	416.8 a	503.8 a	577.3 a

- K supplying capacities of the 0-20 and 20-40 cm soil depth in the treatment K0 were both declined
- K fertilizer application **maintained and even improved** soil K supplying capacity

Dynamic changes of soil test NH_4OAc-K (mg kg^{-1}) and boiling HNO_3-K (mg kg^{-1}) at 0-20 cm and 20-40 cm depths after rice and oilseed rape harvested from the 1st to the 4th rotation cycle at Jingzhou site



- Decreased along with the extension of the rotation cycles in K0 and K1 treatment
- Maintained or improved in the higher K rates treatments
- Enough K fertilizer application played an important role in preserving soil K supplying capacity

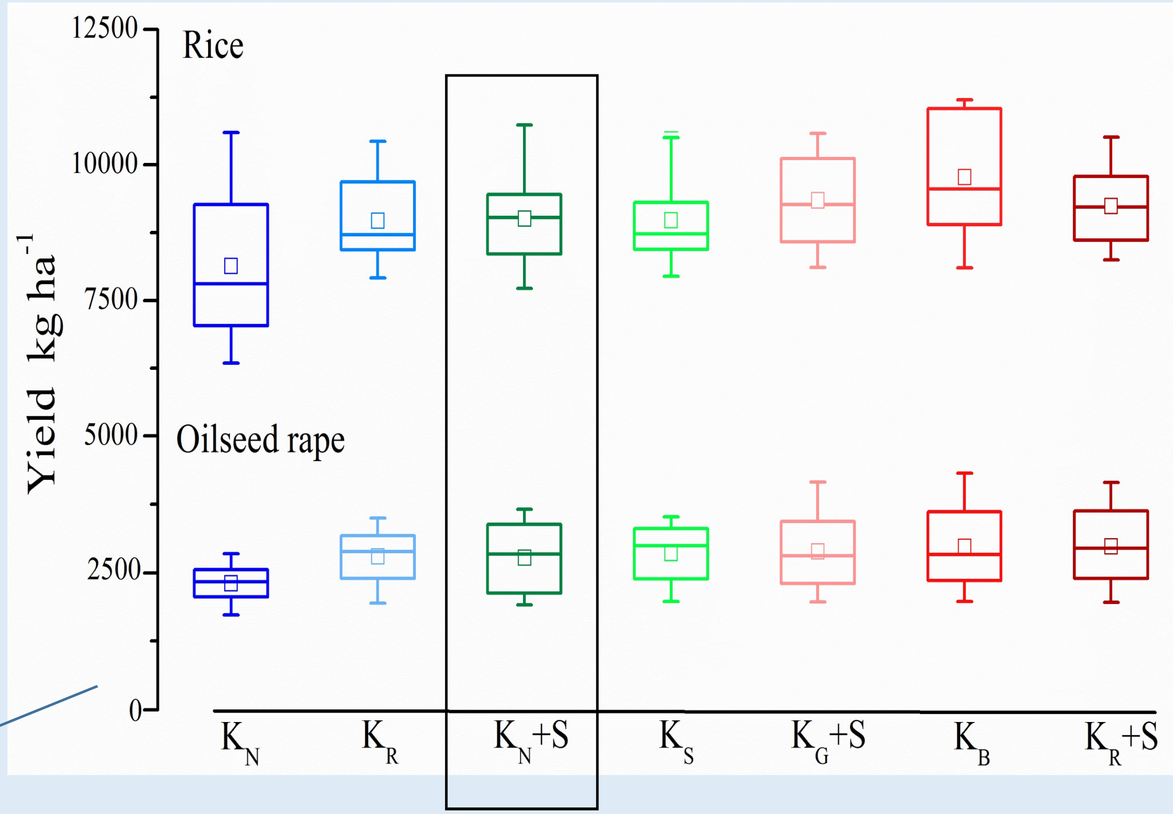
3 Crops responses to K fertilization (2)

- Straw return
- Location experiment (2014-2017)

1. K_N (no K applied)
2. K_R (recommended K fertilization)
3. K_N+S (no K applied and straw return)
4. K_S (K applied amount equal to K that removed by straw)
5. K_G+S (K applied amount equal to K that removed by grain and straw return)
6. K_B (K applied amount equal to K that removed by straw and grain)
7. K_R+S (recommended K fertilization and straw return)

Yield

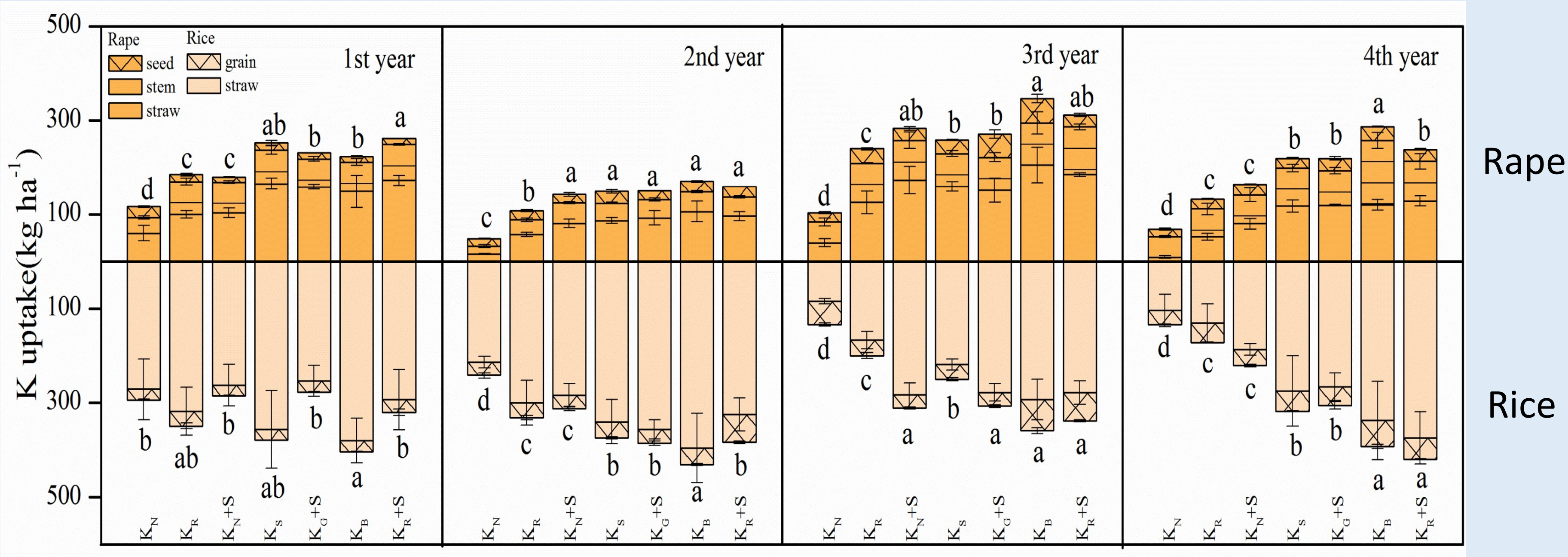
Effects of K management strategy on yield in rice-oilseed rape rotation system



- All the K treatments (Straw return or K fertilization) increased yield significantly
- The effects of K fertilizer on oilseed rape (23.3%) were obviously better than that on rice (14.6%), though rice yields were higher
- There were no significant differences among different K treatments (straw or potash)

K uptakes by aboveground part

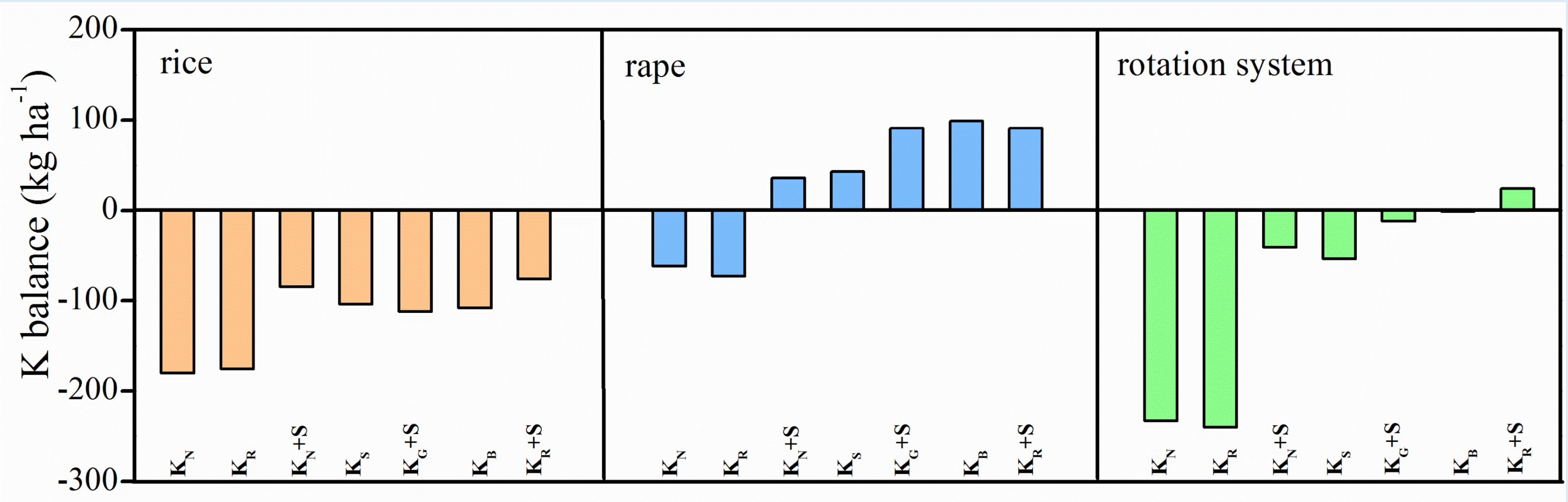
Effects of K management strategy on K uptake in rice-oilseed rape rotation system



- K uptakes by rice was higher than that by oilseed rape due to higher biomass. The ratio was 3:2
- K uptakes were differed in different K treatments. This was significantly related to the amount of K input (K_B, K applied amount equal to K that removed by straw and grain, or K_R+S, recommended K fertilization and straw return)

Apparent K balance (AKB)

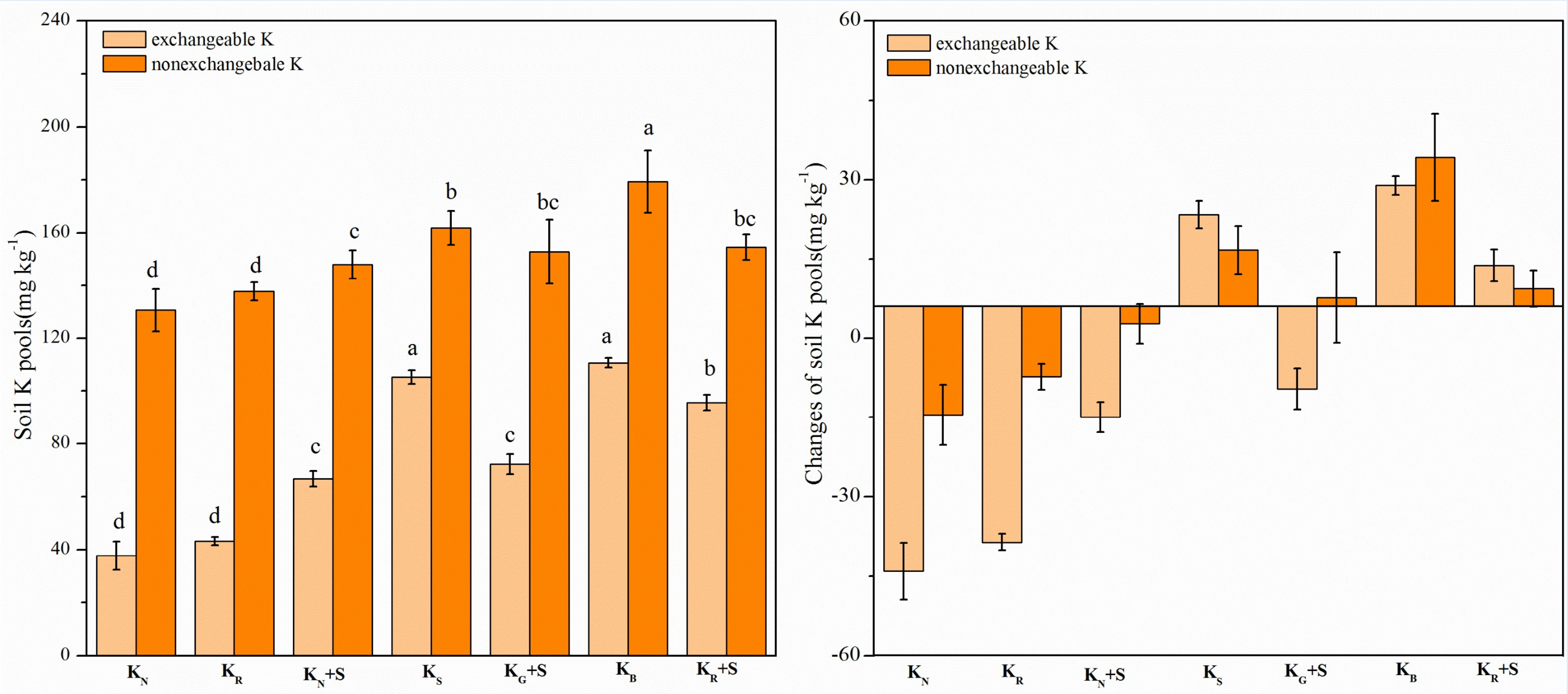
Effects of K management strategy on apparent K balance in rice-oilseed rape rotation system



- The largest negative K balance was noted in the K_N (no K applied) and K_R (recommended K fertilization) treatments
- Straw return decreased the negative apparent K balance
- K_G+S (K applied amount equal to K removed by grain and straw return) could maintain soil-plant K balance and save some potash

Soil available K

Soil exchangeable K and non-exchangeable K as affected by K management strategy



- All the K management treatments (straw return or K fertilization) increased soil exchangeable K and non-exchangeable K
- Enough K input could maintain soil available K supplying
- Excess K input improved soil exchangeable K and non-exchangeable K

Conclusions

- Soil available K was improved significantly as a result of the increase in the application rate of potash and the return of straw, compared with that in 20-30 years ago
- Under the condition of straw taken away, the soil-crop system had a large negative K balance, although the application of appropriate amount of potash could increase the yield
- Under the condition of returning straw to field, applying a small amount of potash (equal to the amount taken away by grain) could increase yield and maintain soil K supply capacity

Thanks for your attention!

Long-term location experimental site on K management **Jingmen, Hubei Province, China**