国际钾肥研究所第一届杂卤石效果学术会议
IPI’s first symposium on polyhalite

2017年10月31日，三亚
31 October 2017，Sanya

冬油菜施用杂卤石效果

Effects of Polysulphate application on seed yield, seed quality and nutrient uptake of winter oilseed rape

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- 材料与方法 Material and Methods
- 研究结果 Results
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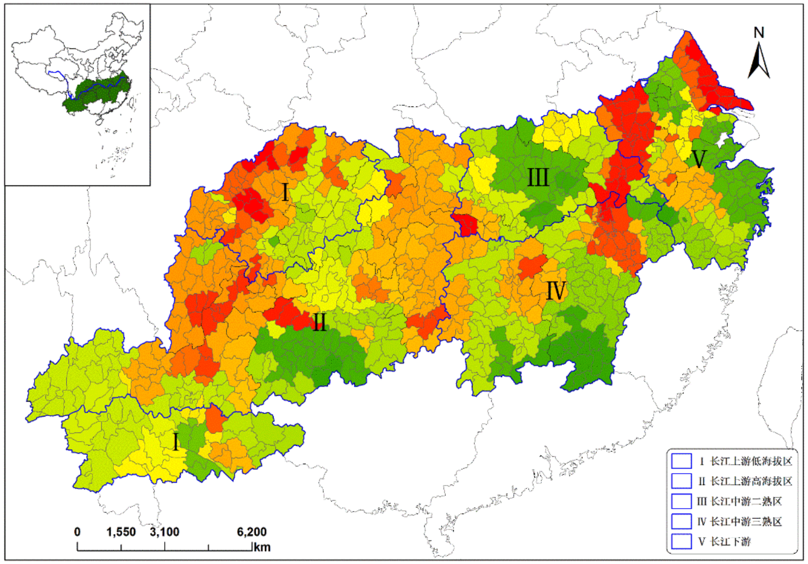
一、研究意义 Introduction

- 油菜是中国的主要油料作物，其中冬油菜占全国油菜总播种面积和总产量的90%左右，常年播种面积为680万公顷。

  Oilseed rape especially the winter oilseed is the main edible oil crops in China. It accounts for 90% of total oilseed rape production. The annual planting area of winter rapeseed is about 6.8 million ha.

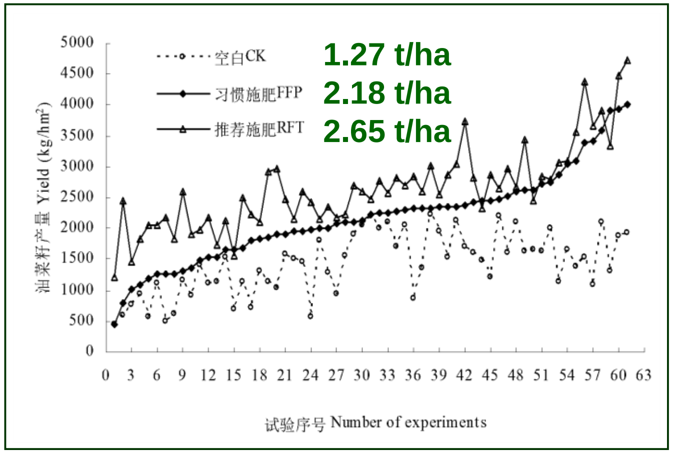
- 中国冬油菜主要分布在长江流域，一般采用一年两熟或三熟的轮作制度。

  Winter oilseed rape is planting in Yangtze River Basin in China. Rice/cotton-rapeseed or early rice-late rice-rapeseed is the major winter oilseed rape rotations.



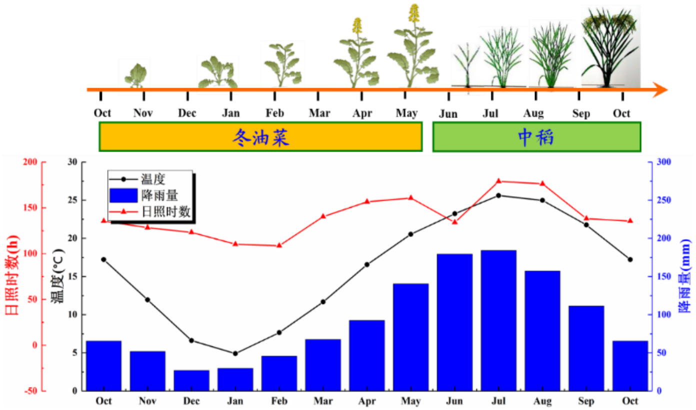
◆ 长江流域冬油菜产区耕地土壤肥力水平较低。

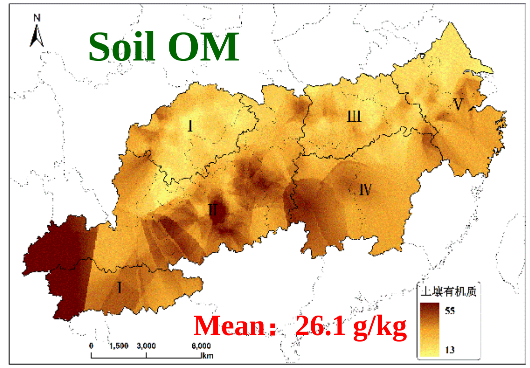
Soil fertility of winter oilseed rape plating soil around Yangtze River basin is low

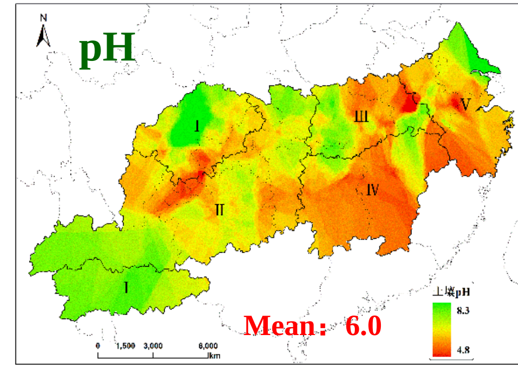


土壤地力对油菜籽产量的贡献率平均只有45.6%

Only 45.6% yield harvest without fertilization compared with fertilization

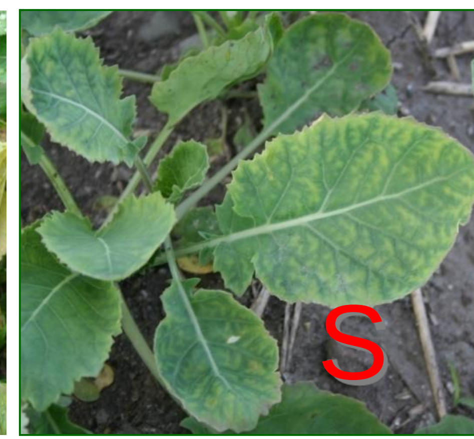






◆ 除氮、磷、钾、硼4种元素外，可能存在其他养分的缺乏

Besides N, P, K and B, there might be other soil nutrients deficiency

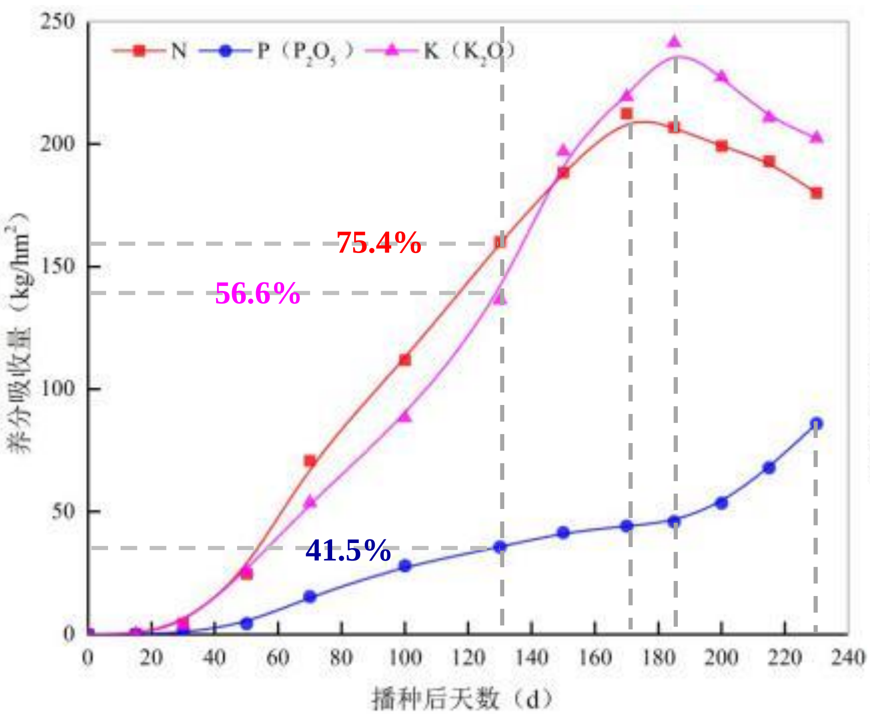


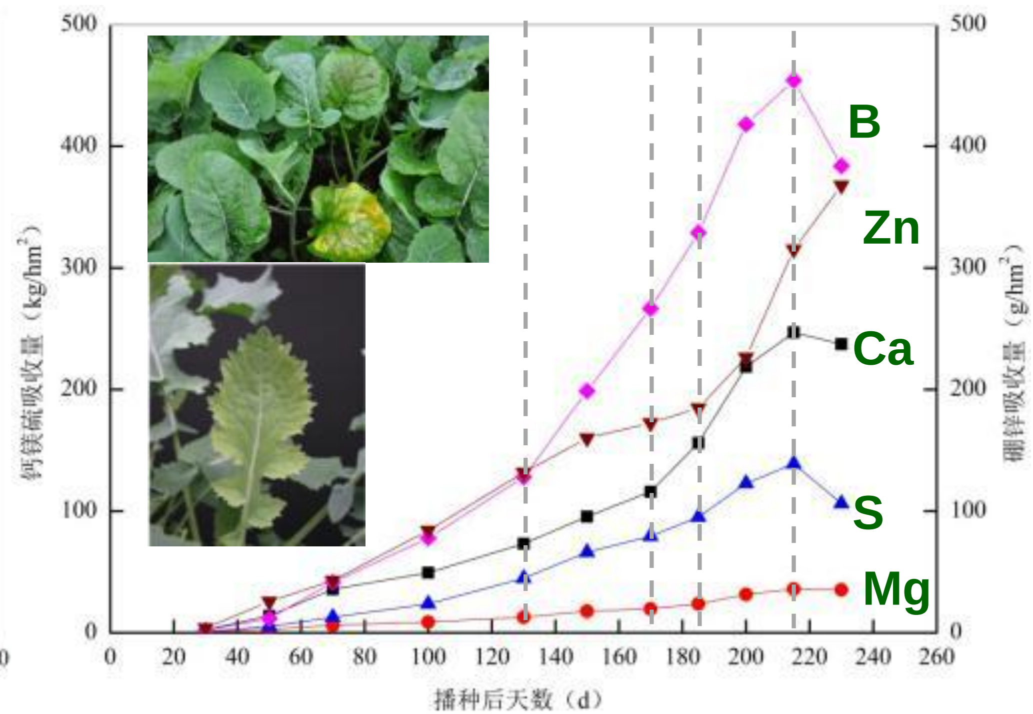
◆ 冬油菜对养分吸收量非常大，形成100kg籽粒的氮、磷、钾吸收量分别为4.6 kg N、1.8 kg P_2O_5和6.9 kg K_2O。

The nutrient uptake of winter oilseed rape is very high. The nutrient requirement to produce 100 kg seed is 4.6 kg N, 1.8 kg P_2O_5 and 6.9 kg K_2O.

◆ 除氮、磷、钾外，油菜对于钙、镁、硫、锌、硼需求量也非常大。

Besides N, P and K, shoot Ca, Mg, S, Zn and B uptake is quite huge.





二、材料与方法 Material and Methods

- 试验地点Experimental Sites:
  湖北省武穴市梅川镇郭坦村
  (30°06′N,115°36′E)

- 供试作物 Crop Rotation
  冬油菜-花生轮作 Winter oilseed rape-peanut rotation

土壤基础理化性质 soil properties

	pH	Soil OM (g/kg)	Total N (g/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)	Avail. B (mg/kg)	Avail. S (mg/kg)	Exchange Ca (mg/kg)	Exchange Mg (mg/kg)
Experiment 1	4.7	27.7	1.54	10.3	54.3	0.34	9.8	156	36.4
Experiment 2	5.0	36.5	2.19	4.6	36.2	0.46	11.0	379	90.2

◆ Trial One

(1) NPKB

(2) NP+PS

(3) NPKB + Ca

(4) NPKB + S

(5) NPKB + Mg

(6) NPB

(7) NPK

◆ NPKB: 180 kg N/ha, 75 kg P_2O_5/ha, 105 kg K_2O/ha, 1.0 kg B/ha

◆ Polysulphate (PS): 750kg/ha, with 105 kg K_2O/ha, 90 kg Ca/ha, 27 kg Mg/ha and 144 kg S/ha (K 12.0%, Ca 12.0%, Mg 3.6%, S 19.2%, B 0.1%)

◆ Treatment 3-5: Ca, Mg, S rate is same as Polyhalite

◆ Trial Two

(1) PS_0: without Polysulphate

(2) PS_{375}: 25kg/亩

(3) PS_{750}: 50kg/亩

(4) PS_{1125}: 75kg/亩

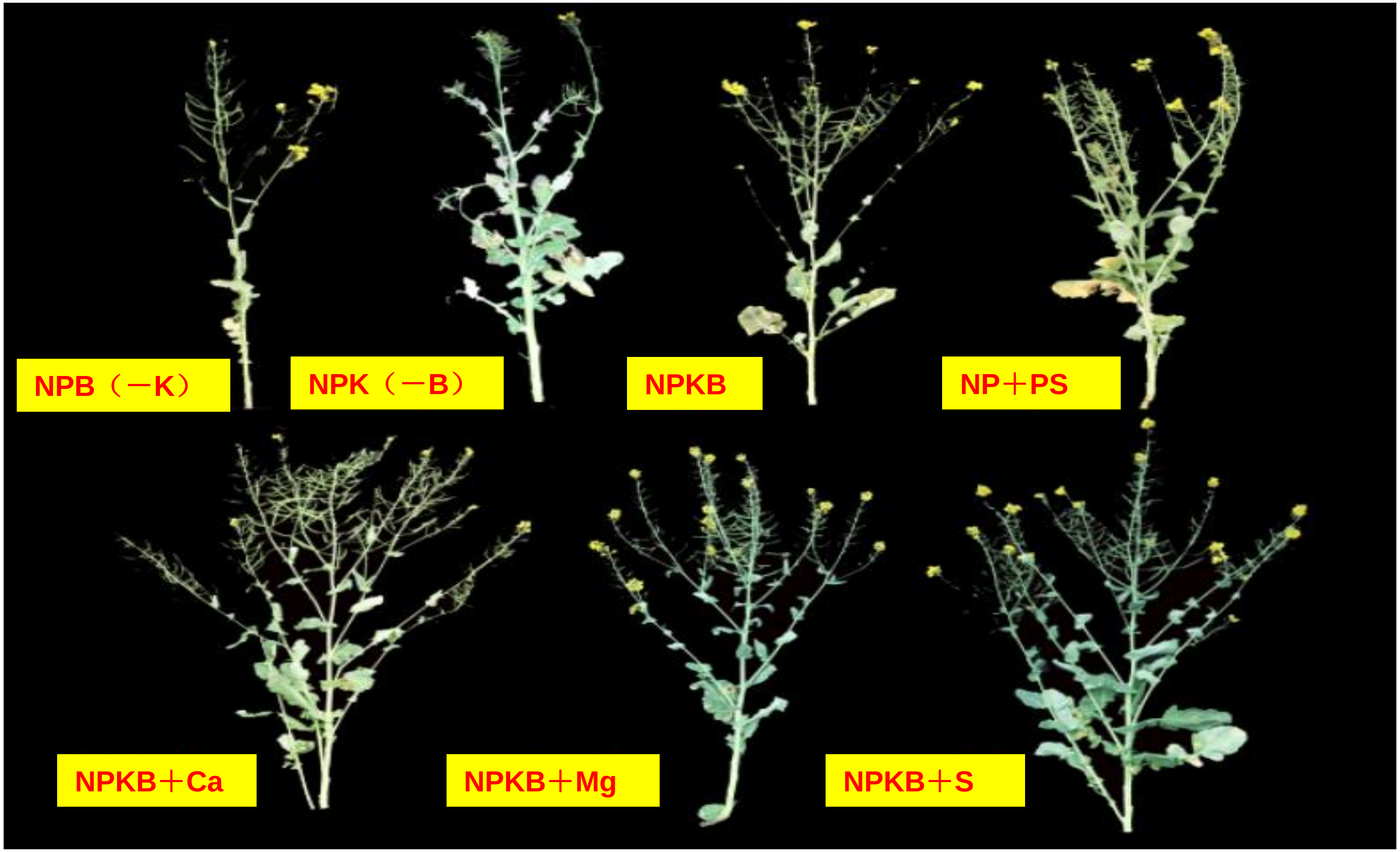
(5) PS_{1500}: 100kg/亩

(6) PS_{1875}: 125kg/亩

◆ NPB: 180 kg N/ha, 75 kg P_2O_5/ha, 1.0kg B/ha

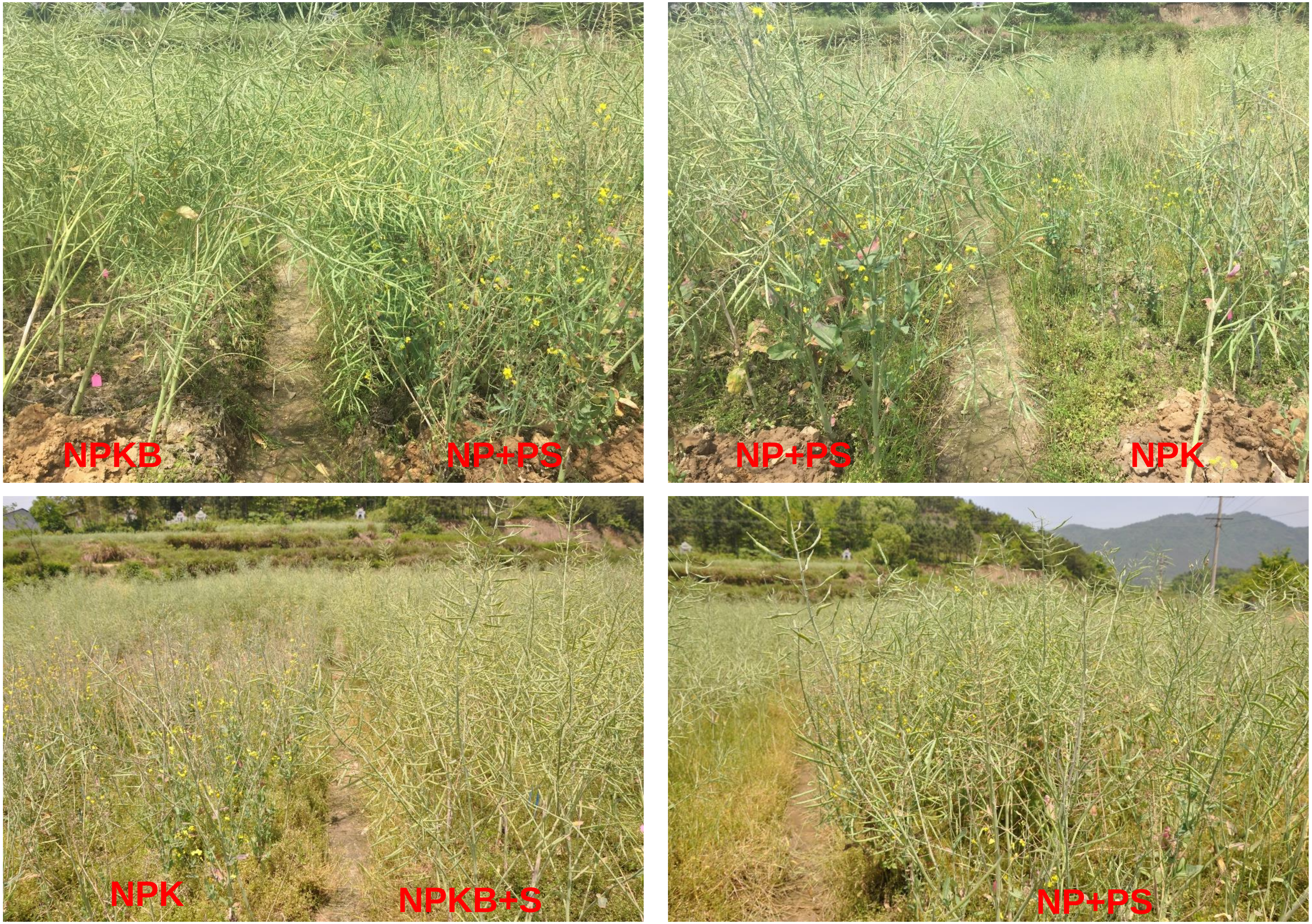
三、研究结果 Results

◆ Trial One Effect of Polysulphate and Ca, Mg, S and B



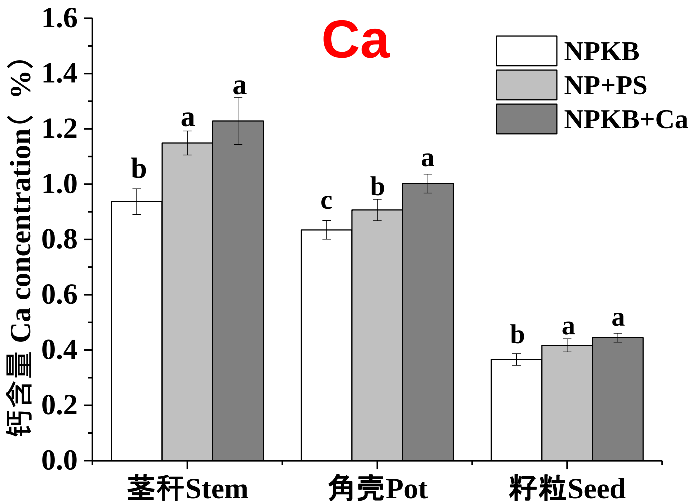
产量及其构成因子 Seed yield and yield components

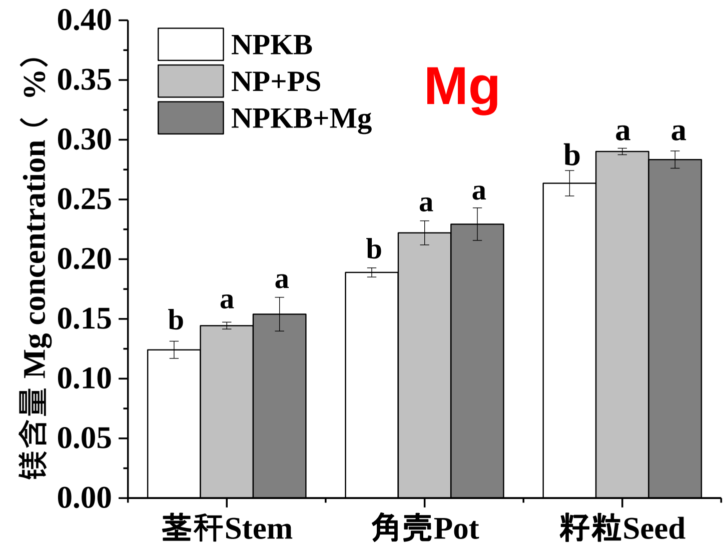
处理 Treatment	产量 Seed yield (kg/ha)	增产量 Yield increase (kg/ha)	增产率 Yield increase rate (%)	单株角果数 Pods per plant	角粒数 Seeds per pod	千粒重 1000-seed weight (g)
NPKB	1259 d	-	-	139 d	27.8 a	3.35 cd
NP+PS	1424 c	165	13.1	168 c	23.7 b	3.67 b
NPKB+Ca	1772 a	513	40.7	211b	26.7 a	3.21 d
NPKB+S	1808 a	549	43.6	207 a	27.3 a	3.23 cd
NPKB+Mg	1634 b	375	29.8	189 ab	28.1 a	3.14 cd
NPB(-K)	780 e	-479	-38.0	101 e	26.5 a	3.37 c
NPK(-B)	1.3 f	-1257	-99.9	11 f	10.8 c	4.74 a

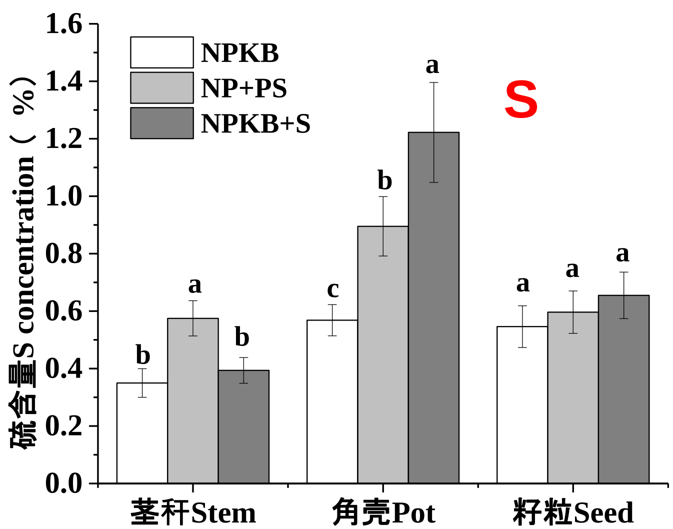

NPKB
NP+PS
NP+PS
NPK
NPK
NPKB+S
NP+PS

油菜地上部Ca、Mg、S养分含量

Rapeseed plant shoot Ca, Mg and S concentration



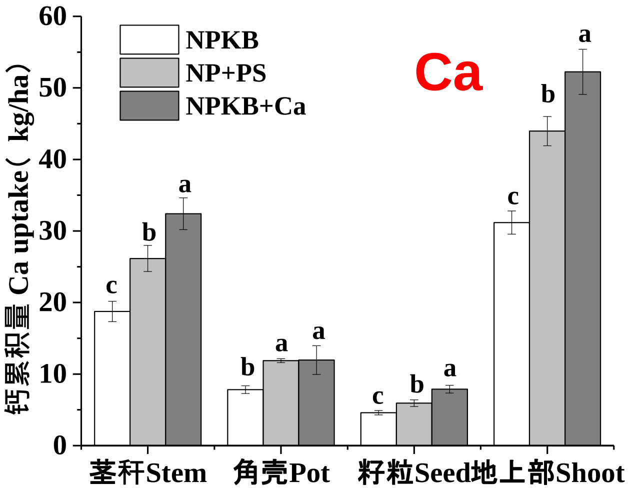


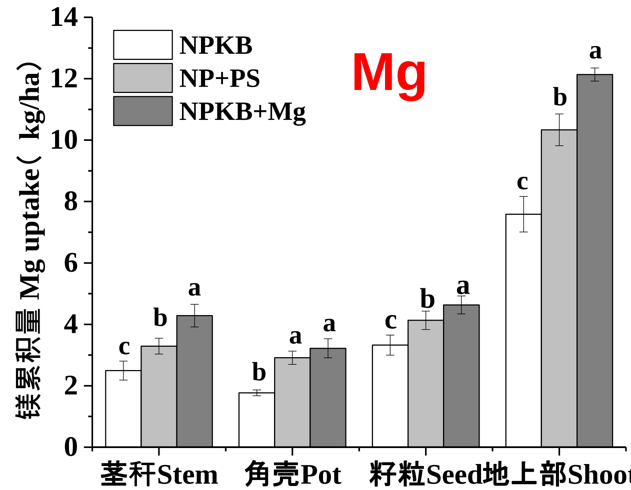


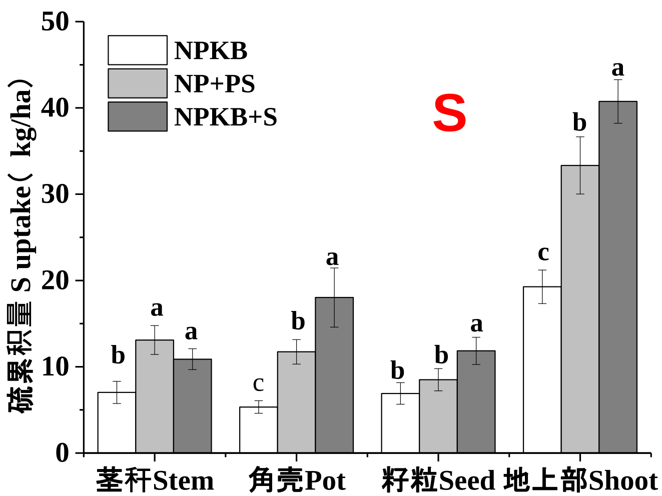
- 杂卤石和单施$CaCl_2$、MgO、硫磺明显提高油菜地上部Ca、Mg和S含量，说明杂卤石能够给作物提供中量元素养分。
- Polysulphate and $CaCl_2$、MgO、element S increased plant Ca, Mg and S content which indicated Polysulphate supplies these nutrients to rapeseed.

油菜地上部Ca、Mg、S养分积累量

Ca, Mg and S accumulation in shoot

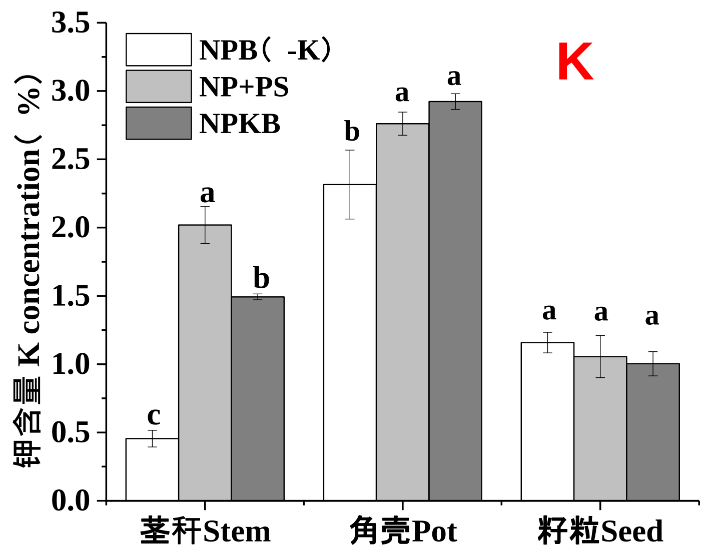


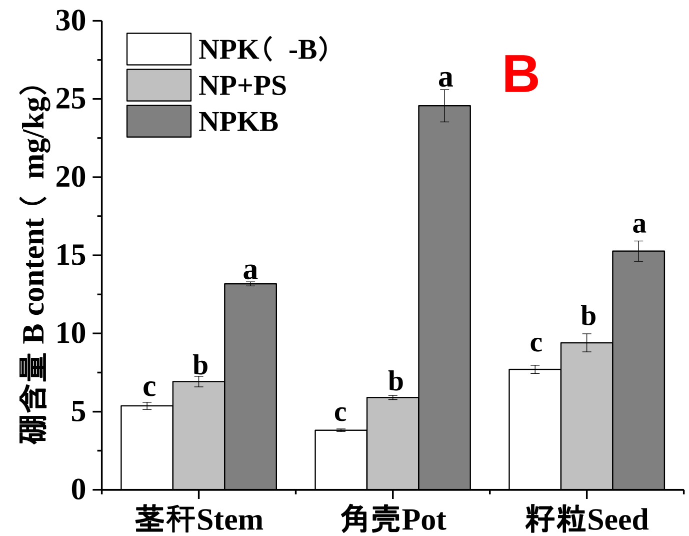




- 与NPKB处理相比，杂卤石处理地上部钙、镁、硫的积累量分别增加41.0%、36.2%和73.0%。
  Compared with NPKB, Polysulphate **increased Ca, Mg and S accumulation by 41.0%、36.2%和73.0%.**
- 与单施$CaCl_2$、MgO、硫磺相比，杂卤石处理对钙、镁、硫的吸收量相应减少15.9%、14.8%和18.2%。
  Compared with $CaCl_2$, MgO and element S application, Polysulphate **decreased Ca, Mg and S accumulation by 15.9%、14.8%和18.2%.**

油菜地上部K、B养分含量 Shoot B and K concentration





- 杂卤石处理地上部钾含量与NPKB处理无明显差异，茎杆中的钾含量高于NPKB处理，显著高于不施钾（NPB）处理，说明杂卤石是一种优质的钾肥资源。K content in Polysulphate and NPKB is no difference except more in stem of PS treatment, which indicated Polysulphate is good K resource.
- 杂卤石处理地上部硼含量显著高于不施硼（NPK）处理，说明杂卤石能够提供一定量的硼养分，但同时显著低于施硼（NPKB）处理，说明杂卤石中硼含量不能满足油菜需要。 B content in Polysulphate is more than that in NPK(without B) indicated Polysulphate can supply some B to crop. However, B content in Polysulphate is much lower than that in NPKB(with B) indicated Polysulphate cannot supply enough B to rape.

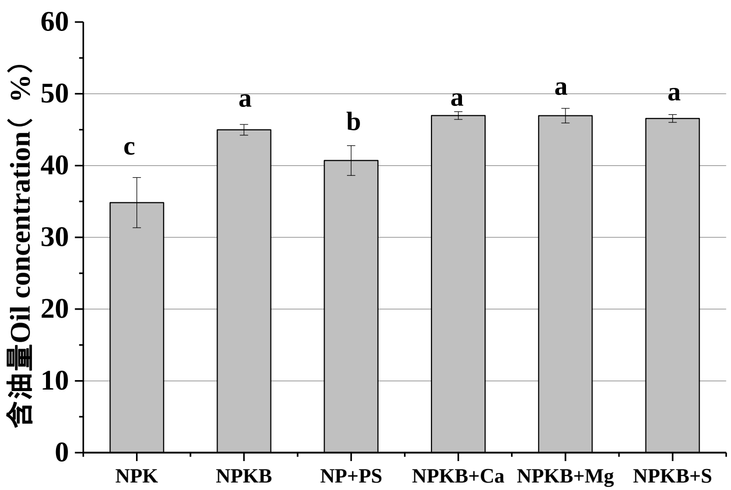
肥料养分利用率 Nutrient use efficiency

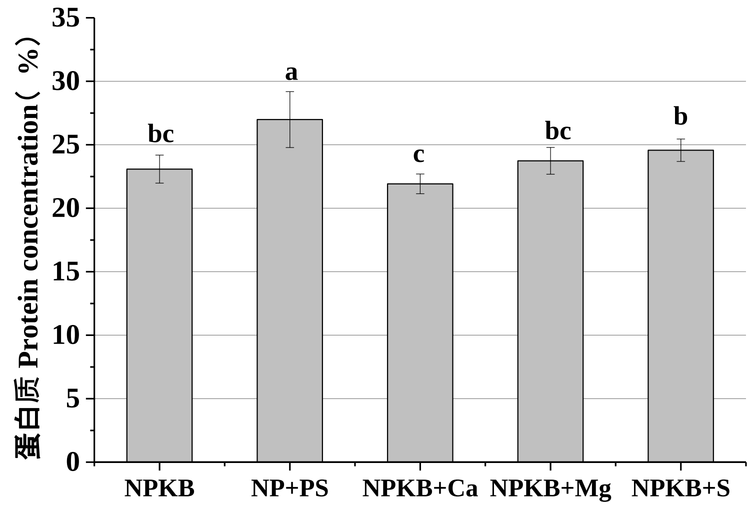
	处理 Treatment	回收利用率 RUE （%）
	NPKB	-
钙 Ca	NP+PS	14.3
	NPKB+Ca	21.9
镁 Mg	NP+PS	10.2
	NPKB+Mg	16.8
硫 S	NP+PS	9.8
	NPKB+Mg	14.9

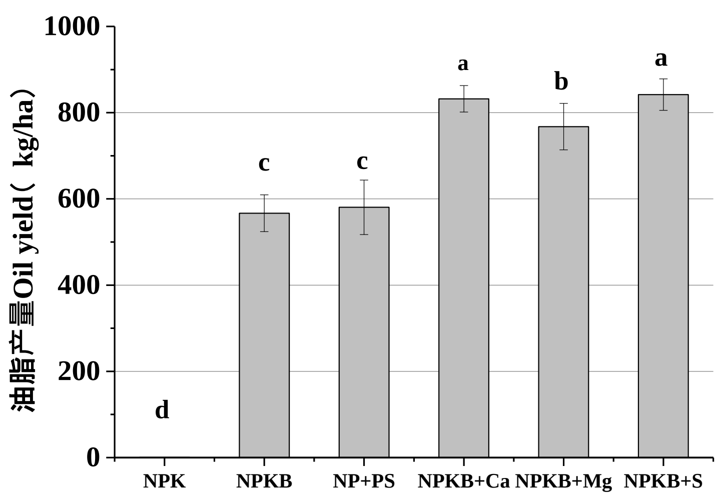
- 杂卤石中钙、镁、硫的利用率分别为14.3%、10.2%和14.9%，低于单施CaCl2、MgO、硫磺的养分利用率。
- Ca, Mg and S RUE in Polysulphate is 14.3%, 10.2% and 9.8% which is lower than that in $CaCl_2$, MgO and element S treatment.

RUE(%)=（Nutrient uptake with application− Nutrient uptake without application）÷Nutrient applied rate×100

油菜籽品质 Seed oil and protein content and oil yield







- 硼的缺乏导致油菜籽含油量下降，杂卤石显著提高蛋白质含量。B deficiency led to oil content decrease in seed and Polysulphate increased protein content.
- 硼的缺乏导致减产和含油量下降，最终导致油脂产量下降，中量元素养分既增产又能提高含油量，可以获得较高的产油量。Ca, Mg and S applied increased oil yield. Low oil yield in Polysulphate treatment is because B deficiency.

◆ Trial Two: Polysulphate rates

产量及其构成因子 Seed yield and yield components

PS rate (kg/ha)	产量 Seed yield (kg/ha)	增产量 Yield increase (kg/ha)	增产率 Yield increase rate (%)	单株角果数 Pods per plant	角粒数 Seeds per pod	千粒重 1000-seed weight (g)
0	2386 d	-	-	198d	24.3c	3.19b
375	2894 bc	508	21.3	233c	26.4b	3.22a
750	3069 bc	683	28.6	253bc	26.4b	3.23a
1125	3161 ab	775	32.5	270b	27.5a	3.23a
1500	3396 a	1010	42.3	336a	27.6a	3.26a
1875	2865 c	479	20.1	240c	26.2b	3.13b

氮磷钾养分积累量 Shoot N, P, K nutrient uptake

PS (kg/ha)	茎秆 Stem (kg/ha)			角壳 Pod wall (kg/ha)			籽粒 Seed (kg/ha)			地上部 Shoot (kg/ha)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	**N**	**P_2O_5**	**K_2O**
0	8.6	0.4	25.8	6.2	0.4	45.6	68.3	6.7	29.1	**83.1d**	**7.5d**	**100.5e**
375	12.1	0.7	58.4	9.0	0.8	73.6	84.0	10.0	38.5	**105.1c**	**11.5c**	**170.5d**
750	15.5	0.9	113.5	10.2	0.8	99.1	89.4	10.2	42.6	**115.1ab**	**11.9ab**	**255.2c**
1125	16.4	1.1	142.0	8.8	0.6	96.4	85.4	10.3	48.2	**110.6bc**	**12.0bc**	**286.6b**
1500	17.4	1.2	159.8	9.7	1.1	105.4	92.9	10.7	55.2	**120.0a**	**13.0a**	**320.4a**
1875	14.4	1.2	150.7	11.1	1.3	101.9	86.7	9.8	46.1	**112.2abc**	**12.3abc**	**298.7ab**

- 在氮磷肥用量相同时，随着杂卤石用量的增加，油菜地上部氮、磷积累量明显增加，在用量1500kg/ha时达到最大。钾的积累量随着杂卤石用量的增加急剧上升。
- At the same N and P rate, N and P accumulation increased with Polysulphate rate increase.

钙镁硫养分积累量 Shoot Ca, Mg, S nutrient uptake

PS (kg/ha)	茎秆 Stem (kg/ha)			角壳 Pod wall (kg/ha)			籽粒 Seed (kg/ha)			地上部 Shoot (kg/ha)		
	Ca	Mg	S	Ca	Mg	S	Ca	Mg	S	**Ca**	**Mg**	**S**
0	19.0	2.5	9.2	10.4	2.6	8.0	7.5	7.1	12.1	**36.9e**	**12.2e**	**29.3e**
375	30.0	3.6	19.2	15.2	3.5	16.6	9.0	8.8	16.0	**54.2d**	**15.9d**	**51.8d**
750	40.5	5.1	31.4	16.4	3.7	18.6	10.0	9.4	16.5	**66.8bc**	**18.3bc**	**66.6bc**
1125	46.8	5.6	35.9	17.2	3.7	17.9	8.4	9.8	18.3	**72.3ab**	**19.1b**	**72.0ab**
1500	48.0	5.7	37.0	19.8	4.2	20.7	9.1	10.9	19.4	**76.9a**	**20.8a**	**77.1a**
1875	37.0	4.7	27.8	18.9	3.7	19.7	8.2	8.9	17.1	**64.1c**	**17.3c**	**64.6c**

- 随着杂卤石用量的增加，油菜地上部钙、镁、硫的积累量明显增加，在用量为1500kg/ha时达到最大量。
- Ca, Mg and S accumulation increased with Polysulphate rate increase.

经济效益分析 Economic benefit

PS (kg/ha)	产值 Income （yuan/ha）	施肥增加值 Incre value （yuan/ha）	杂卤石投入 PS cost （yuan/ha）	纯利润 Net profit （yuan/ha）	产投比 VCR
0	11930				
375	14470	2540	1688	853	1.51
750	15345	3415	3375	40	1.01
1125	15805	3875	5063	-1188	0.77
1500	16980	5050	6750	-1700	0.75
1875	14325	2395	8438	-6043	0.28

油菜籽的收购价为5.0元/公斤，Polyhalite肥料成本为4.5元/公斤。

- 杂卤石施用明显提高油菜籽产量和产值，当用量为1500kg/ha时产值最大；考虑杂卤石成本，用量375kg/ha时纯利润最高。
- Rapeseed yield and income increase with Polysulphate applied rates increase, at the rate 1500 kg/ha reached the top. The largest net profit got at the rate 375 kg/ha.

四、结论 Summary

（1）在部分中国冬油菜产区，油菜生产不仅需要施用氮、磷、钾、硼肥，还需要通过施肥补充钙、镁、硫养分来提高油菜籽产量和品质。**In some area of China, rapeseed production not only need N, P, K, B fertilization, but also need Ca, Mg and S fertilization as well, which lead to high yield and high quality seed.**

（2）杂卤石是一种能够为油菜生长提供钾、钙、镁、硫养分的肥料，在适宜用量时显著提高油菜籽产量和经济收益。**Polysulphate is a good resource of K, Ca, Mg and S nutrients for rapeseed in south China. Rapeseed yield and profit increased with suitable dosage Polysulphate application.**

（3）杂卤石施用显著提高油菜籽产量和产值，当用量为1500 kg/ha时产量和产值最高，比不施用增产42.3%；考虑杂卤石成本，用量375 kg/ha时纯利润最高。**Rapeseed yield and income increase with Polysulphate applied rates increase, at the rate 1500 kg/ha reached the top, the yield increased by 42.3% compared with CK(NPB). The largest net profit got at the rate 375 kg/ha.**

（4）杂卤石含有一定量的硼，但不能满足油菜高产的需要，在油菜生产中应配合施用硼肥来发挥各种养分的效率。**Polysulphate can supply some B to crop but cannot supply enough B for rape. B application combined with Polysulphate can improve all nutrients use efficiency, rapeseed yield and benefit.**

五、致谢 Acknowledgement

- 项目支持：国际钾肥研究所（IPI）
- Support by International Potash Institute （IPI）

- 团队成员：鲁剑巍、任涛、高洁、张洋洋
- Research team: Jianwei Lu, Tao Ren, Jie Gao and Yangyang Zhang

- 项目协调：Eldad Sokolowski 博士 国际钾肥研究所
  李国华 博士 以色列化工集团
  虞凤仪 局长 武穴市农业局
- Coordinators: Dr. Eldad Sokolowski (IPI), Dr. Guohua Li (ICL Fertilizers), Mrs Fanyi Yui (Agricultural Bureau of Wuxia)

Thank you for your attention!