1st IPI Symposium on Polyhalite
第一届国际钾肥研究所硫酸钾钙镁研讨会

Effects of calcium and magnesium on potato tuber yield, quality and disease incidence in Inner Mongolia of China

钙和镁对内蒙古马铃薯产量、品质和抗病性的影响

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Outline

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2. **Experimental Design**
3. **Results**
4. **Conclusion**

汇报提纲

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二、试验设计

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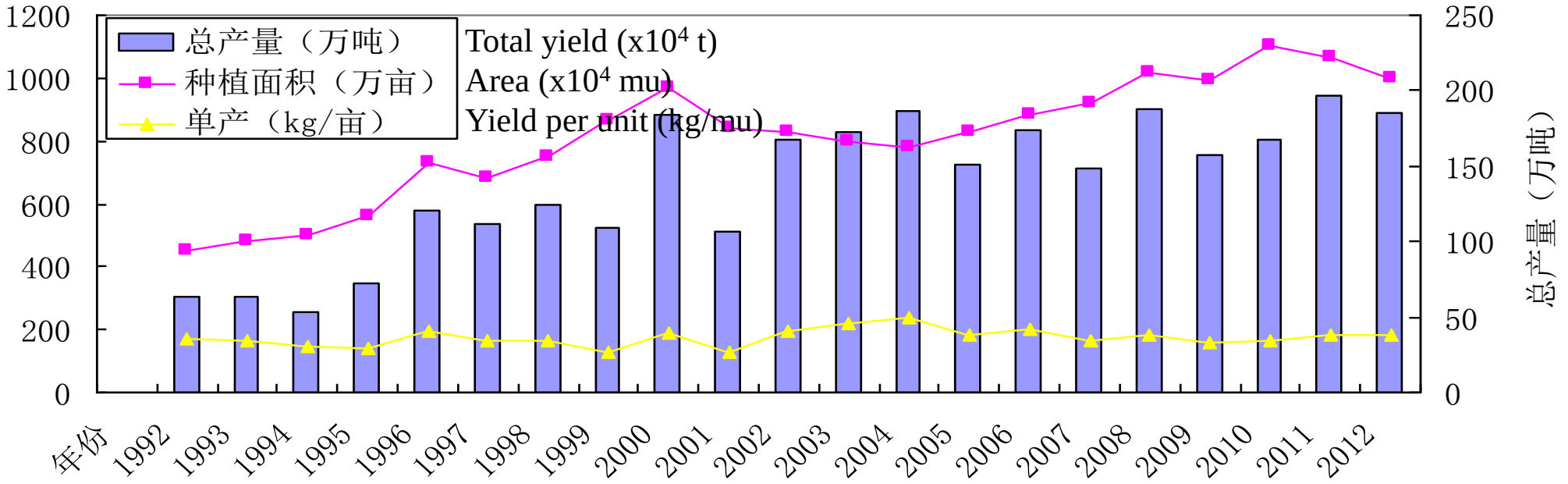
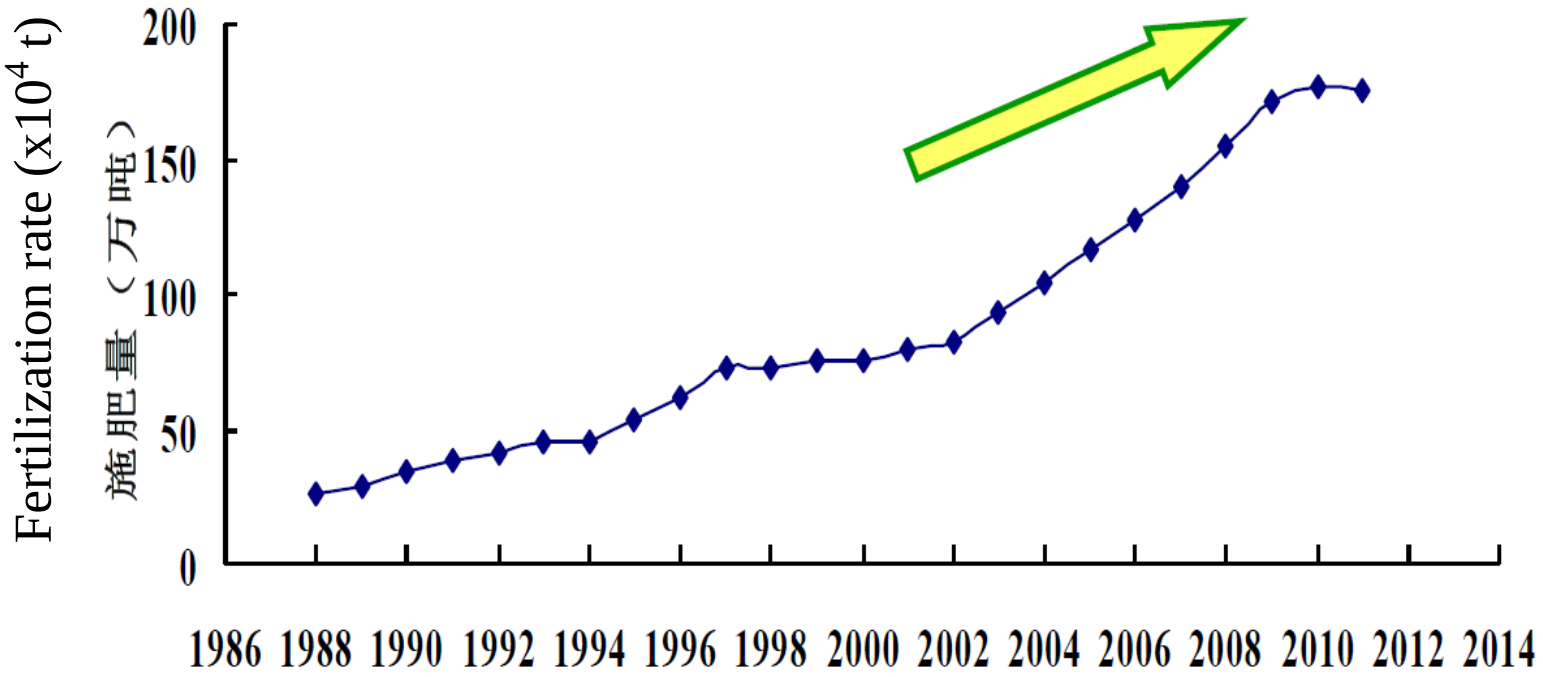
一、研究背景
Background



内蒙古马铃薯生产现状

Potato production in Inner Mongolia

马铃薯施肥及其研究现状
Fertilization and related research in Potato



内蒙古作物施肥状况
Fertilizer use in Inner Mongolia(Main potato production area)

表 “马铃薯+元素”中国知网检索结果

主题词	文章数
马铃薯+氮	2354
马铃薯+磷	2679
马铃薯+钾	2419
马铃薯+钙	665
马铃薯+镁	357

Publications in Chinese by searching key words “potato” and “mineral element”

马铃薯钙素营养研究进展
Progress of calcium research on potato

It was inconsistent on the effect of Calcium to potato yield and tuber.
施钙马铃薯产量和结薯数影响的结论不一致。

(Nadeem et al., New Zealand Journal of Crop and Horticultural Science, 2009)
(张昕硕士论文，2015；辛建华博士论文,2008）

The protein, Vitamin C and starch in tuber are all increased as Calcium concentration increase.
随着钙水平的提高，马铃薯块茎中蛋白质、V_C和淀粉的含量均有一定幅度的增加。

（辛建华博士论文，2008）

Reduced severity of internal brown spot and Erwinia soft rot in potato tubers with increased calcium content.
随着马铃薯块茎中钙浓度的增加，褐斑病和软腐病的发病程度降低。

(Mcguire and Kelman. Phytopathology, 1984; Tzeng et al. American Potato Journal, 1986)

- Calcium could increase chlorophyll content and net photosynthetic rate of potato.
  施钙可以有效提高马铃薯叶片的叶绿素含量和净光合速率,特别是对上位叶片光合速率的提高更为明显。

(张昕硕士论文，2015；辛建华博士论文,2008)

- Calcium deficiency induced shoot tip injury and loss of apical dominance.

缺钙会导致马铃薯组培苗顶端坏死，丧失顶端优势。

HORTSCIENCE 46(10):1358–1362. 2011.

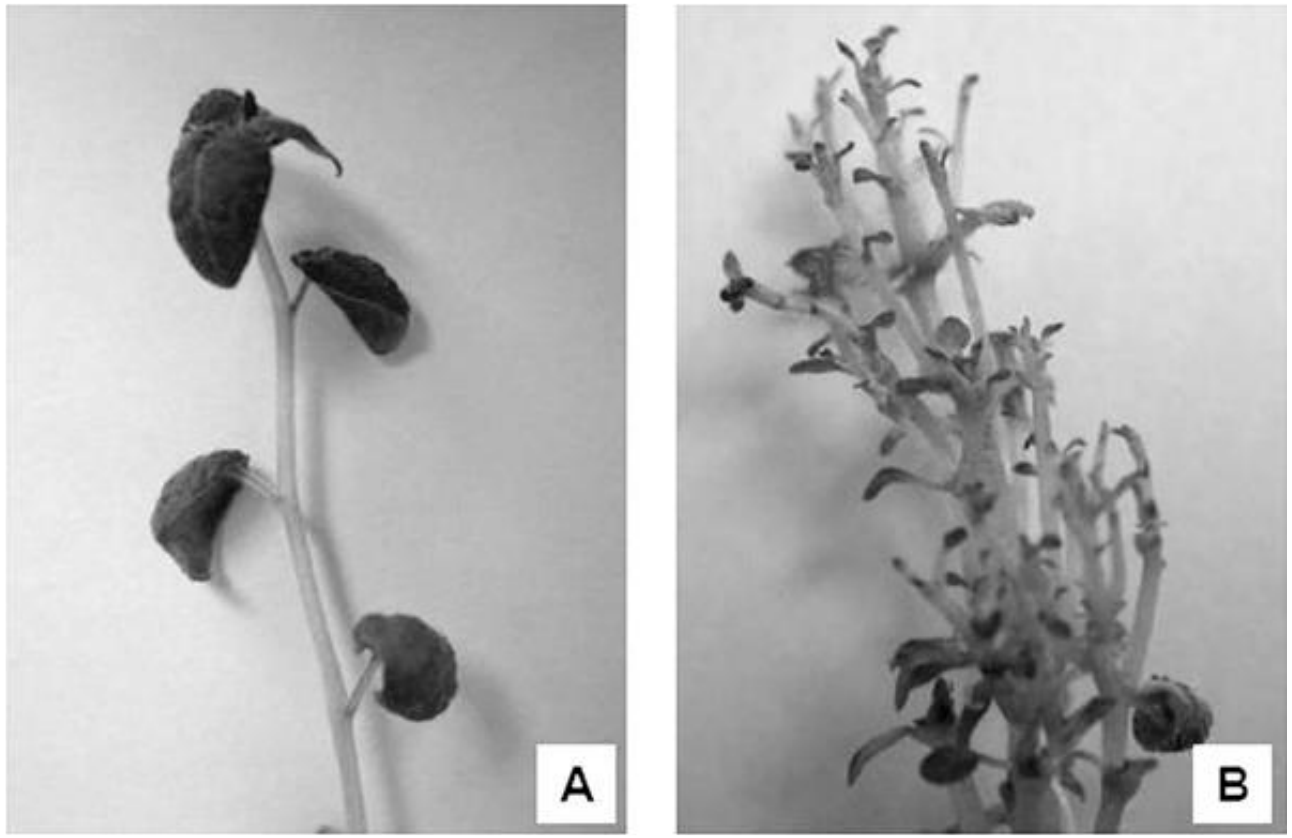
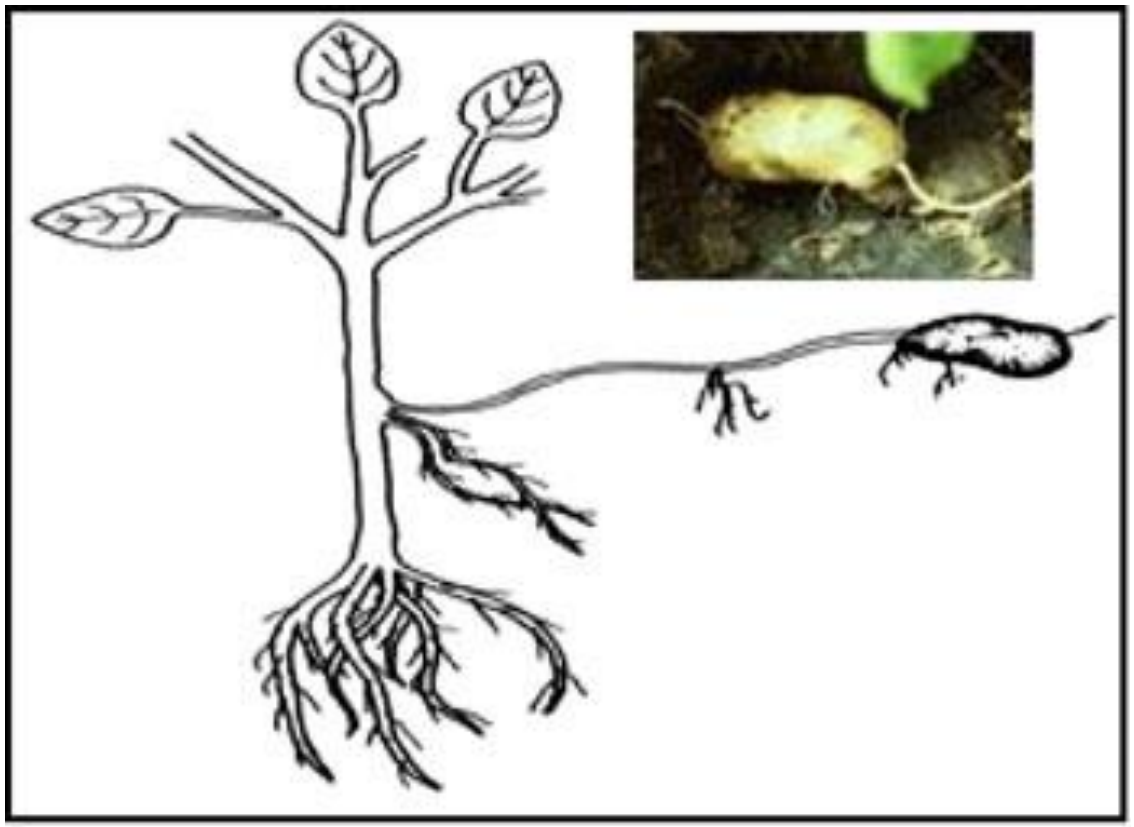


Fig. Growth of ‘Dark Red Norland’ potato shoots for 30 days in media containing single shoots at 3000 mM calcium (Ca) (A) and 6.8 mM Ca (B).

钙素的吸收和运输

Absorption and Transportation of Ca^{2+}



♦♦ Water and calcium taken up by the main root system bypass the tubers and are delivered to the above-ground portion of the plant, and roots arising from the stolons and tubers supply calcium to the tubers.

钙素吸收的特点：

1. 通过主根系吸收的水分和钙素不经过块茎，直接运输到地上部，起始于匍匐茎和块茎的根系给块茎提供钙素；
2. 马铃薯植株木质部中的水势梯度是钙素吸收和运输的驱动力。

Palta J P. Potato Research, 2010, 53(4):267-275.

马铃薯镁素营养研究进展
Progress of Magnesium research on potato

研究较少, 仅限于对产量性状的初探!

There are little reports of Magnesium on potato production!

研究目的
Aims of the project

1. 在内蒙古的气候和土壤条件下马铃薯钙、镁吸收和需求规律；

To clear the absorption and requirement of calcium and magnesium by potato in Inner Mongolia of China.

2. 新型肥料“硫酸钾钙镁肥”在马铃薯上的效果和应用方法。

To detect the effects of new-style fertilizer Polyhalite in potato production and its application method.

二、试验设计
Experimental Design

试验田鸟瞰图
Experimental site
（内蒙古乌兰察布市察右中旗）

品种：克新1号
Cultivar: Kexin No.1

密度：42000株/公顷
Density: 42000 plants/ha

灌溉模式：滴灌
Irrigation method: drip irrigation

施肥量(Fertilization rates):
300 kg/ha N, 180 kg/ha P_2O_5

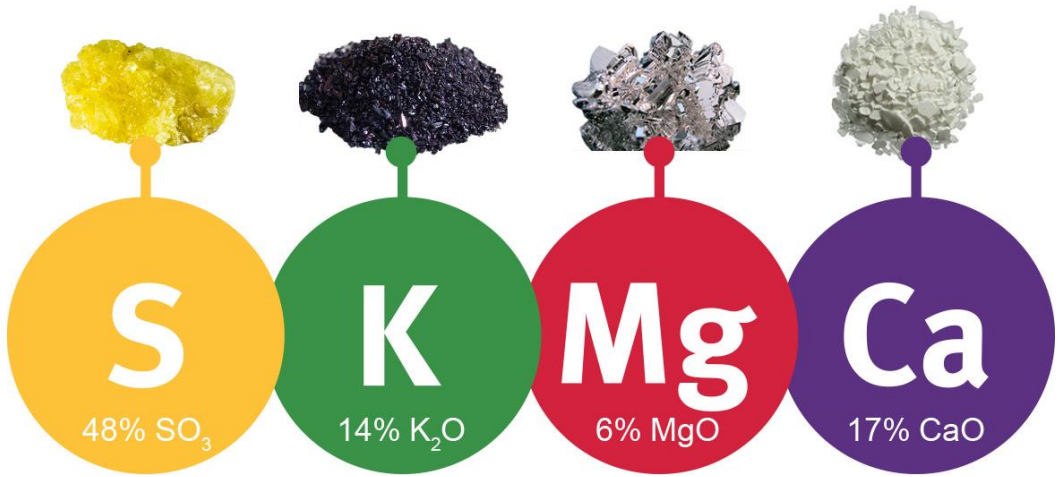
小区设置：100 m^2/小区，3次重复，随机区组设计
The plot area was 100 m^2 , the experiments were completely randomized block design with three replicates.

试验处理
Treatments

试验1. 硫酸钾钙镁肥的应用研究处理
Exp.1 Treatment of of Polyhalite application in potato

Treatments 处理	Basal Dressing (kg ha^{-1})	
	K_2O	Polyhalite
T2（CK）	300 (as K_2SO_4)	
T1	90 (as K_2SO_4)	1500
T6	234(as K_2SO_4)	469

四合一创新型肥料
The new 4-in-1 fertilizer



试验2. 钙、镁吸收和需求规律研究处理

Exp.2 Absorption and requirement of calcium and magnesium by potato

Treatments 处理	Basal Dressing (kg ha^{-1})		
	K_2O	MgO	CaO
T2 (ck)	300 (as K_2SO_4)		
T3	300 (as K_2SO_4)	90 (as MgSO4)	
T4	300 (as K_2SO_4)		225 (as Ca(NO3)2)
T5	300 (as K_2SO_4)	90 (as $MgSO_4$)	255 (as Ca(NO3)2)

三、研究结果（Results）

1. 硫酸钾钙镁肥的应用研究

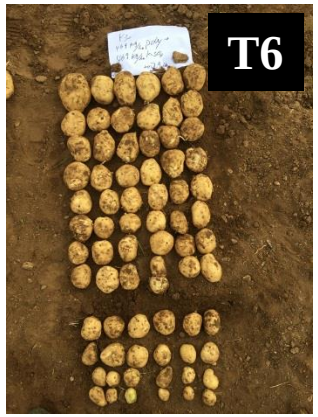
Application of Polyhalite in potato

产量指标

表1. 马铃薯产量及其构成因子

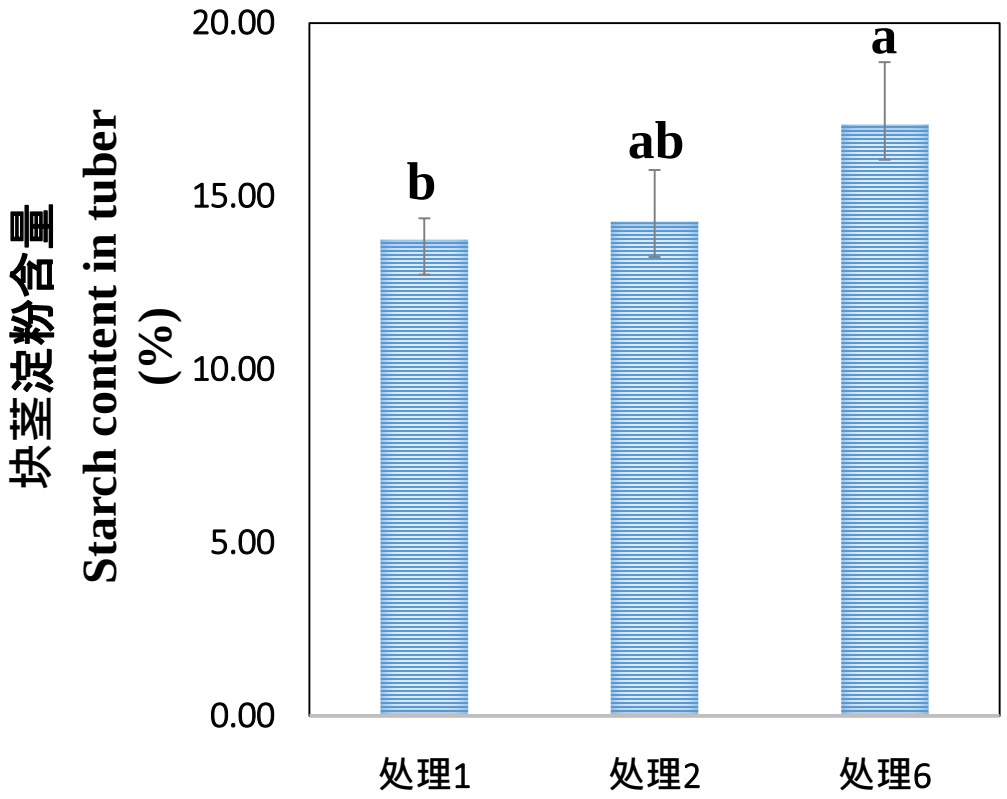
Table 1. Potato yield and its components under different treatments

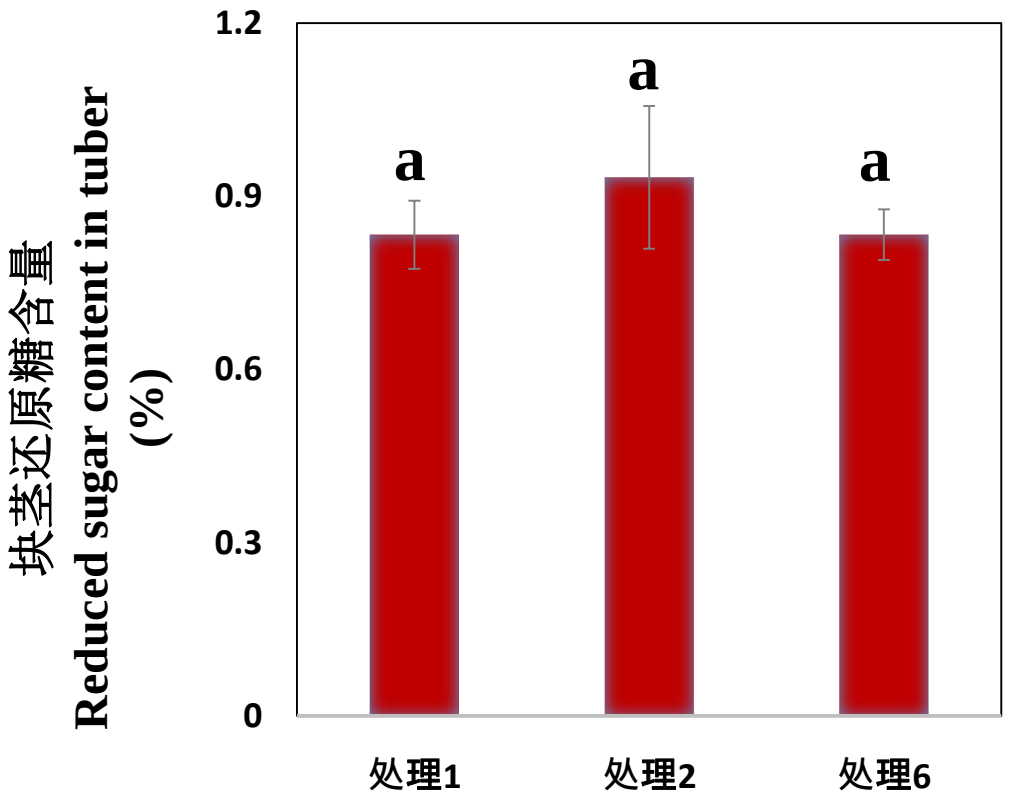
处理	产量（kg/ha）	单株结薯数（个/株）	单个薯重（g/个）	大薯率（%）	商品薯率（%）
Treatments	Yield	Tuber number per seedling	Average tuber weight	Percentage of large tuber number	Commercial tuber rate
T1	36190 b	5.7 b	187.7 a	57.5 a	84.4 a
T2(CK)	41835 ab	6.9 ab	198.6 a	62.7 a	84.6 a
T6	50727 a	7.4 a	191.9 a	61.2 a	83.0 a



品质指标

淀粉和还原糖
Starch and reduced sugar





♦ 1/2 polyhalite + 1/2 K_2SO_4 施肥组合**能够促进块茎中淀粉的积累，还原糖在不同处理间没有显著差异。**

The suitable fertilization combination (1/2 polyhalite + 1/2 K_2SO_4) promotes starch accumulation in potato tuber, but no effect on reduced contents.

抗病性

疮痂病发病情况
The incidence of Common scab

表2. 不同处理下马铃薯疮痂病发病情况

Table 2. The incidence of common scab of under different treatments

处理 Treatment	发病率 Disease incidence	病情指数 Disease index
处理1	53.70%	14.5
处理2	54.80%	16.4
处理3	43.10%	11.5
处理4	30.30%	9.3
处理5	23.10%	6.9
处理6	21.90%	6.7

* **病情指数**=∑（**病**级x该病级个数）/**最高病**级数x总调查数 x100

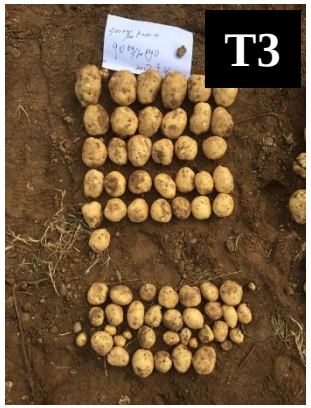
2. 钙、镁吸收和需求规律研究

Absorption and requirement of calcium and magnesium by potato

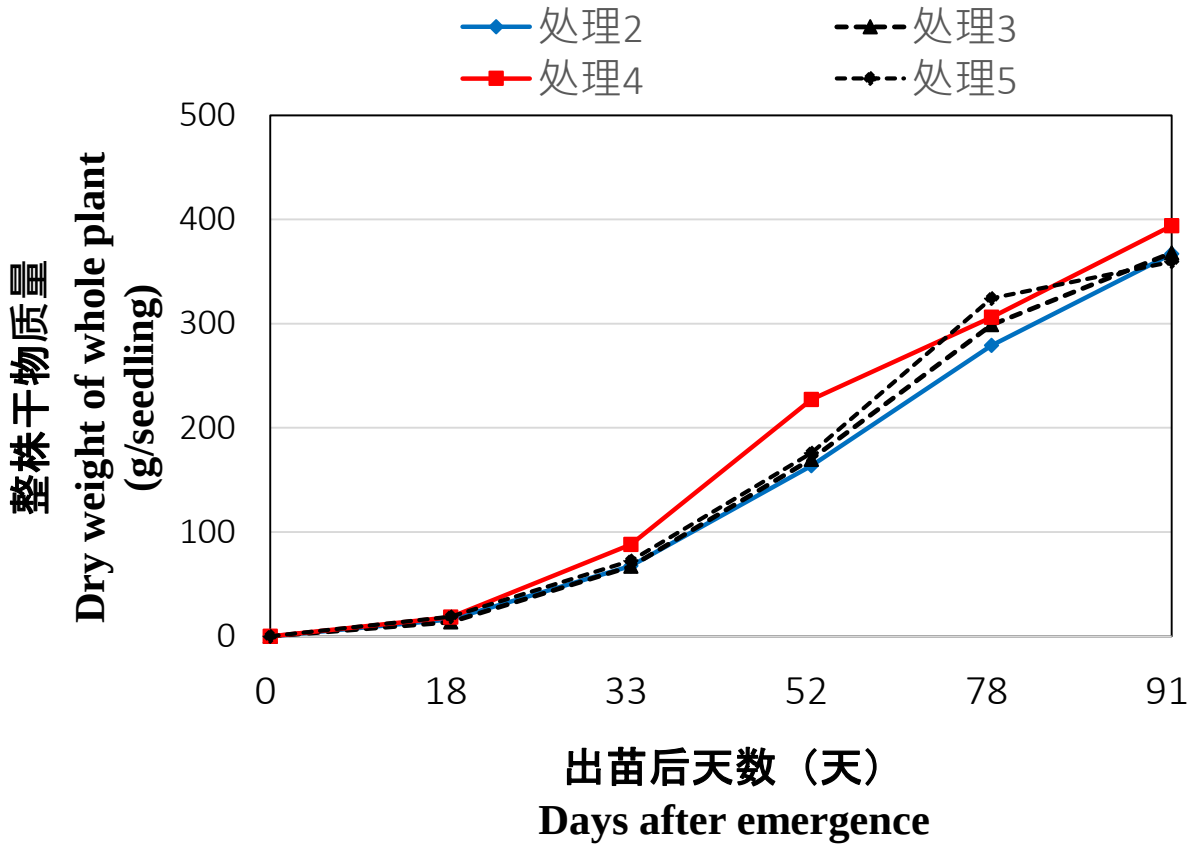
表3. 马铃薯产量及其构成因子

Table 3. Potato yield and its components under different treatments

处理 Treatments	产量（kg/ha） Yield	单株结薯数（个/株） Tuber number per seedling	单个薯重（g/个） Average tuber weight	大薯率（%） Percentage of large tuber number	商品薯率（%） Commercial tuber rate
T2（CK）	41835 a	6.9 a	198.6 a	62.7 a	84.6 a
T3	35634 a	5.7 a	184.2 a	58.9 a	83.2 a
T4	44898 a	6.5 a	207.7 a	60.5 a	81.9 a
T5	37969 a	5.7 a	192.9 a	54.2 a	79.2 a



整株干物质积累动态
Dry matter accumulation of whole plant



☼ **镁肥（处理3）和钙肥（处理4）对马铃薯中后期干物质积累均有一定的促进作用（与处理2相比），且钙的促进作用更加明显。**

Both Calcium and magnesium have promotion effects on potato dry matter accumulation at the middle and (or) later developmental stages, but the effect of Calcium is more obvious.

光合作用相关指标

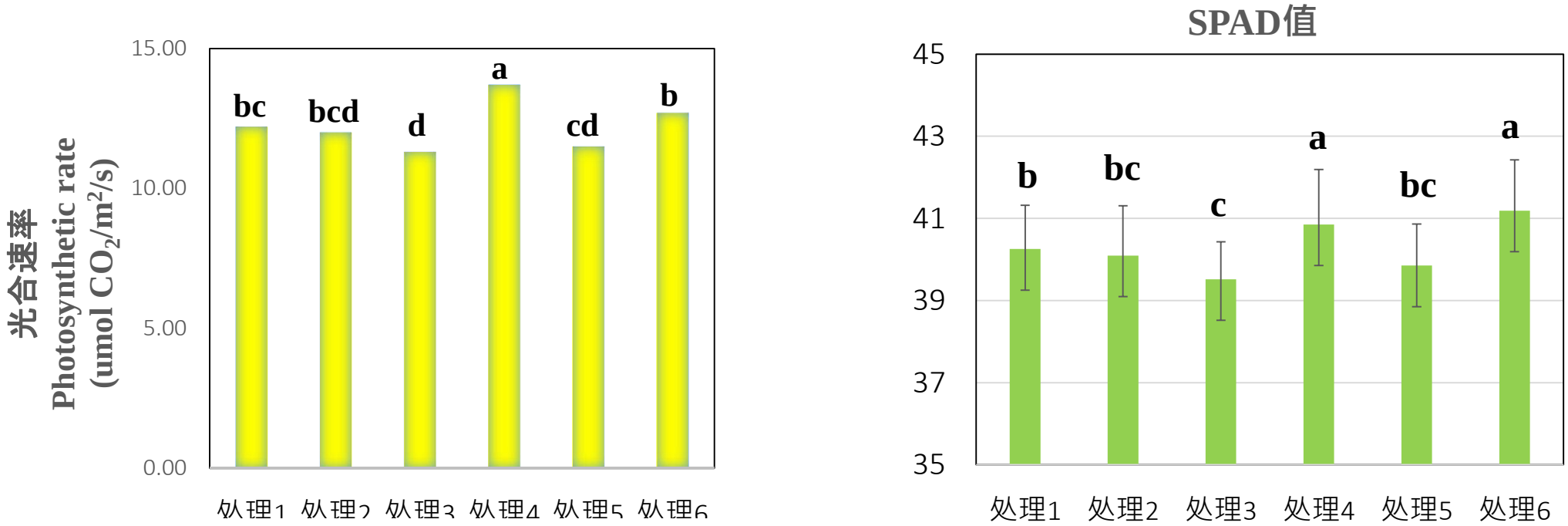


图. 不同处理下马铃薯的光合速率(左)和SPAD值(右)

Table 3. Photosynthetic rates (Left) and SPAD value (Right) of potato under different treatments

*** 钙对马铃薯叶片的叶绿素含量和光合作用有显著的促进作用。

钙镁吸收和需求

钙素吸收和累积规律
Absorption and accumulation of Calcium

表4. 不同处理下马铃薯生育期各器官的钙浓度(mg/g)

Table 4. Calcium concentration in different organs during potato developmental stages under different treatments

器官	处理	出苗后天数（Days after emergence）				
Organ	Treatment	18	33	52	78	91
叶片	处理2	21.06 b	22.68 a	44.23 b	42.52 a	34.04 abc
	处理3	19.76 b	26.71 a	40.90 b	46.27 a	32.64 bc
	处理4	23.34 a	30.45 a	48.31 ab	41.49 a	31.80 c
	处理5	23.35 a	25.91 a	54.00 a	44.29 a	37.86 a
块茎	处理2	/	0.47 a	0.22 ab	0.16 a	0.08 a
	处理3	/	0.34 a	0.43 a	0.10 a	0.11 a
	处理4	/	0.44 a	0.18 ab	0.19 a	0.10 a
	处理5	/	0.31 a	0.23 ab	0.12 a	0.12 a

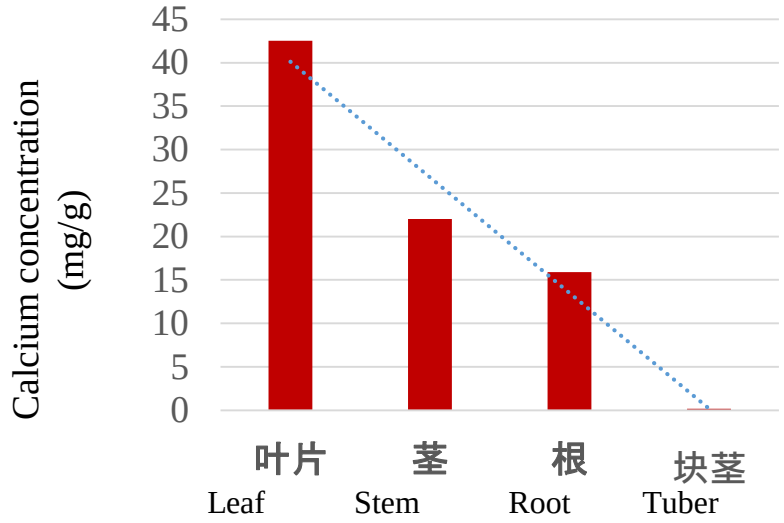


图. **不同器官中的**钙素含量

Fig. Calcium concentrations in different organs of potato

注：块茎膨大期(78 DAE)处理2的数据

- **叶片中的**钙浓度随着随着生育时期的推进逐渐增加，在块茎膨大期达到最高，而后又有所下降；块**茎中**钙素浓度随生育时期逐渐下降；
- **不同器官中**钙浓度在叶片、茎、根和块茎中呈显著下降趋势；
- **施**钙处理的叶片基本表现出较高钙浓度，但是块茎中的钙浓度在不同处理间无显著差异。

钙素在块茎中的分配
Distribution of calcium in potato tuber

表5. 收获时钙素在各器官的分配比例
Table 5. The distribution of calcium amount in organs

处理 Treatment	钙素分配比（%） 叶片 Leaf	茎 Stem	根 Root	块茎 Tuber
处理2	64.89	31.47	2.52	1.13
处理3	67.89	28.52	1.89	1.70
处理4	62.46	34.49	1.55	1.51
处理5	60.82	37.12	1.07	0.99

♫ **钙素在块茎中的分配极低，介于1.0%~1.7%之间;**
The distribution of Calcium in tuber is very low (1.0%~1.7% in our experiment);

♫ **千公斤马铃薯需钙量2.3~3.0 kg (克新1号品种)。**
About 2.3~3.0 kg CaO is needed to produce 1000 kg fresh tuber (Cultivar Kexin No.1 as example).

镁素吸收和累积规律 Absorption and accumulation of Magnesium

表6. 不同处理下马铃薯生育期各器官的镁浓度(mg/g)

Table 6. Magnesium concentration in different organs during potato developmental stages under different treatments

器官	处理	出苗后天数（Days after emergence）				
Organ	**Treatment**	**18**	**33**	**52**	**78**	**91**
叶片	处理2	8.176 b	8.522	10.361 b	10.472 b	10.684 b
	处理3	8.194 b	8.661	10.148 b	10.774 b	10.187 b
	处理4	8.590 ab	9.487	10.132 b	10.256 b	10.625 b
	处理5	9.010 a	8.524	16.113 a	13.602 a	10.729 b
块茎	处理2	/	5.619 bc	5.325 b	4.697 bc	4.363 b
	处理3	/	5.679 c	6.209 a	4.533 c	4.556 ab
	处理4	/	6.109 ab	5.114 b	4.883 bc	4.518 b
	处理5	/	6.259 a	5.402 b	5.641 a	4.891 a

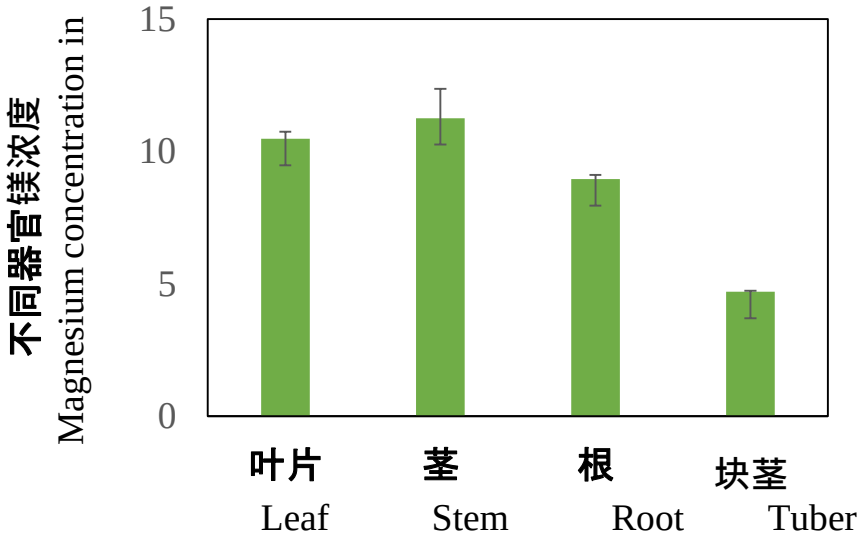


图. 不同器官中的镁素含量

Fig. Magnesium concentrations in different organs of potato

注：块茎膨大期(78 DAE)处理2的数据

- 施镁处理的叶片和块茎中含有较高的镁含量；
- 不同器官中镁浓度表现为茎中最高，块茎中最低。

镁素在块茎中的分配
Distribution of Magnesium in potato tuber

表7. 收获时镁在各器官的分配比例
Table 7. The distribution of magnesium amount in organs

处理 Treatment	镁素分配比（%） 叶片 Leaf	茎 Stem	根 Root	块茎 Tuber
处理2	19.80	17.13	1.53	61.53
处理3	18.10	22.53	1.47	57.90
处理4	18.96	17.55	1.13	62.36
处理5	23.62	20.53	0.93	54.91

☼ **收获时一半以上的镁分配到块茎中；**
Over halves of Magnesium were distributed to tuber as harvest;

☼ **千公斤马铃薯需每镁量3.0~3.4 kg。**
About 3.0~3.4 kg MgO is needed to produce 1000 kg fresh tuber (Cultivar Kexin No.1 as example).

四、主要结论
Conclusion

1. 在内蒙古气候和土壤条件下，施用polyhalite可以实现马铃薯产量的显著提升，同时增加了块茎的淀粉含量，降低了疮痂病的发病率；最佳的施用方法是 1/2 polyhalite + 1/2 K_2SO_4 施肥组合。

Under the climate and soil condition 1/2 polyhalite + 1/2 K_2SO_4 fertilization combination has significant effect on potato yield promotion, starch content increase and the elimination of common scab in tuber.

2. 克新一号马铃薯品种生产千公斤块茎需钙量（CaO）2.3~3.0 kg，需镁（MgO）3.0~3.4 kg。

About 2.3~3.0 kg CaO and 3.0~3.4 kg MgO are needed to produce 1000 kg fresh tuber (Cultivar Kexin No.1 as example), respectively.


欢迎批评指正！
Thanks ！