Adjust potassium nutrition to activate intrinsic immunity against apple Valsa Canker

钾营养激活树体免疫力抵抗苹果树腐烂病

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- **Valsa canker, caused by the fungus *Valsa mali*, is one of the most destructive diseases of apple in eastern Asia, seriously impeding apple production in China , Japan and Korea.**

The average incidence of Valsa canker on apple was 52.7% in 2008.

Twenty year's orchard, Xunyi County, Shaanxi

5-8% orchards were cut off in Shaanxi in recent years

(Cao et al. 2009)

Lots of prevention methods were developed to control Valsa canker.

Surgery

Bridging

Wound healing and protectant agents

Surrounding soil

Plaster

（Li et al 2009）

Biocontrol agent：*Pythium oligandrum*

Ozonation soybean oil

（Yang et al 2014）

Apple tree Cancer!!!

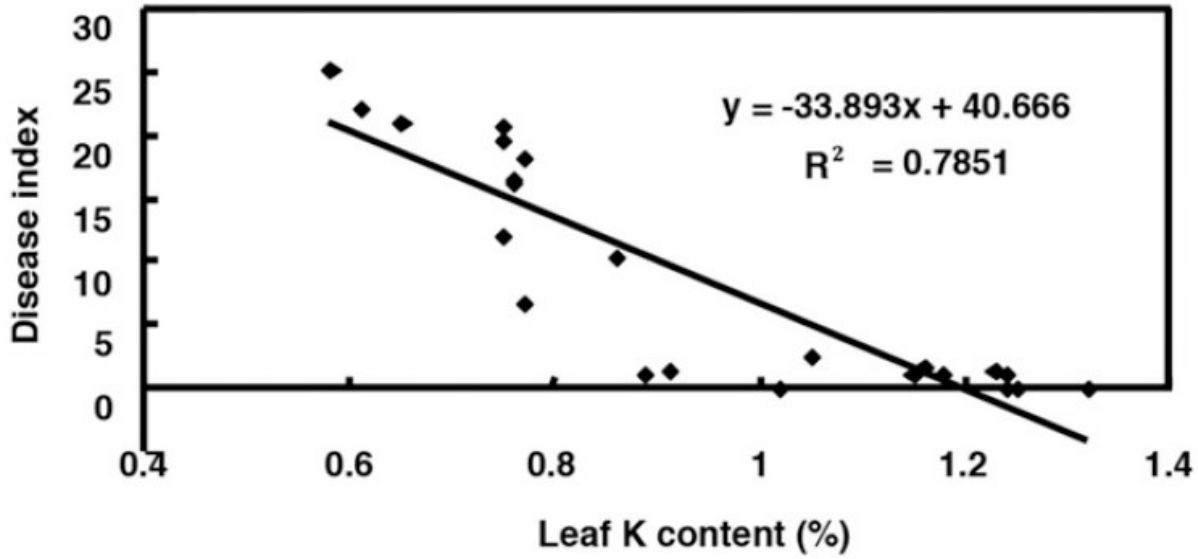
The Apple tree are too old to suffer Valsa canker?

59 years' old apple tree in Lingbao, Henan

560 years' old apple tree in Yili, Xingjiang

- Severity of Valsa canker is highly related with tree vigor.
- BUT: The reasons for wide occurrence of Valsa canker from the point of view in plant resistance are unclear.

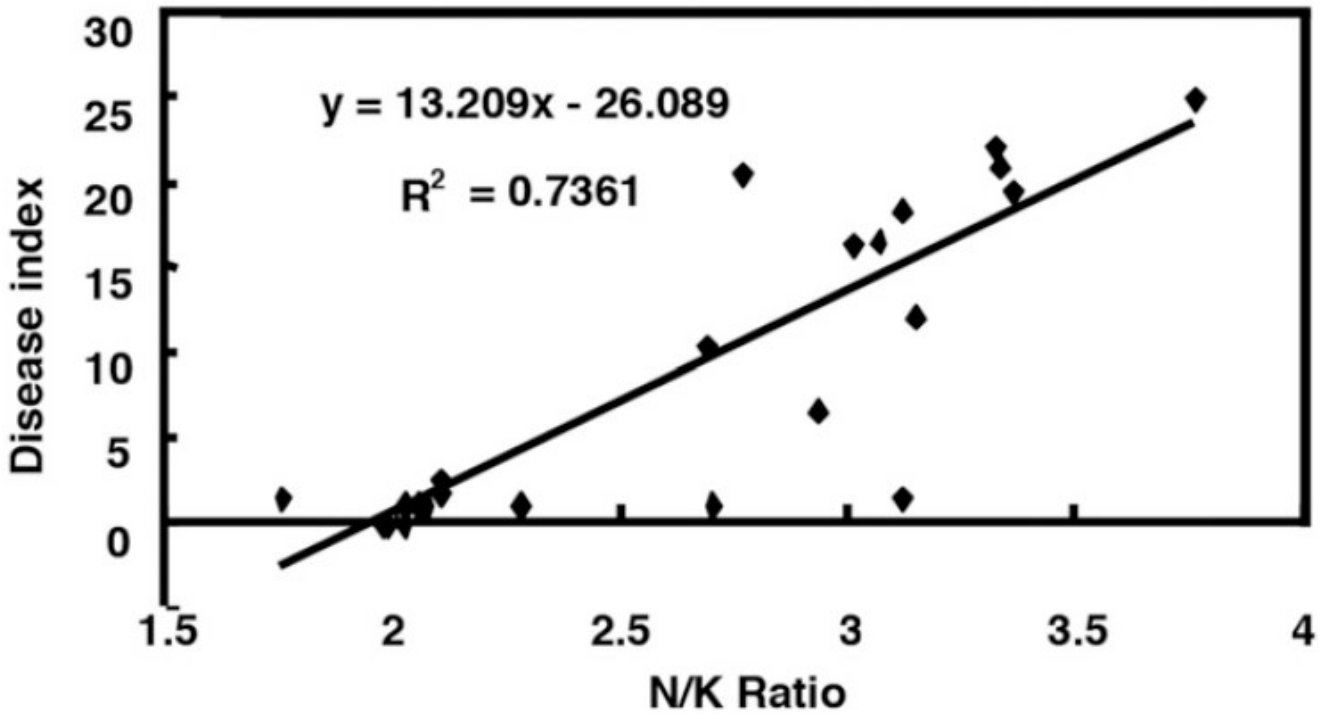
- **There was a significant negative correlation of leaf potassium (K) content with incidence and severity of Valsa canker.**



Nutrient element	Regression equation[z]	R^2	P value
N	$y = 57.80 - 20.94x_N$	0.2153	0.019
P	$y = -11.98 + 78.61x_P$	0.0834	0.171
K	$y = 40.67 - 33.89x_K$	0.7851	<0.001

Leaf K content (%)	DI[z]
0.5 to 06	> 20 a
0.7 to 0.8	10 to 20 b
0.9 to 1.3	<10 c

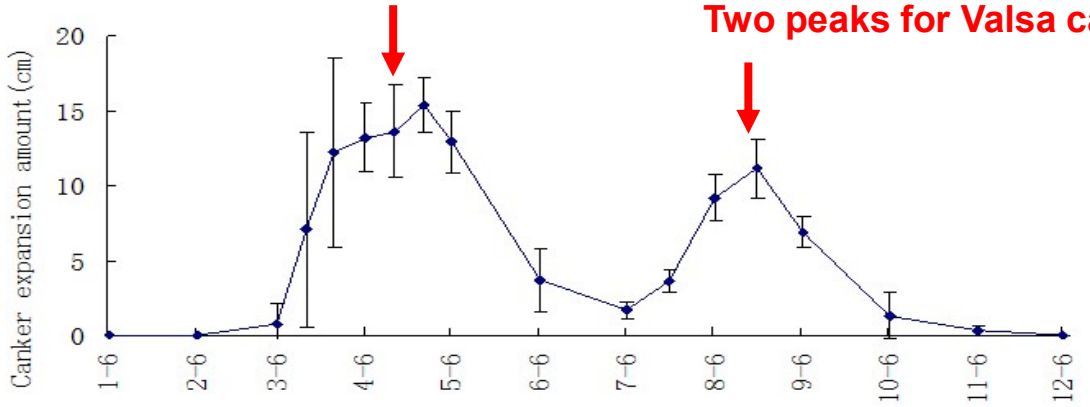
- There was a significant positive relationship between the N/K ratio and disease index



- **The peak of canker lesion appearance coincided with the low ebb of the branch potassium content in the year-around period.**

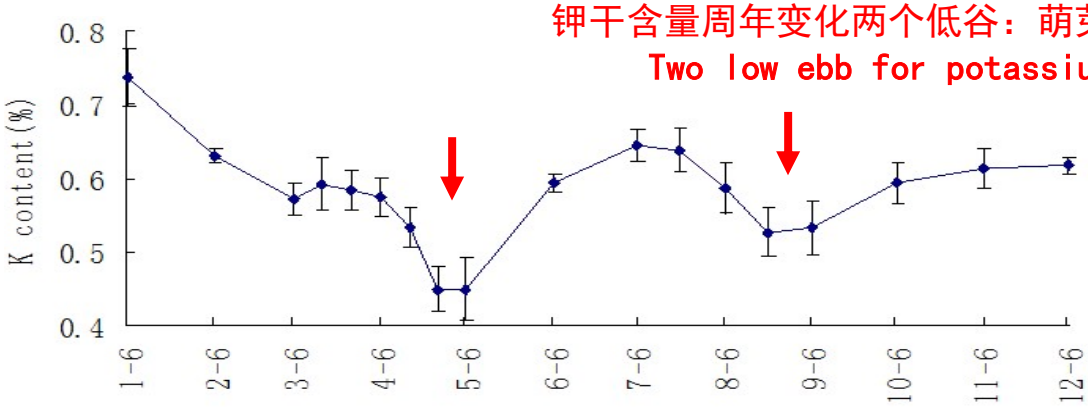
腐烂病周年发生两个高峰：春季、秋季

Two peaks for Valsa canker

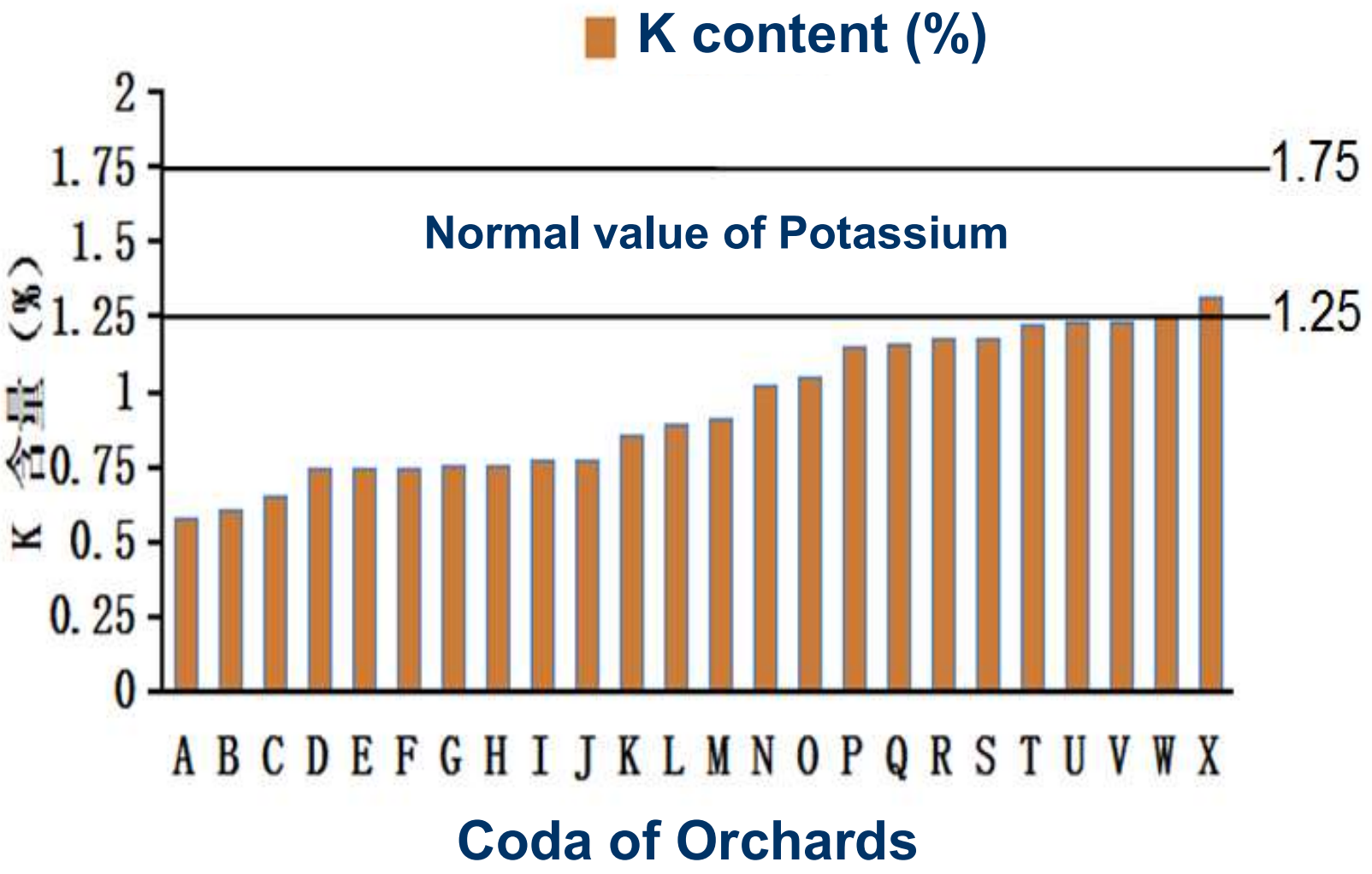


钾干含量周年变化两个低谷：萌芽-花期、果实膨大

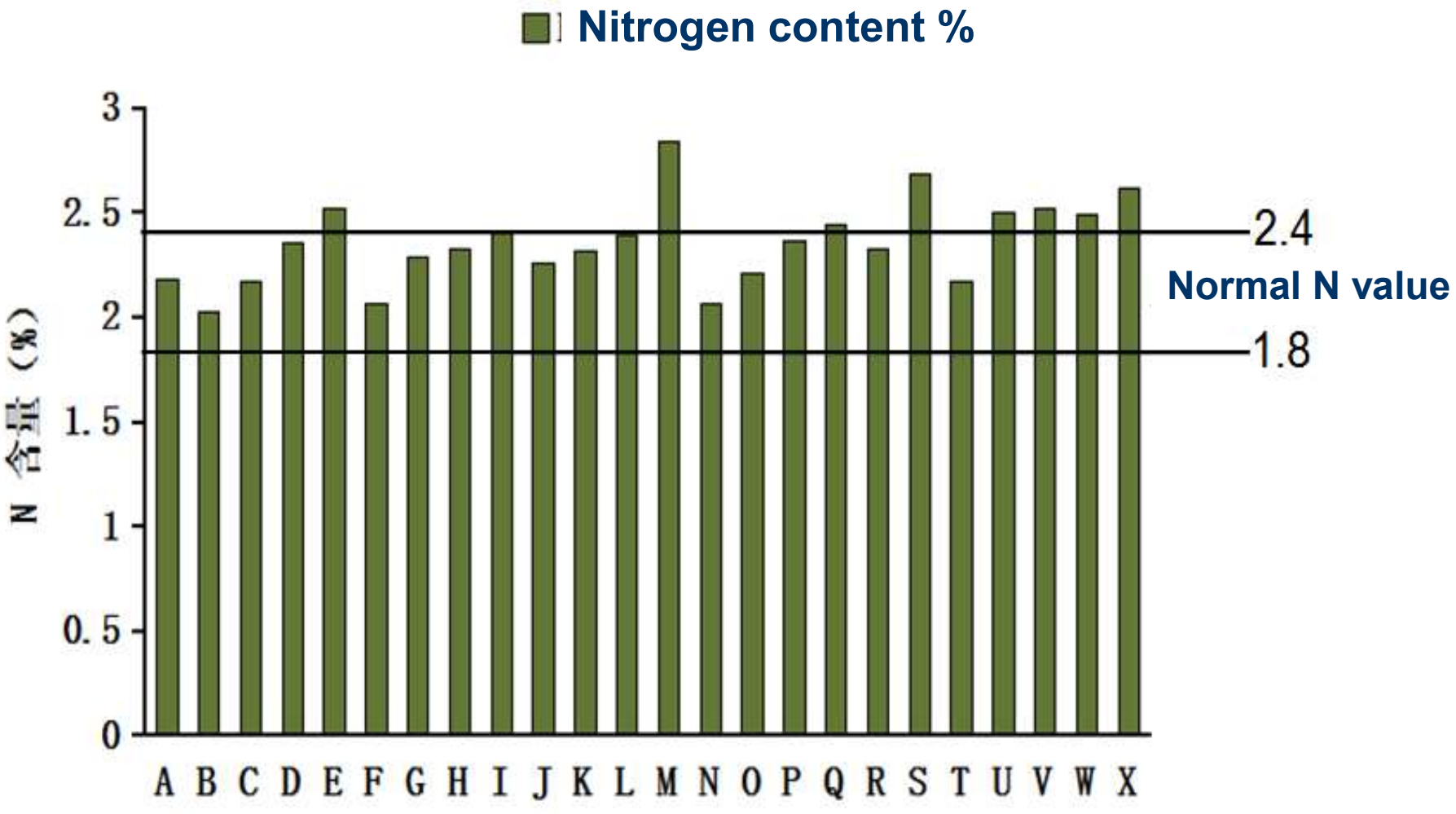
Two low ebb for potassium content



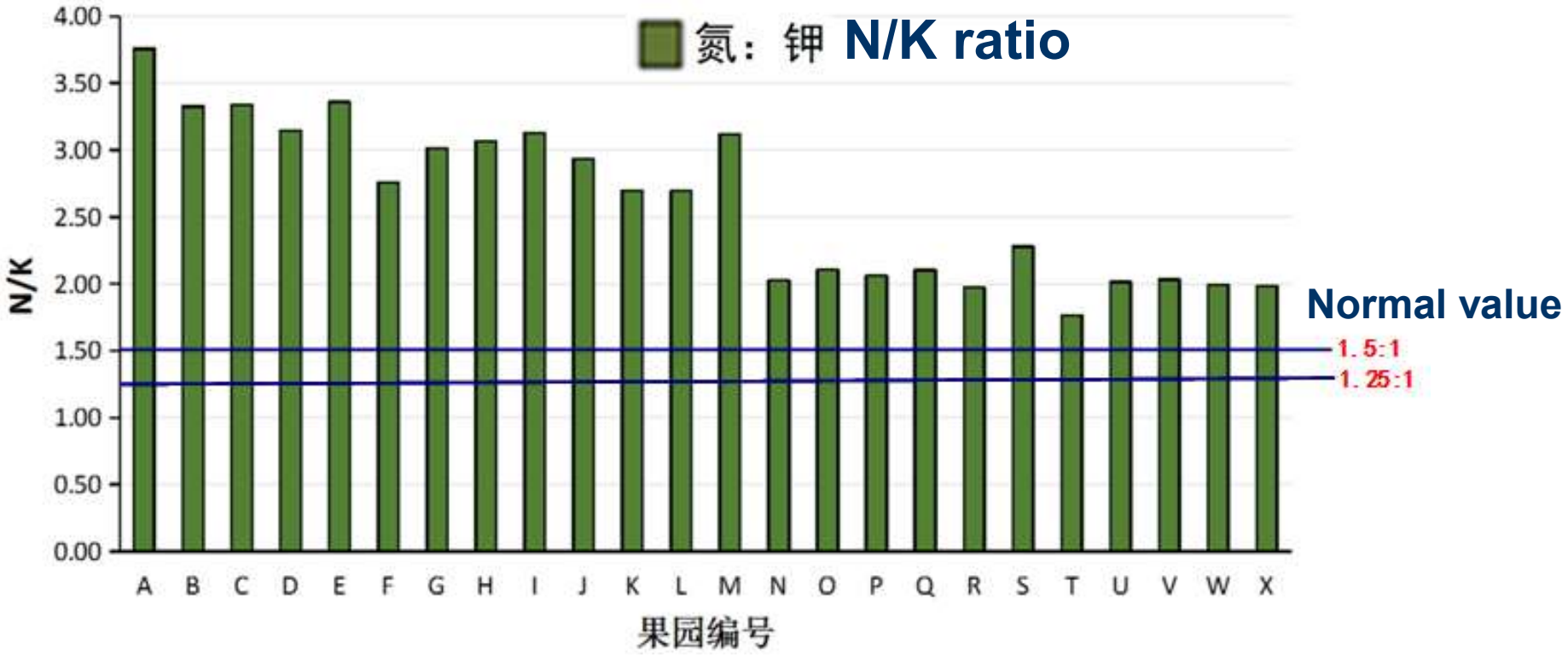
- **Leaf K content of most orchards was low to deficient severely.**



Leaf nitrogen contents are higher or too high in 1/3 orchards.

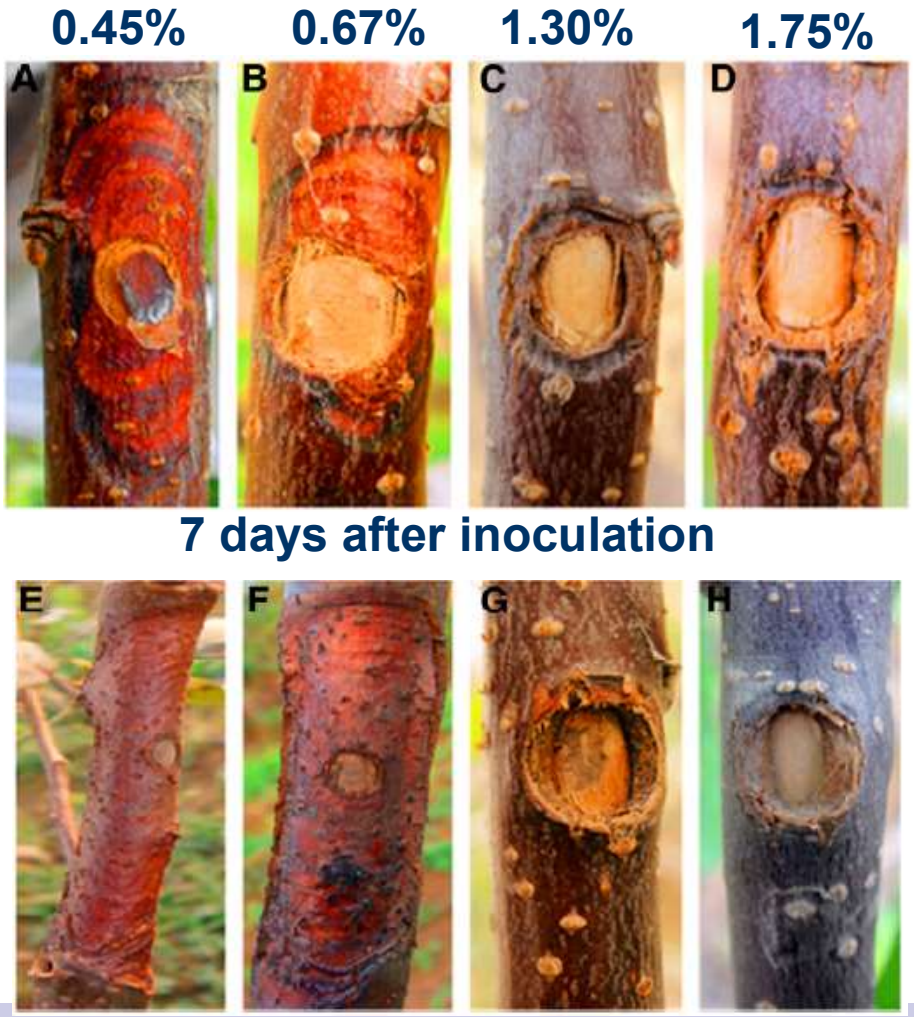


N/K ratio are over normal value (1.25-1.5) in all orchards.



Coda of Orchards

The trees with above 1.30% leaf K had not developed canker lesions.

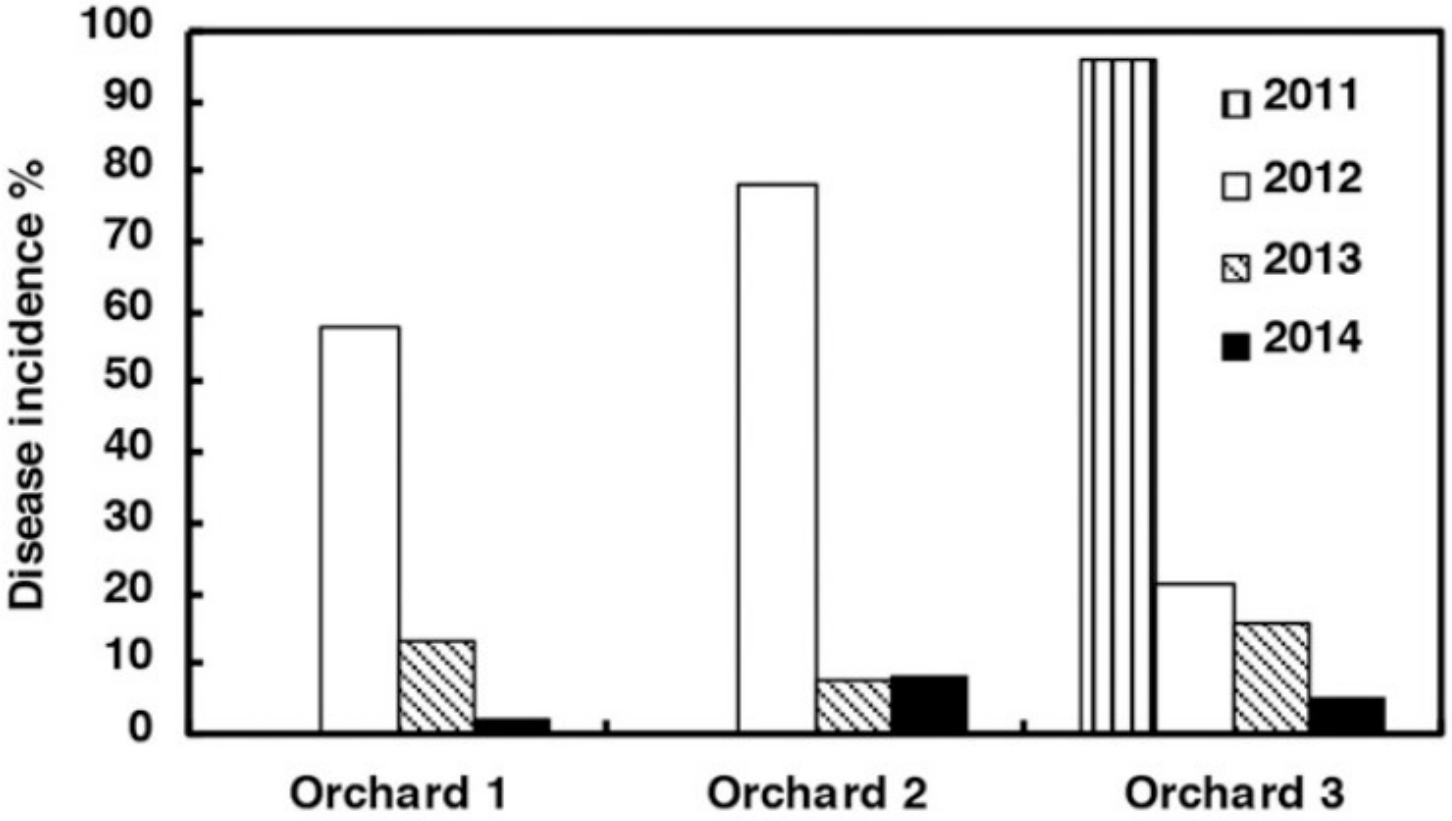


On greenhouse potted trees

Leaf nutrient content, nutrient content ratios, and Valsa canker lesion length from orchard fertilization trials

Fertilizing	N (%)	P (%)	K (%)	N/K	P/K	Lesion length (cm)
No	2.25 a	0.25 a	0.75 a	3.00 a	0.33 a	7.06 a
K_2SO_4 on leaves	2.36 b	0.26 a	1.16 b	2.03b	0.22 b	3.64 b
KH_2PO_4 to soil	2.43 c	0.27 a	1.17 b	2.08 b	0.23 b	3.40 c
$K_2SO_4 + KH_2PO_4$	2.34 b	0.28 a	1.37 c	1.71 c	0.20 b	0.09 d

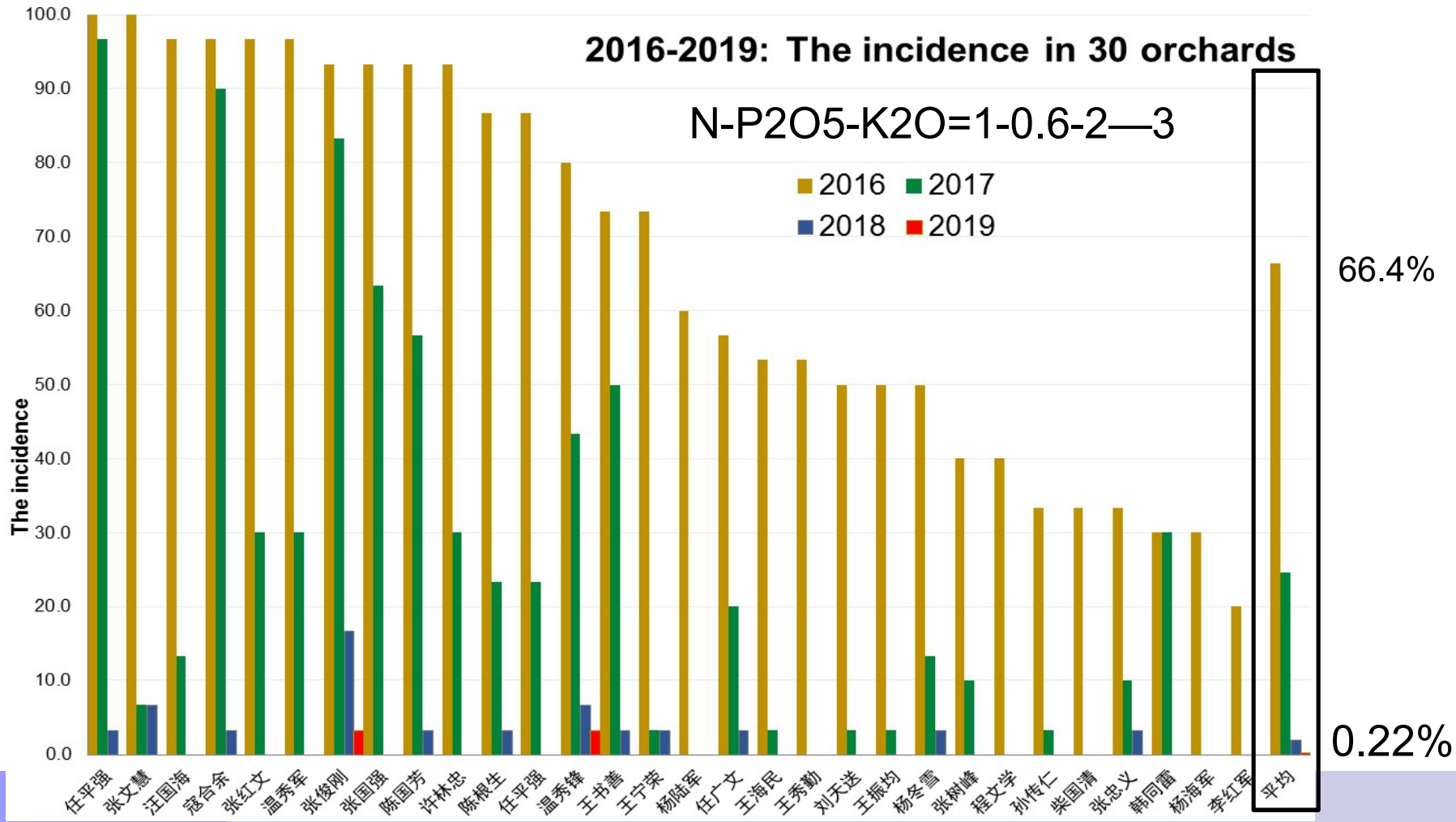
- **By increasing K fertilization significantly reduced the incidence and severity of Valsa canker from 58.1%-96% to 2.1%-8.1% in commercial orchards trials.**



Peng et al, 2016,Plant Disease

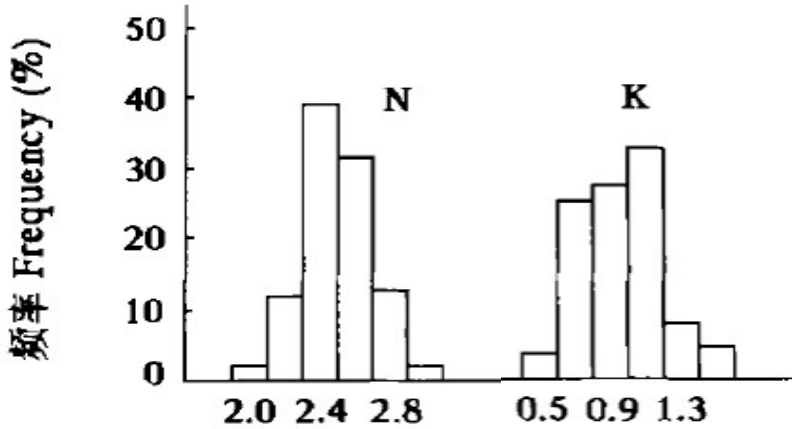
For 30 commercial orchards demonstration, by reducing nitrogen and increasing potassium usage, the disease control effect was up to 99.7% in three years.

通过三年减氮增钾措施，苹果树腐烂病仅在个别果园零星发生。



Low and deficient potassium are common in Loess Plateau region,China.

460 orchards in Shaanxi: 0.8%K



(An et al 2004)

309 orchards in Huangling, Shaanxi: 0.9%K

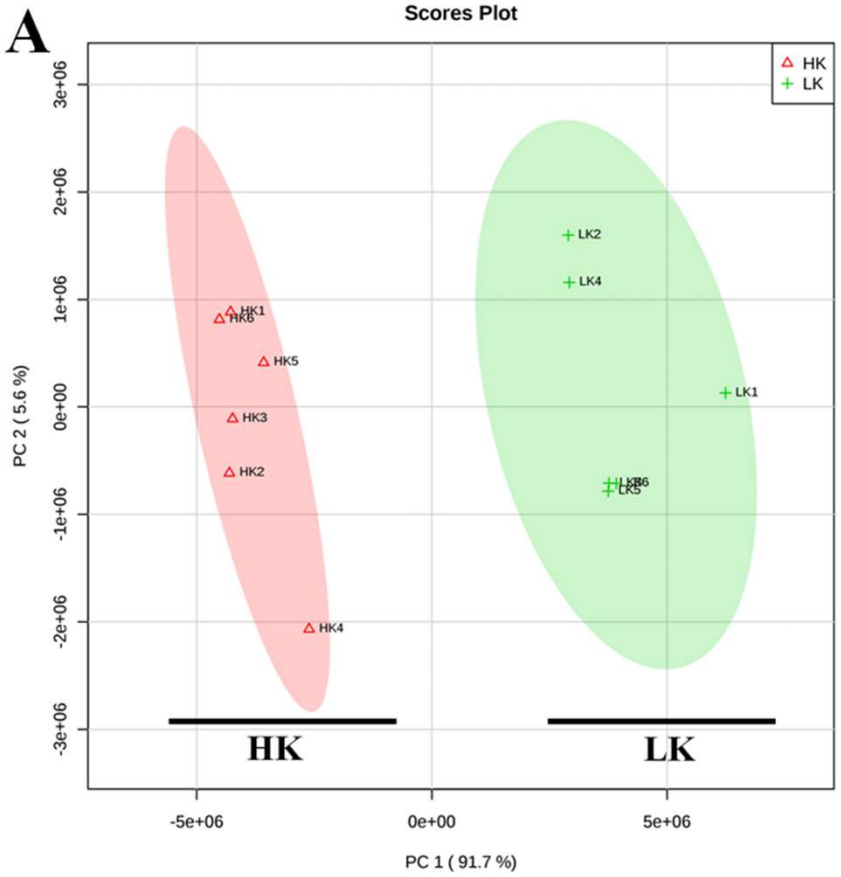
黄陵县苹果叶片养分含量

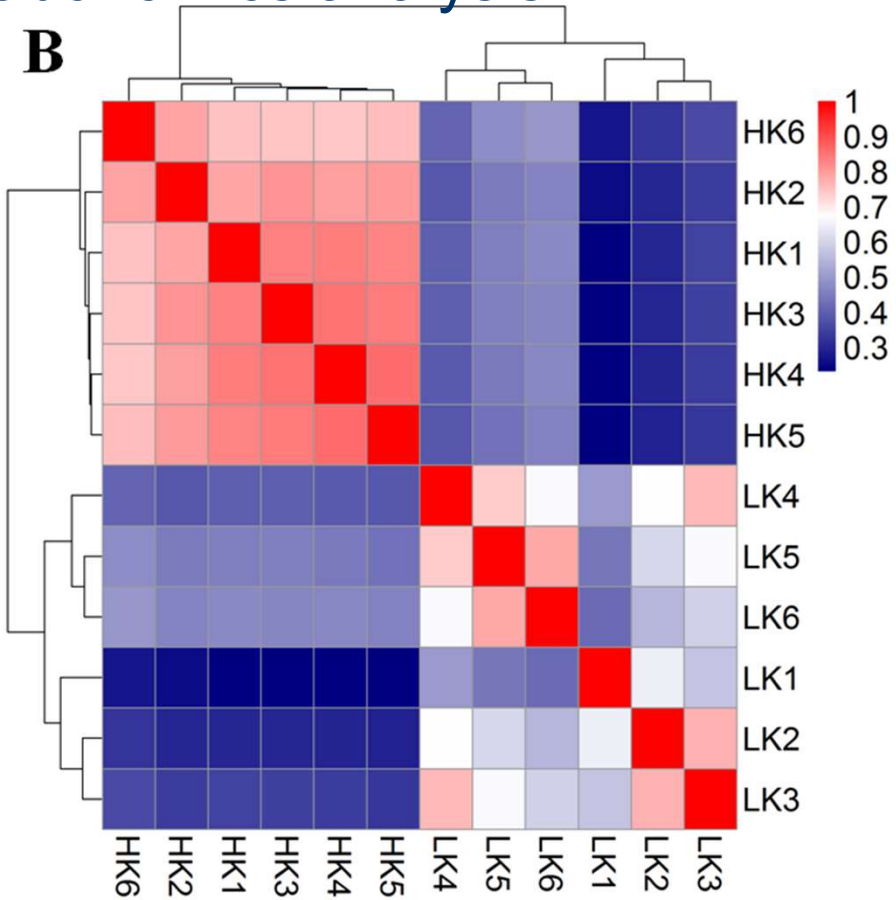
采样点	样品数	全氮 (g/kg)	全磷 (g/kg)	全钾 (g/kg)
田庄	44	21.84 ~ 25.80	1.01 ~ 2.97	6.15 ~ 12.21
桥山	35	10.15 ~ 23.12	1.19 ~ 4.73	6.87 ~ 10.86
隆纺	64	7.89 ~ 26.36	1.16 ~ 2.76	5.55 ~ 11.77
侯庄	35	10.62 ~ 23.98	1.15 ~ 2.45	5.90 ~ 12.26
仓村	57	1.1.74 ~ 25.69	1.19 ~ 3.30	6.44 ~ 12.59
太贤	45	11.76 ~ 24.78	1.16 ~ 2.35	8.96 ~ 10.32
阿党	24	21.66 ~ 25.20	1.19 ~ 3.25	8.69 ~ 13.00
平均值		21.96	1.81	9.24

(Guo et al 2015)

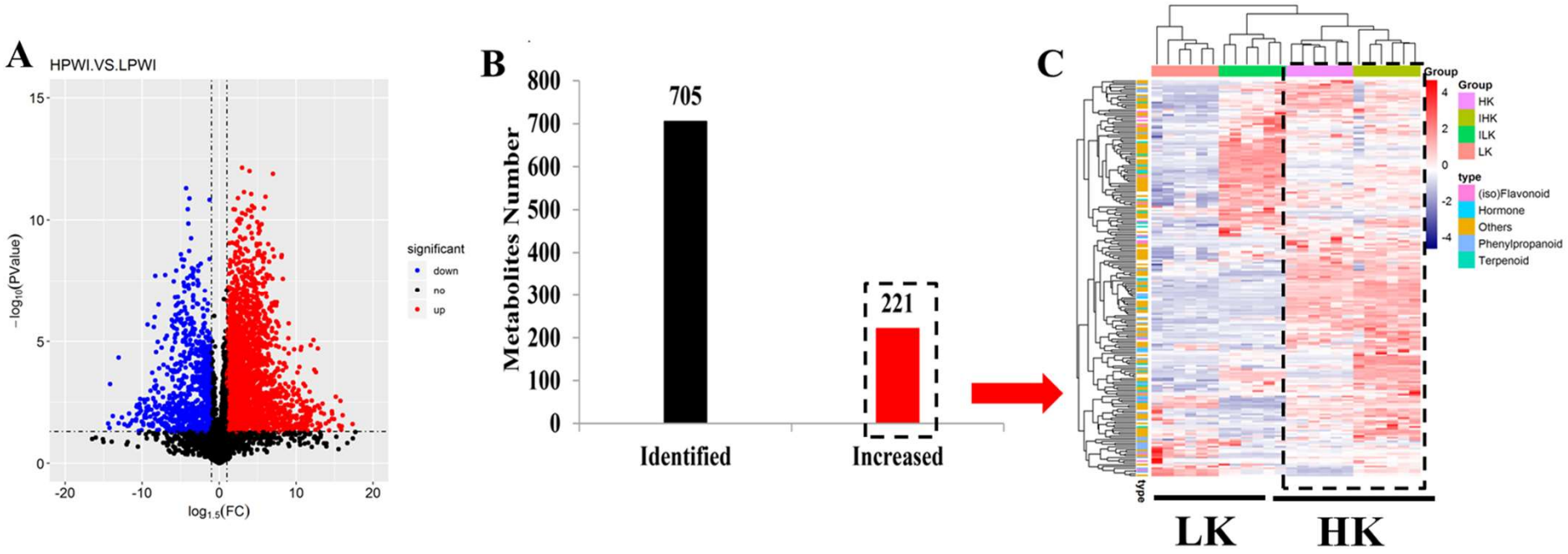
Why apple trees are resistant to Valsa canker in high potassium level?

Increasing K content in vivo has significant effect on the plant metabolism in metabonomics analysis.



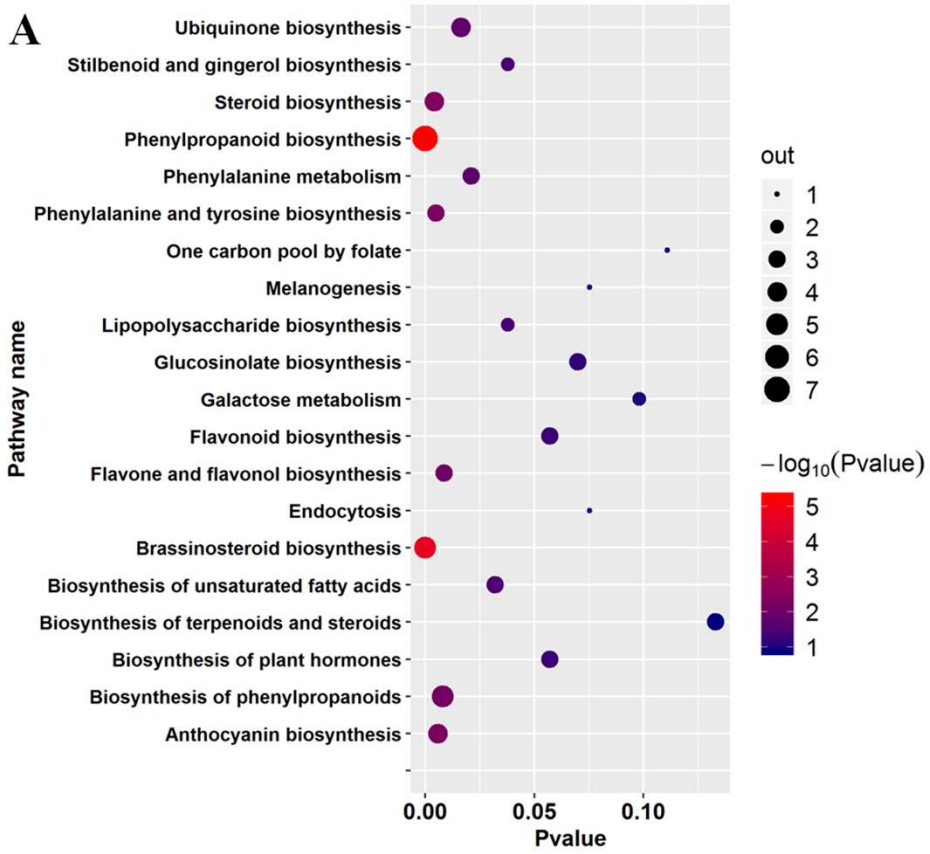


221 compounds were significantly increased under the condition of high content potassium



Most of 221 compounds identified were in the four key metabolic pathways: stilbenoid, phenylpropanoid, flavonoid and phenylalanine biosynthesis.

多数与钾相关化合物归属四个关键代谢物合成途径：二苯乙烯类、苯丙类、黄酮类、苯丙氨酸类



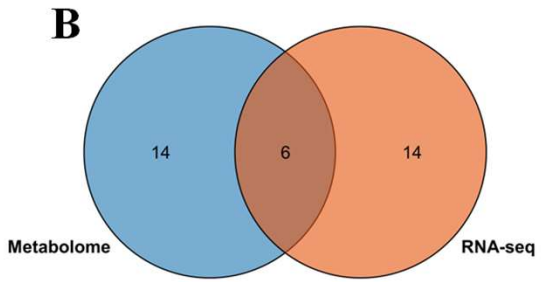
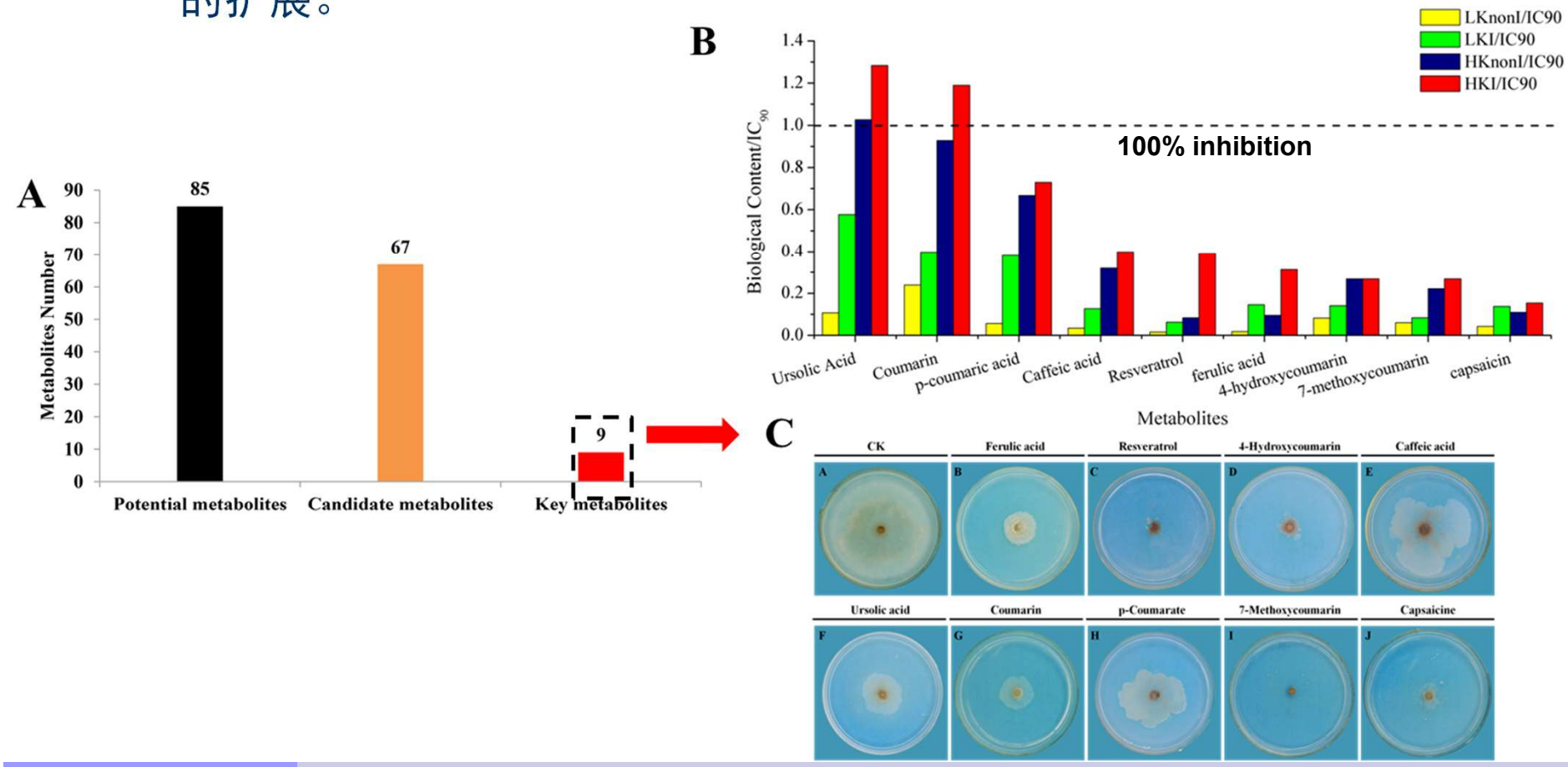


Table 1

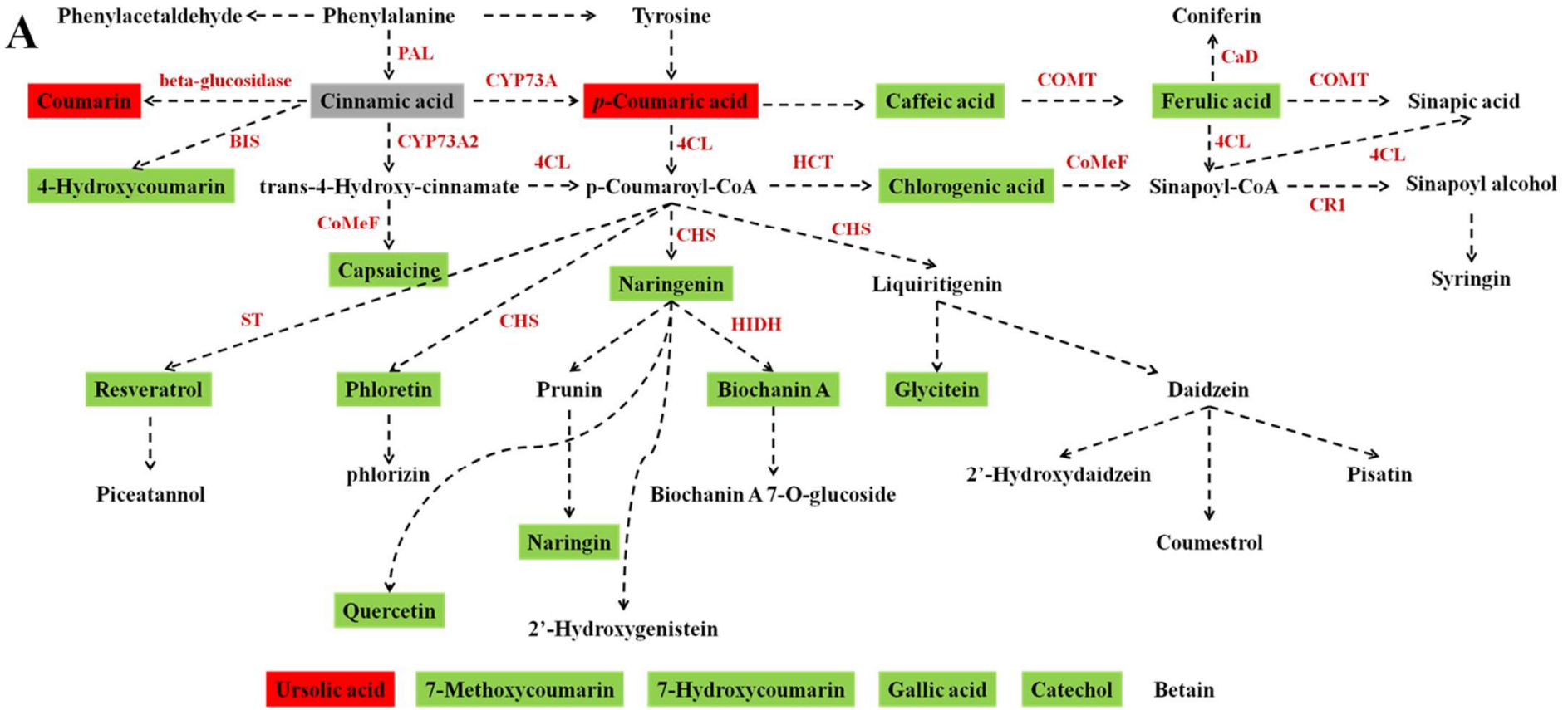
	RNA-seq		Metabolome	
Name	Out	Pvalue	Out	Pvalue
Stilbenoid and gingerol biosynthesis ▲	8	0.002	2	0.038
Endocytosis	17	0.071	1	0.075
Flavonoid biosynthesis ▲	8	0.026	3	0.057
Phenylalanine metabolism ▲	9	0.003	3	0.021
Phenylpropanoid biosynthesis ▲	36	7.184E-09	7	0.0000053
Brassinosteroid biosynthesis	4	0.051	5	0.0000199

For 67 candidate metabolites, 9 compounds had obvious antifungal activities in vitro, ursolic acid and coumarin could completely inhibit the colony growth of Vasa *mali* with its biological content.

乌索酸和香豆素可以在生物学含量下完全抑制腐烂病菌在皿内的扩展。



The synthesis of secondary metabolism can be activated by increasing the potassium content of plants.



Summary

- Potassium plays a significant role in Valsa canker resistance. Potassium deficient and the nutrient unbanlance could be the main reasons of Valsa canker epidemic in China.
- Apple trees with leaf K content greater than 1.3% exhibited almost complete resistance to *V. mali*.
- Improved K management could reduce or control the occurrence of Valsa canker efficiently.
- Potassium nutrition can activate the intrinsic immunity against apple Valsa Canker.

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