Vetiver grass as a trap plant for controlling rice stem borers in China

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Why need trap plants to control stem borers？

Most economically important rice insect pests in China

Stem borers

Planthoppers

Leaf folders

Overwinter in China

Could not overwinter in China, and migrate from SE Asian

Striped, Pink and Yellow stem borers , Brown and White backed planthoppers

WHY frequent outbreak of rice insect pests in China

- High rice yield practices
- High resistance to insecticides
- Low host resistance (hybrid rice)
- Low natural control functioning
- Low ecosystem services

Three reasons led outbreak of stem borers

(1) high resistance of stem borers to dominant insecticides

Year	Insecticide	Dose (g/ha)	Control efficiency (%)
2008	Chlorantraniliprole	150	90.2
2009	Chlorantraniliprole	150	91.4
	flubendiamide	150	92.5
2013	Chlorantraniliprole	150	56.5
	tetrachlorantraniliprole	600	51.3
2015	Chlorantraniliprole	225	16.8
	flubendiamide	225	51.2
	cyantraniliprole	300	59.3
2016	Chlorantraniliprole	300	21.4

Dominant insecticides (amides) fail to control rice stem borers

(2) High source of stem borers

because of returning rice straw to field

(3) **Higher larval survival of stem borers in winter season because of global warming**

The main methods to control stem borers

Reducing initial population size BY

- sex pheromone trap (male adults only）
- light trap (both of SBs and NEs)
- trap plants (vetiver, long-term use)

Reforming and worsening environment

- resistant plants (no resistant gene)
- smart management of water & fertilizer

Improving natural control by NEs

- conservation bio-control
- releasing trichogramma parasitoid

Precise application of pesticides

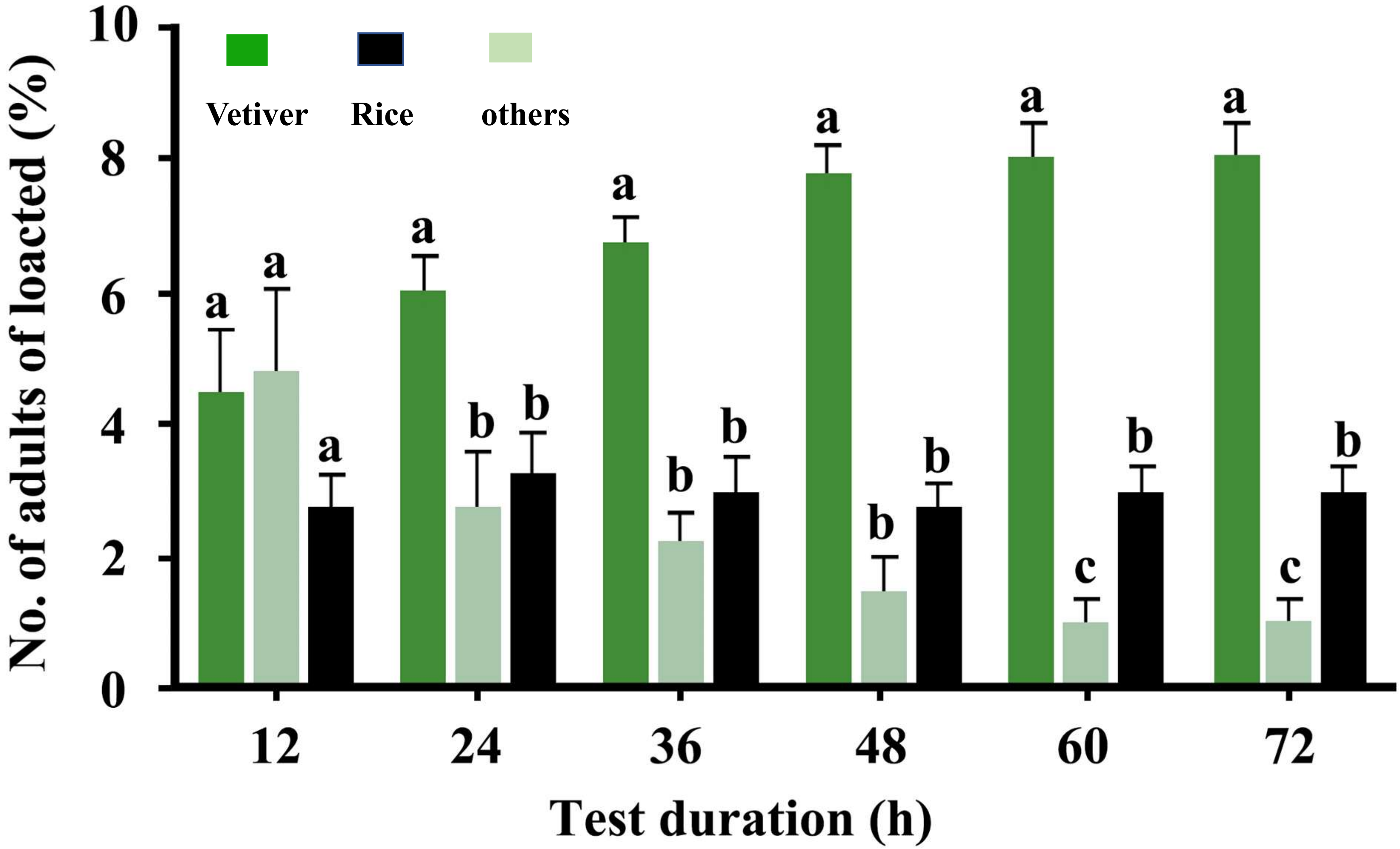
- bio-insecticides
- low eco-risk insecticides

Two

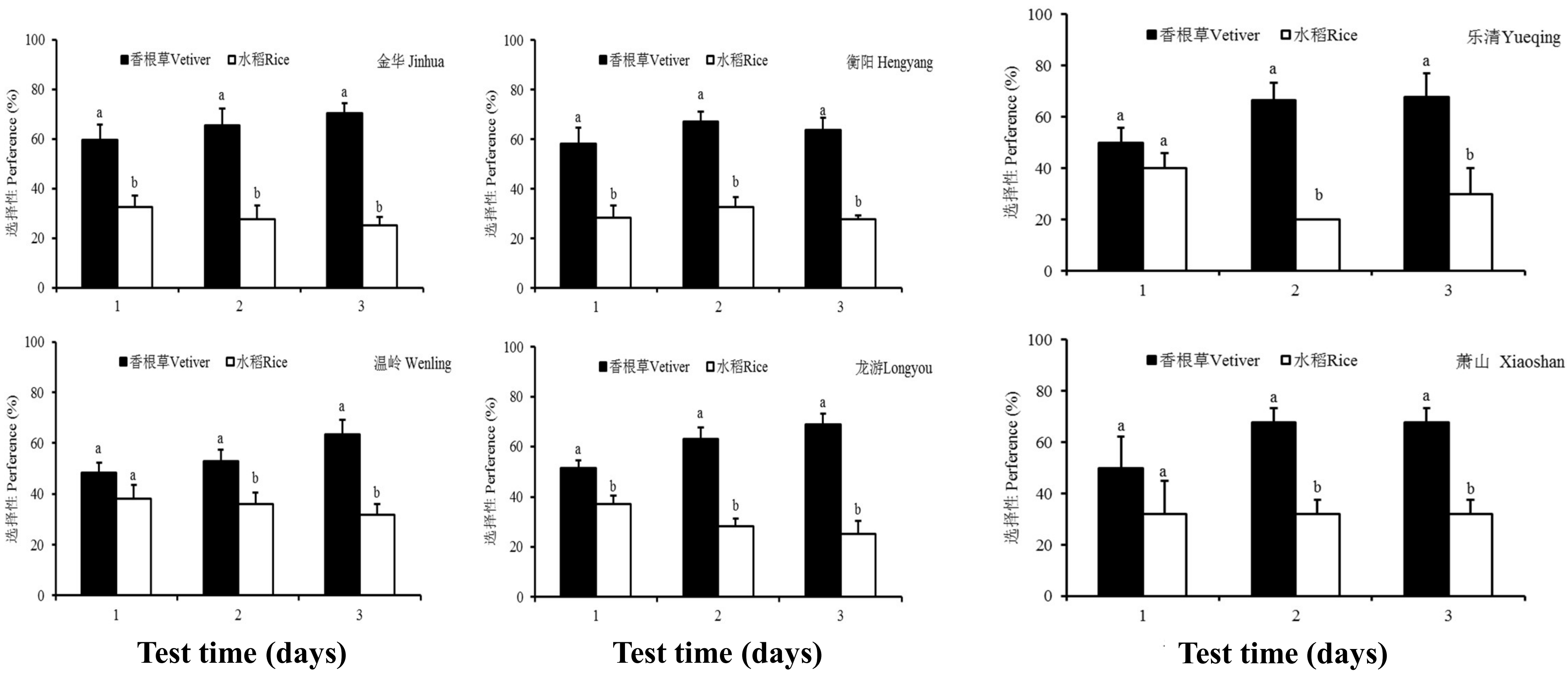
How to work of vetiver as a trap plants ?

Vetiver as a trap plant for the control of rice stem borers

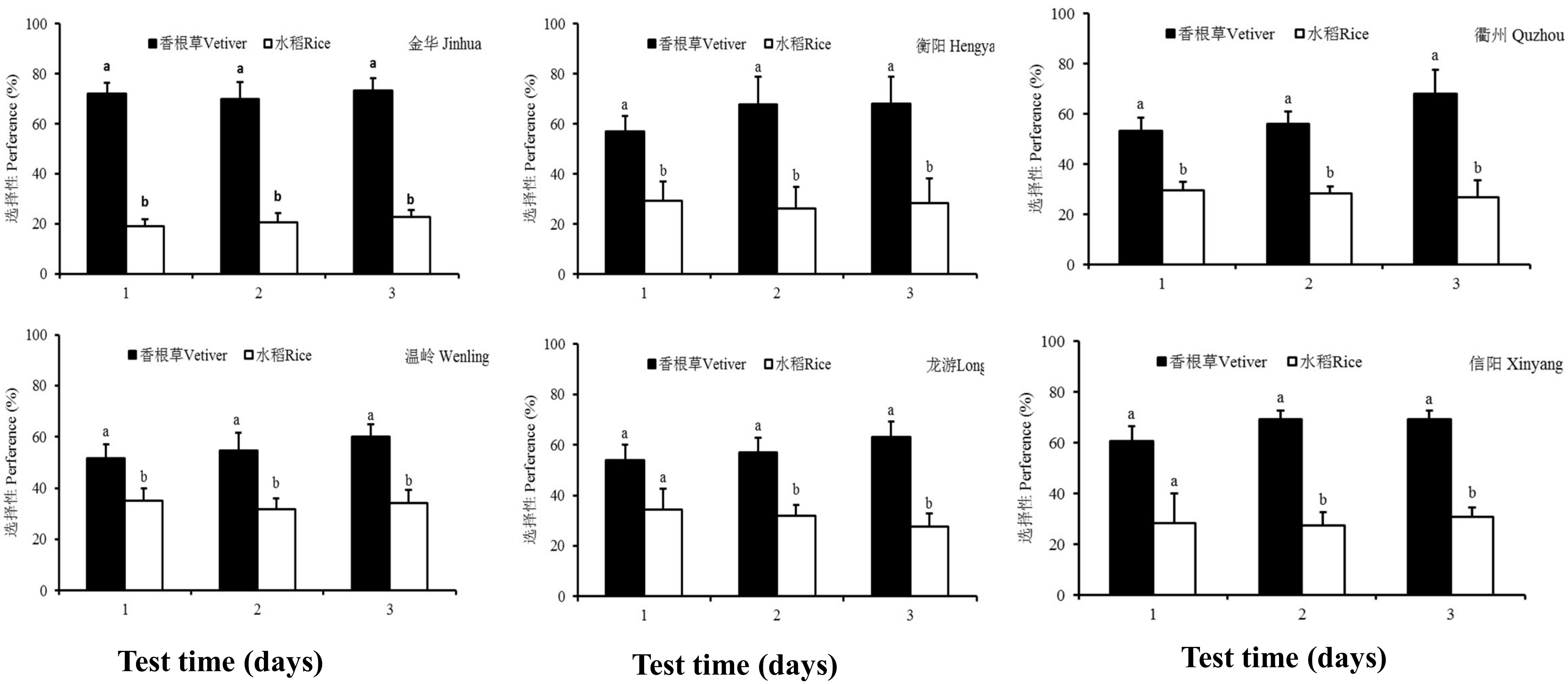
Random selection of striped stem borer (SSB) to host plants



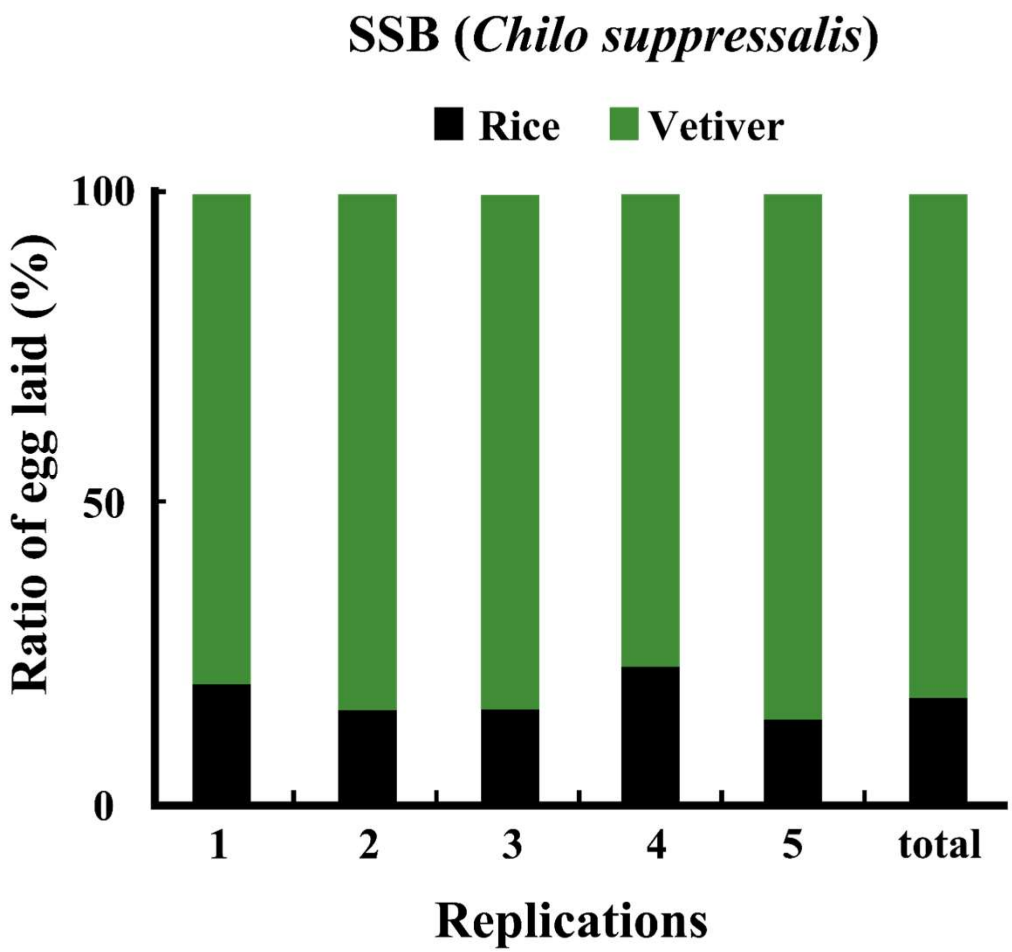
Selection of SSB females of different geographical populations to rice and vetiver

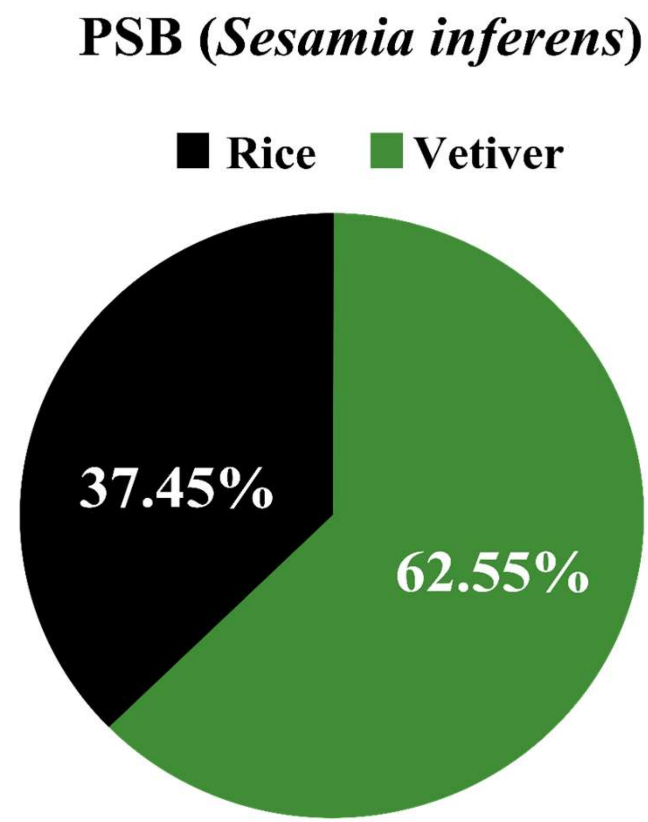


Selection of SSB males of different geographical populations to rice and vetiver



Vetiver attracts stem borers to lay eggs





Number of SSB eggs of different geographical populations laid on rice and vetiver

Populations	Ratio of egg laid（%）	
	Vetiver	Rice
Jinhua, Zhejiang	62.94±3.74 a	37.06±3.74 b
Hengyang, Hunan	70.01±10.10 a	29.99±10.10 b
Quzhou, Zhejiang	60.71±2.12 a	39.29±2.12 b
Yueqing, Zhejiang	68.98±3.90 a	31.02±3.90 b
Xinyang, Henan	62.50±3.24 a	37.50±3.24 b
Xiaoshan, Zhejiang	61.51±0.84 a	38.49±0.84 b

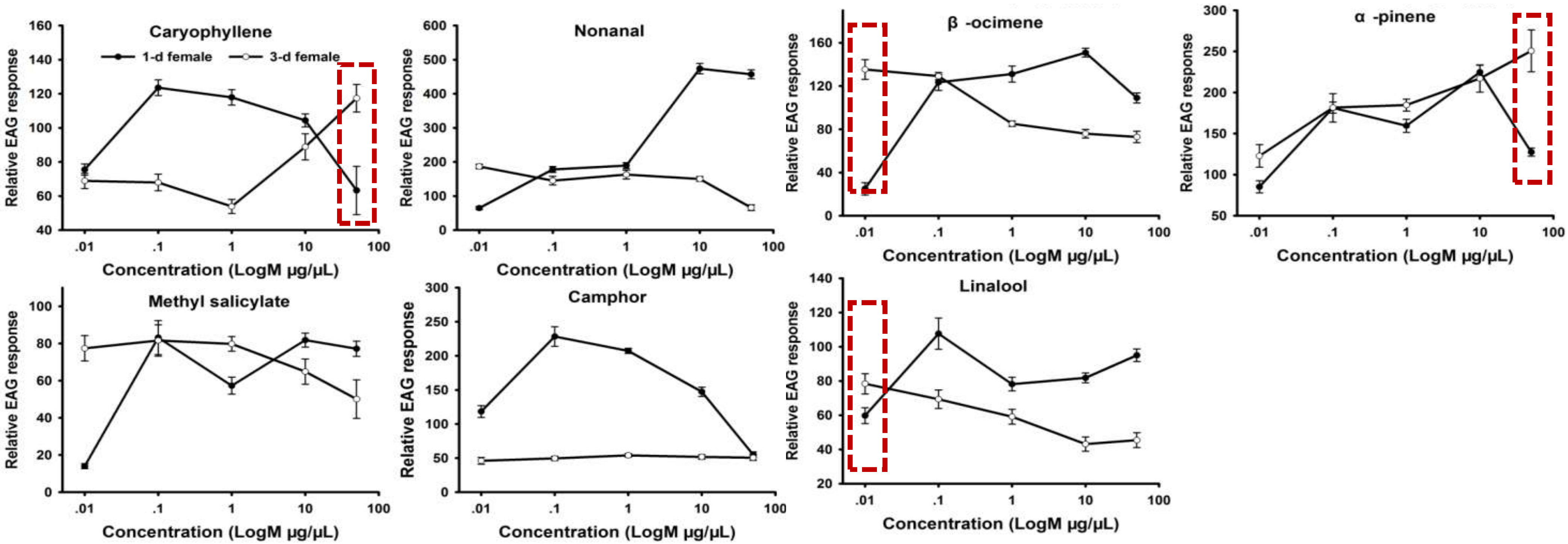
Volatiles from vetiver at different growth stages

Compounds	Growth stages of vetiver		
	40 days	60 days	80 days
顺式-3-己烯-1-醇（cis-3-hexen-1-ol）	2.67±1.09 a	2.89±1.49 a	2.95±1.02 a
α-蒎烯（α-pinene）	0.16±0.03 a	0.26±0.13 a	0.25±0.14 a
壬醛（nonanal）	35.83±8.81 a	48.53±15.16 a	49.51±16.57 a
杜烯（durene）	1.95±0.66 a	2.27±1.01 a	2.66±0.50 a
7-十五酮（7-pentadecanone）	3.95±1.25 a	5.12±2.51 a	4.79±0.96 a
樟脑（camphor）	1.75±0.61 a	2.45±0.62 a	2.65±0.18 a
薄荷醇（menthol）	5.08±1.50 a	9.48±2.05 a	8.45±1.98 a
萘（naphthaline）	3.70±1.66 a	2.68±0.66 a	3.76±1.06 a
癸醛（decanal）	2.85±1.05 a	3.20±1.57 a	3.21±1.08 a
1-甲基萘（1-methylnaphthalene）	16.44±9.43 a	13.09±2.70 a	14.81±5.16 a
2-甲基萘（2-methylnaphthalene）	0.83±0.15 a	1.32±0.66 a	0.98±0.30 a
甲基丙酸酯（dimethylpropyl ester	4.96±1.48 a	5.20±1.68 a	7.45±4.22 a
十四烷（n-tetradecane）	14.58±2.55 b	15.19±2.59 b	31.62±7.22 a
长叶烯（longifolene）	1.14±0.27 a	0.96±0.64 a	1.53±0.79 a
α-雪松烯（α-cedrene）	53.19±12.76 a	79.93±23.04 a	63.42±27.90 a
β-雪松烯（β-cedrene）	18.64±2.66 a	23.77±10.01 a	21.49±9.30 a
十五烷（n-pentadecane）	6.49±0.04 a	6.85±1.38 a	7.65±0.49 a
四甲基-1-十六烷醇（tetramethylhexadecane）	8.80±1.77 a	17.86±7.13 a	10.55±2.01 a
十六烷（n-hexadecane）	14.91±3.16 a	23.06±12.52 a	16.84±4.33 a
柏木脑（cedrol）	3.77±0.46 a	3.64±0.84 a	3.42±1.69 a
十七烷（n-heptadecane）	69.59±27.91 a	73.73±8.22 a	90.55±47.82 a
十二烷醇（dodecanol）	7.13±1.57 a	4.61±3.38 a	8.37±4.57 a
去甲植烷（pristane）	30.05±17.05 a	37.38±13.78 a	38.33±19.40 a

Volatiles from vetiver at different N regimes

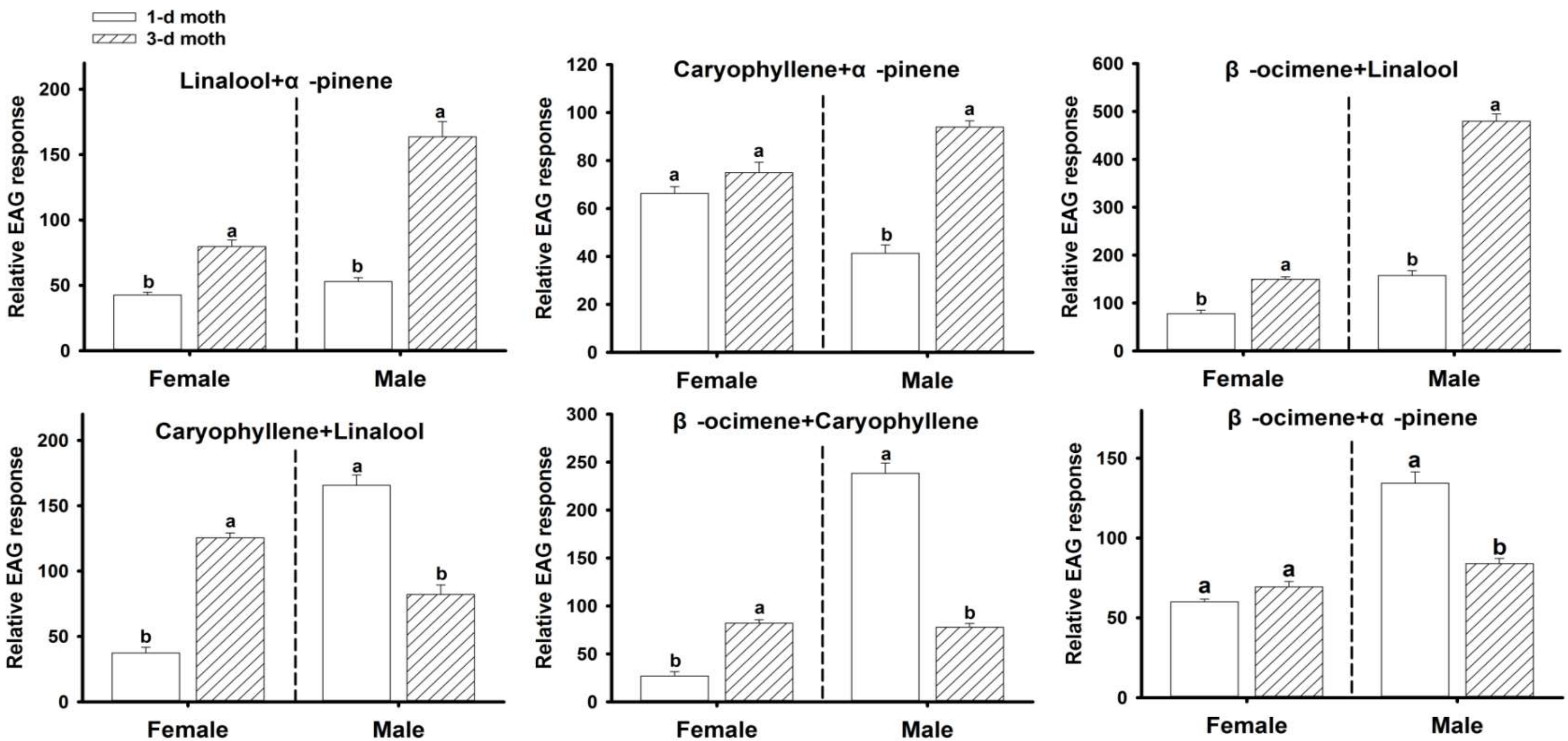
Volatiles	N applied（g/cluster）		
	0	10	20
顺式-3-己烯-1-醇（cis-3-hexen-1-ol）	2.10±0.84 a	4.36±1.01 a	5.64±2.19 a
α-蒎烯（α-pinene）	2.89±0.27 a	2.41±0.14 ab	1.74±0.63 b
壬醛（nonanal）	40.51±13.08 a	26.42±3.98 ab	22.63±6.07 b
杜烯（durene）	1.53±0.76 a	3.41±1.02 a	4.53±1.80 a
7-十五酮（7-pentadecanone）	3.24±0.03 a	3.90±1.22 a	3.43±0.70 a
樟脑（camphor）	6.13±1.29 a	2.70±1.48 a	3.24±2.27 a
薄荷醇（menthol）	8.98±0.93 a	5.99±1.95 a	5.57±3.78 a
萘（naphthaline）	1.13±0.67 a	1.87±0.36 a	3.04±0.56 a
癸醛（decanal）	2.37±0.60 a	4.40±1.13 a	6.17±2.56 a
1-甲基萘（1-methylnaphthalene）	20.12±1.77 a	29.32±13.01 a	20.71±6.28 a
2-甲基萘（2-methylnaphthalene）	0.95±0.05 a	1.27±0.62 a	1.16±0.35 a
2-甲基丙酸酯 dimethylpropyl ester	7.34±4.31 a	7.26±0.36 a	7.57±2.05 a
十四烷（n-tetradecane）	9.06±6.47 a	15.60±8.64 a	6.21±1.65 a
长叶烯（longifolene）	0.71±0.30 a	0.98±0.42 a	0.65±0.35 a
α-雪松烯（α-cedrene）	42.67±2.95 a	53.19±30.61 a	32.03±10.05 a
β-雪松烯（β-cedrene）	12.84±0.74 a	17.02±9.67 a	14.97±7.43 a
十五烷（n-pentadecane）	5.57±0.70 a	6.07±1.82 a	5.22±1.55 a
十六烷醇tetramethylhexadecane	10.10±0.90 a	8.81±1.53 a	12.13±3.87 a
十六烷（n-hexadecane）	19.08±1.24 a	21.84±9.65 a	18.58±4.53 a
柏木脑（cedrol）	1.88±0.12 b	5.46±1.55 a	4.11±1.19 a
十七烷（n-heptadecane）	92.67±18.73 a	118.70±22.36 a	93.68±17.97 a
三甲基-1-十二烷醇（trimethyl-1-dodecanol）	3.96±1.87 a	5.38±1.55 a	2.43±2.09 a
去甲植烷（pristane）	27.80±23.70 a	29.57±7.28 a	29.96±7.30 a

EAG responses of female adult antennae to volatiles



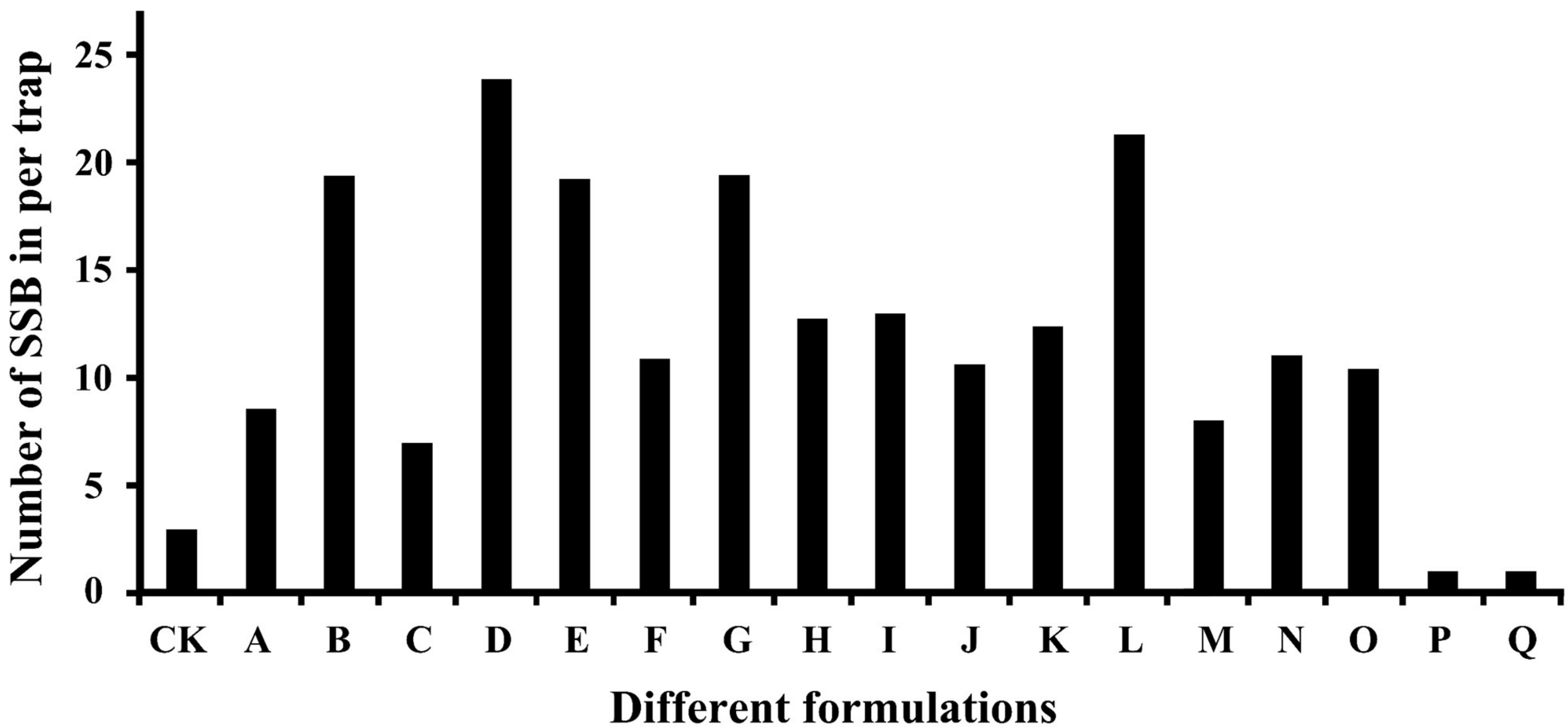
Concentration：0.01， 0.1， 1， 10， 50 μg/ μL

EAG responses to volatile combinations

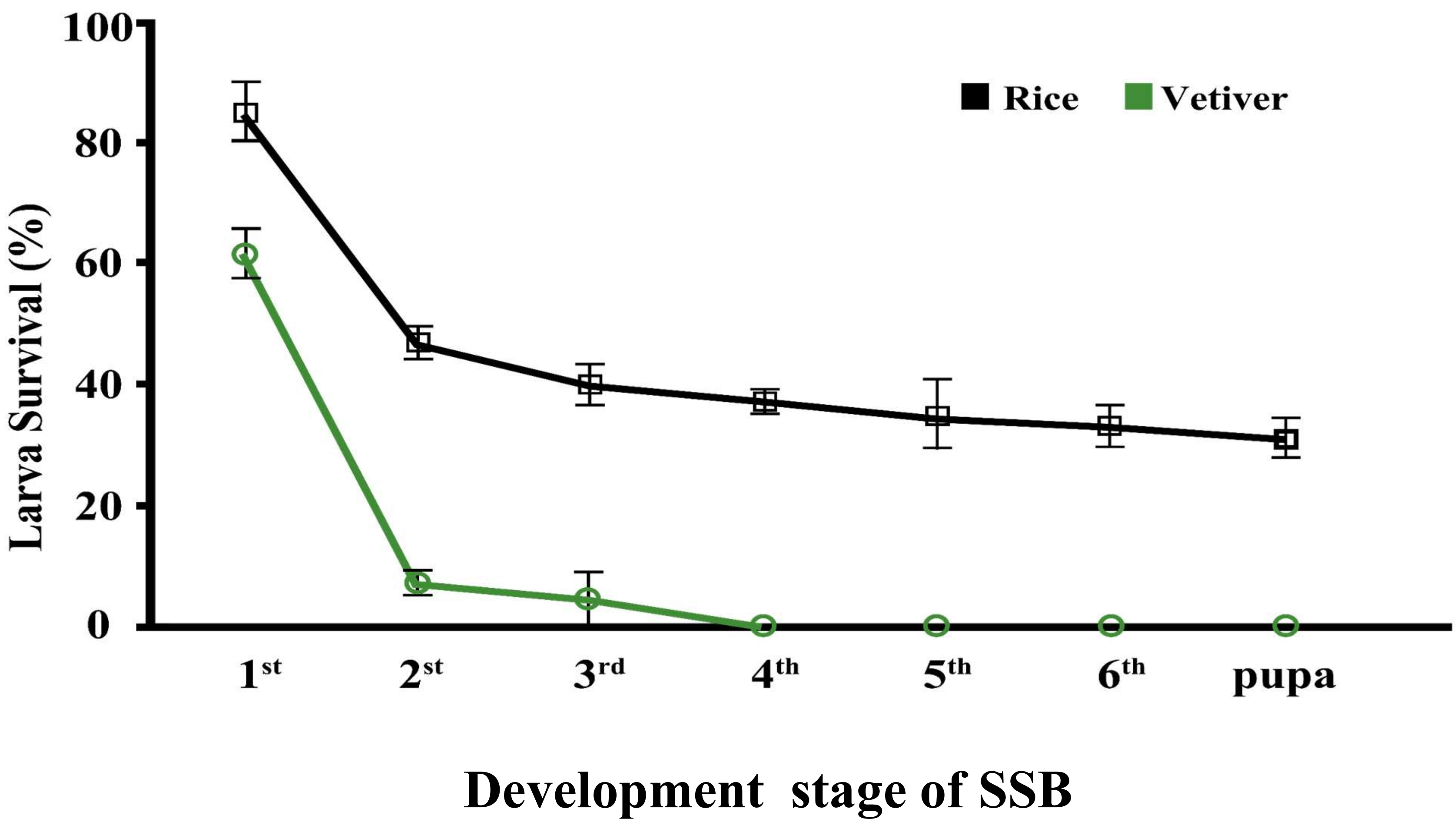


Testing volatile formulas in rice fields

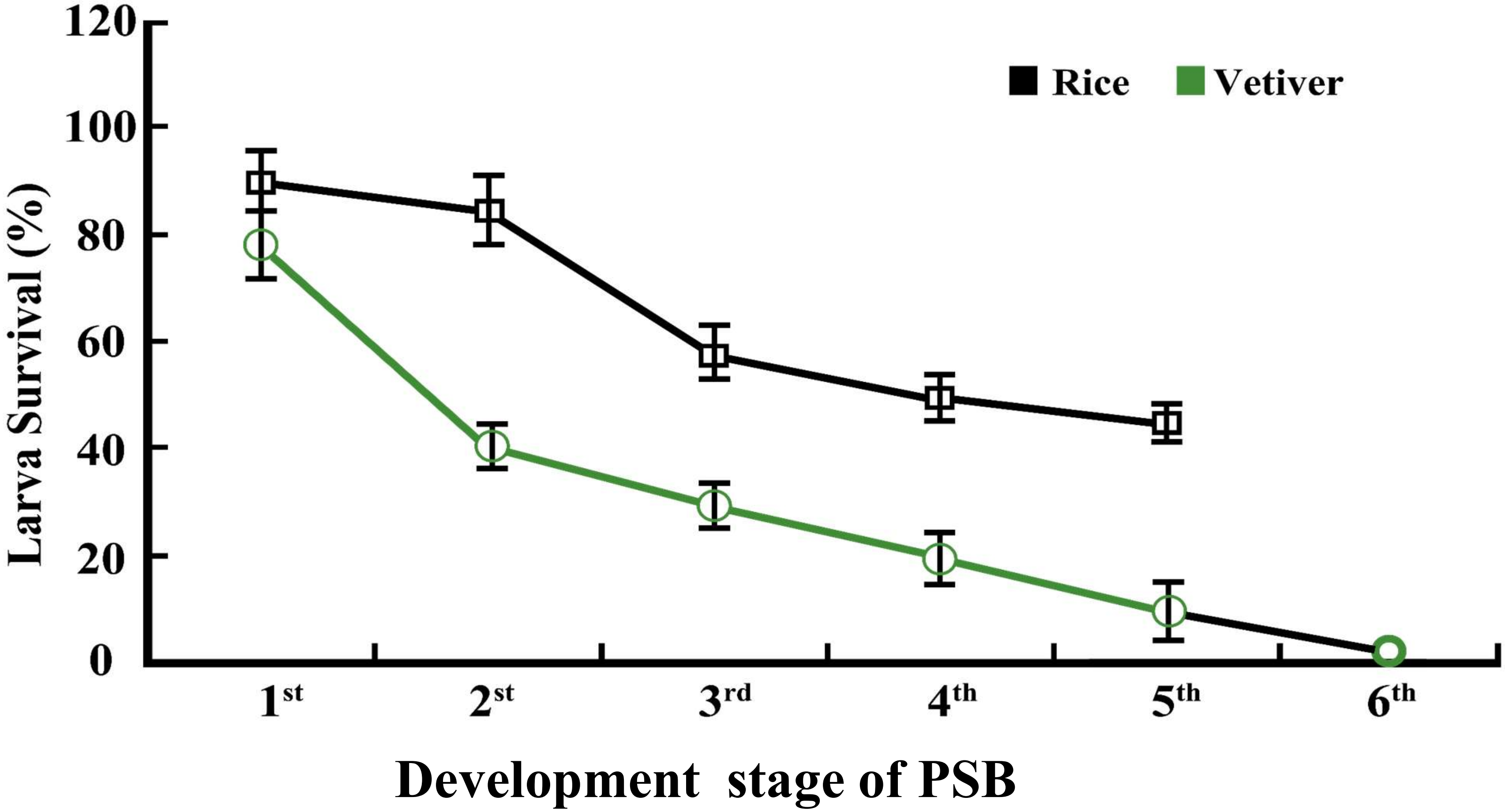
Adults trapped by different combination formula of vetiver volatiles



SSB could not complete life history on vetiver

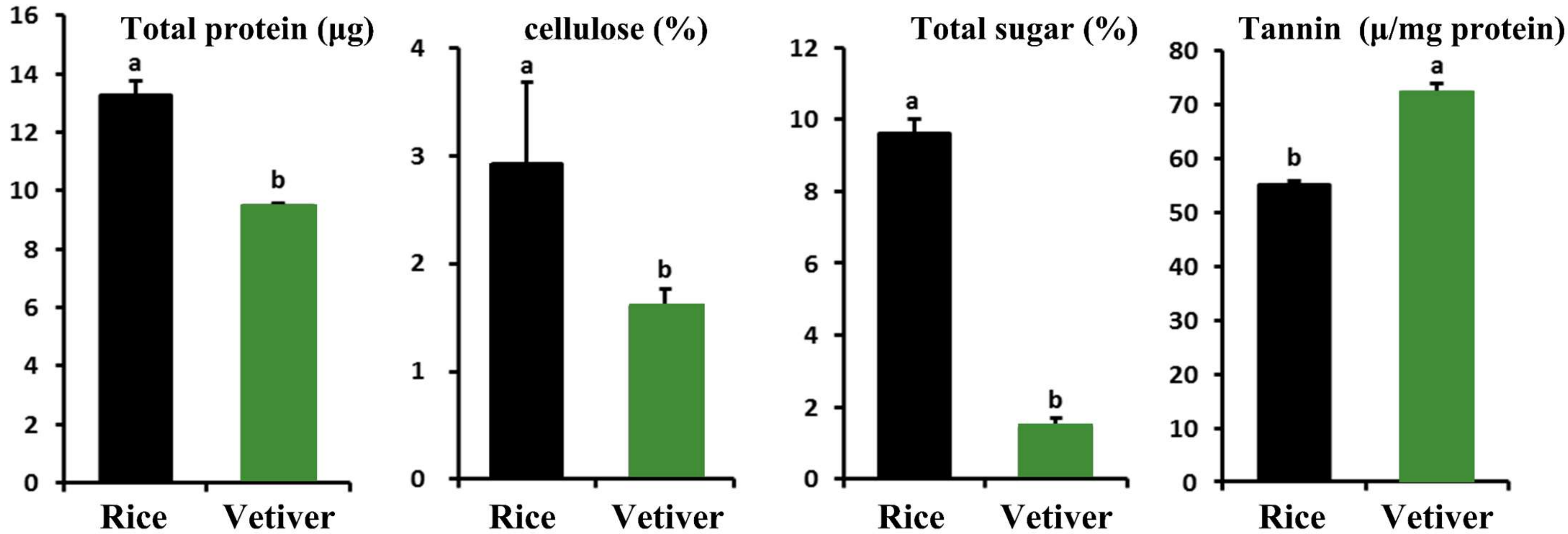


PSB survival fed on rice and vetiver



Nutritional factors in rice and vetiver plants

The content of nutrients such as total protein, cellulose and total sugar in vetiver is significantly lower than those in rice. The toxic substance tannin in vetiver is significantly higher than that in rice.

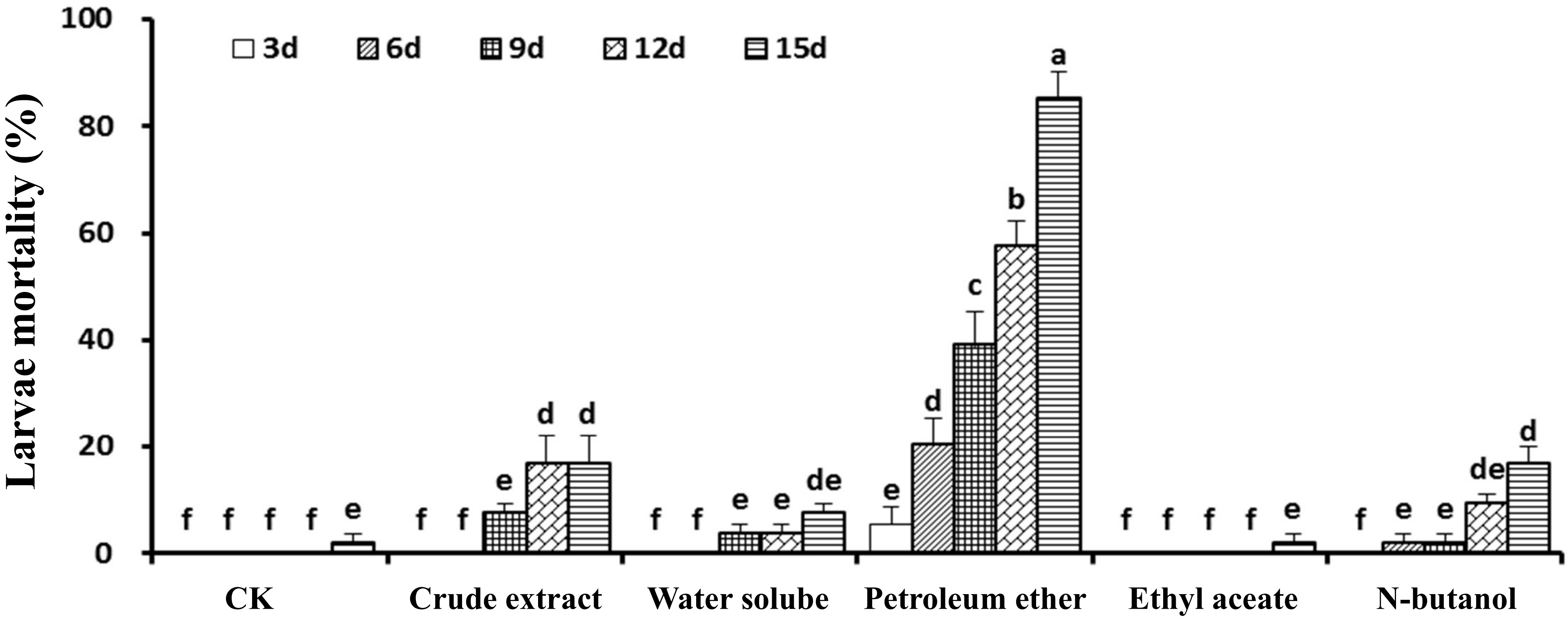


Therefore, the nutrients of vetiver grass are scarce compared with rice, and the larvae of stem borers feeding on vetiver with unbalanced nutrition, thus affecting the activity of digestive enzymes in the body, causing digestive disorders and eventually death.

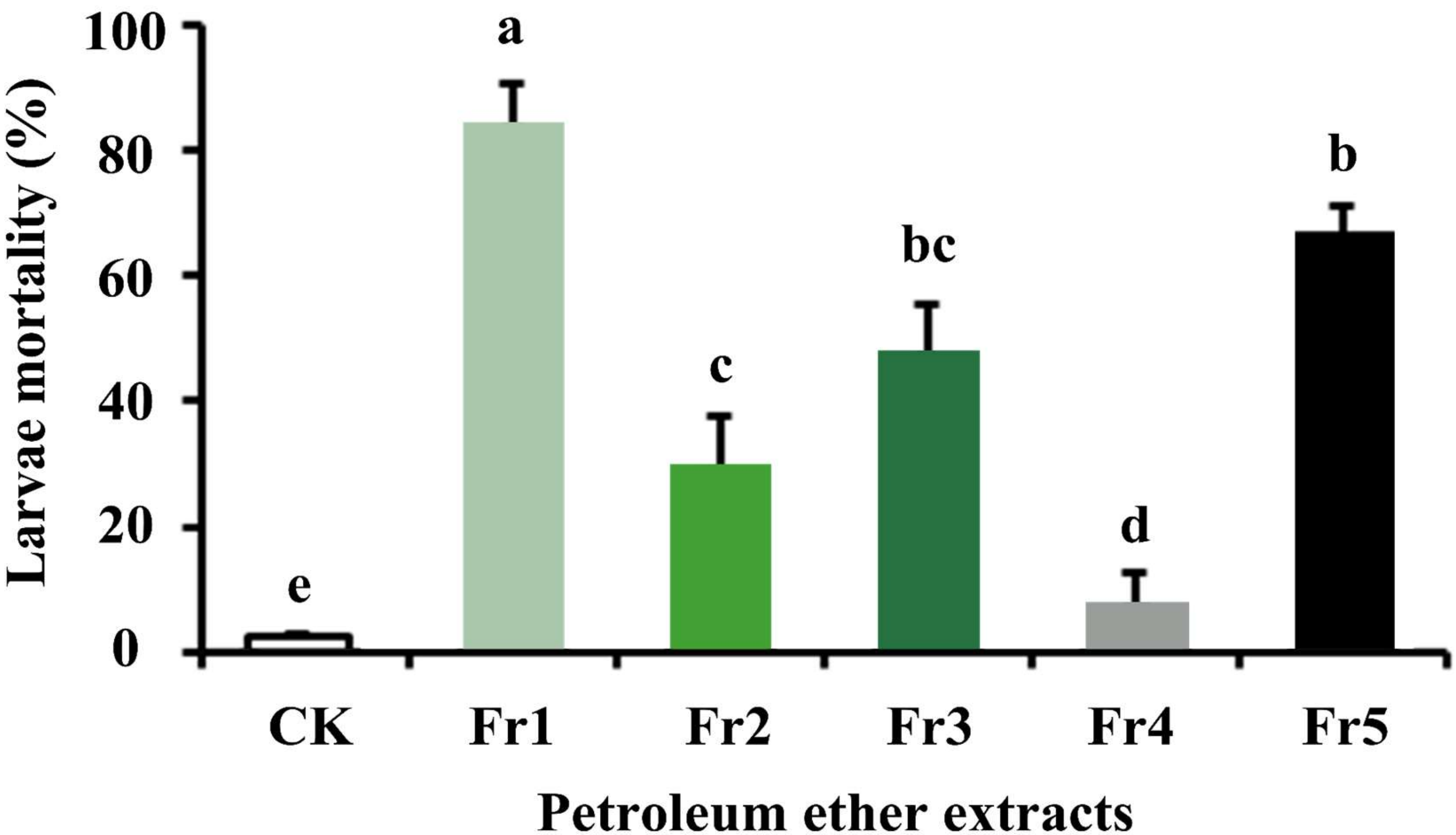
Amino acids in rice and vetiver plants

Amino acids	Content of amino acid（%）		Rice/Vetiver
	Rice	Vetiver	
ASP	1.86±0.04 a	0.59±0.10 b	3.15
THR	0.69±0.03 a	0.20±0.02 b	3.45
SER	0.76±0.06 a	0.23±0.03 b	3.30
GLU	2.10±0.11 a	0.52±0.06 b	4.04
PRO	0.68±0.02a	0.21±0.02 b	3.24
GLY	0.82±0.06 a	0.24±0.03 b	3.42
ALA	1.09±0.07 a	0.30±0.04 b	3.63
VAL	0.86±0.03 a	0.24±0.03 b	3.58
MET	0.14±0.00 a	0.02±0.00 b	7.00
ILE	0.63±0.03 a	0.17±0.03 b	3.71
LEU	1.28±0.08 a	0.34±0.05 b	3.76
TYR	0.34±0.04 a	0.09±0.01 b	3.78
PHE	0.78±0.06 a	0.22±0.02 b	3.55
HIS	0.53±0.01 a	0.21±0.04 b	2.52
LYS	0.91±0.06 a	0.29±0.04 b	3.14

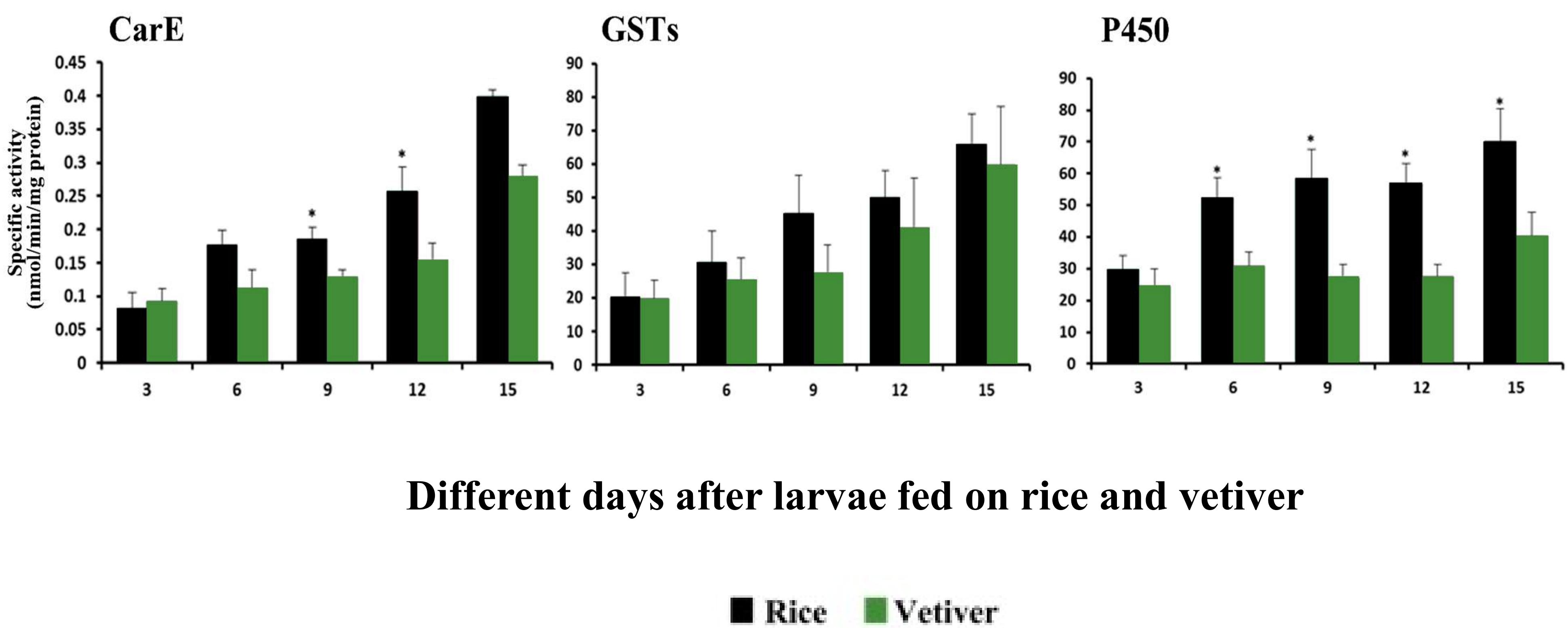
Insecticidal activity of extracts from vetiver plant with different solvents



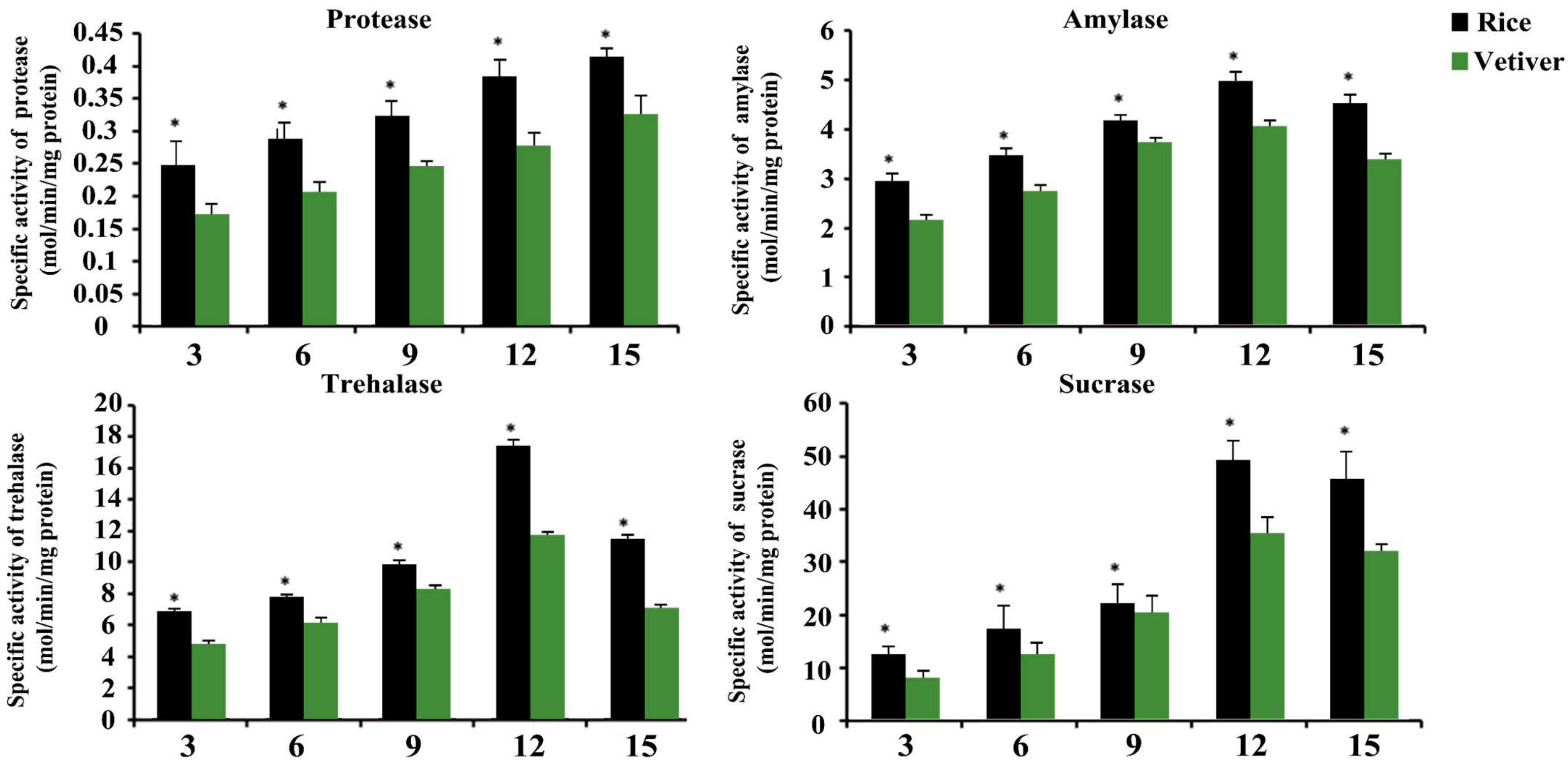
Insecticidal substances in petroleum ether extracts of vetiver



Detoxifying enzymes of SSB fed on rice and vetiver

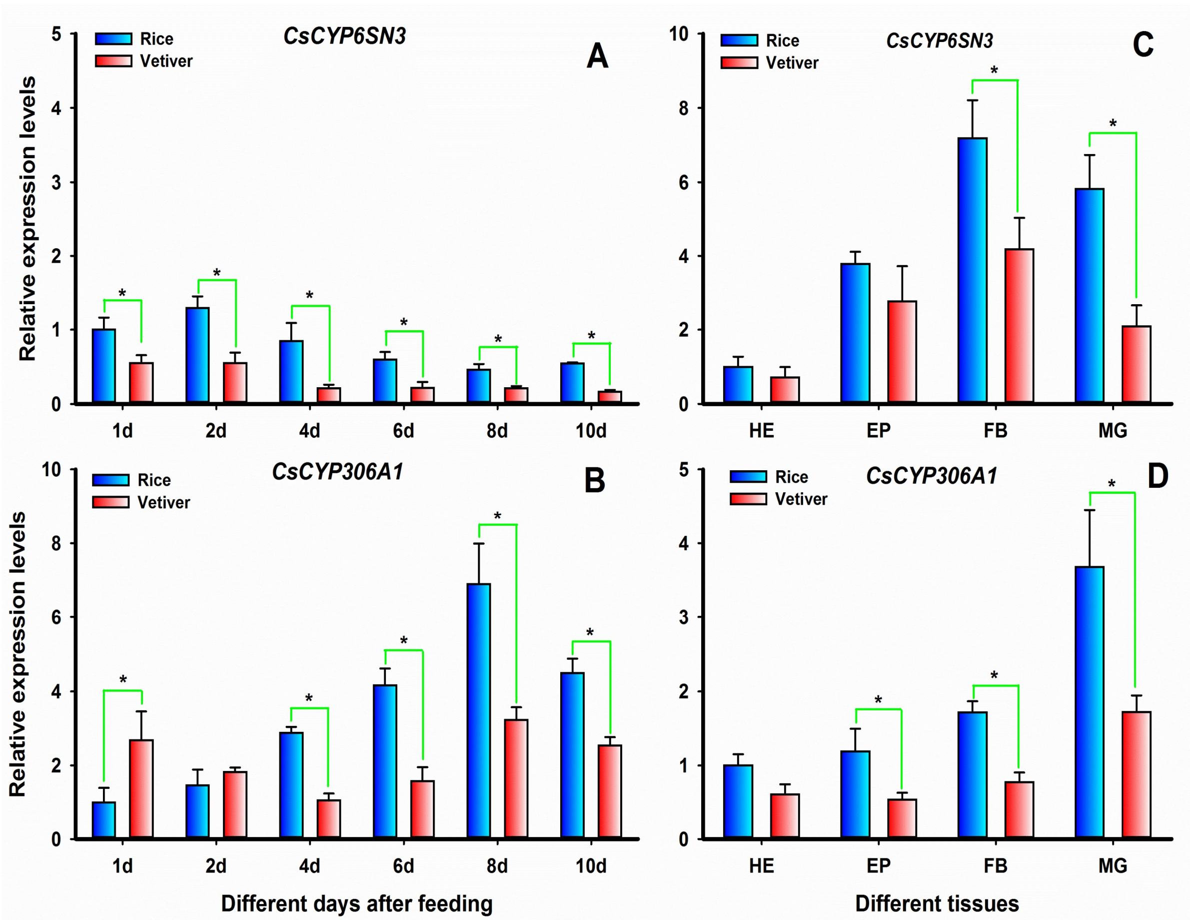


Digestive enzymes of SSB fed on rice and vetiver



Different days after larvae fed on rice and vetiver

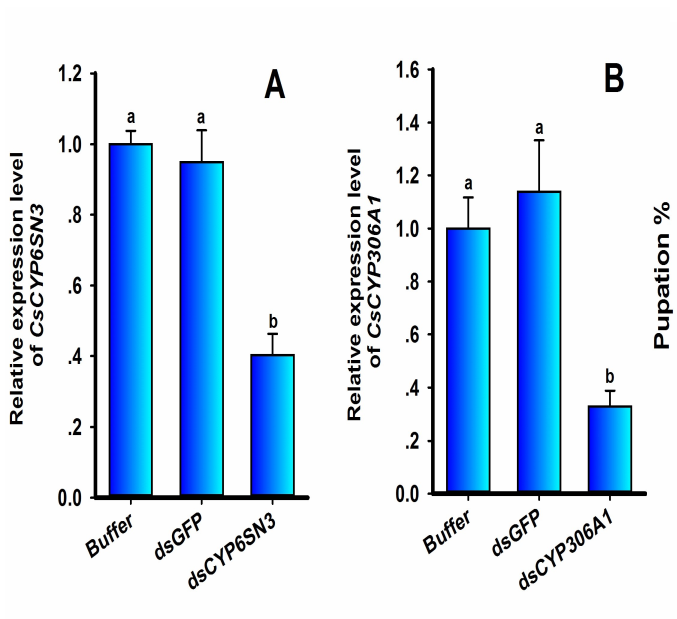
CYP6SN3 and *CYP306A1* involved in the lethal effect of SSB caused by vetiver grass

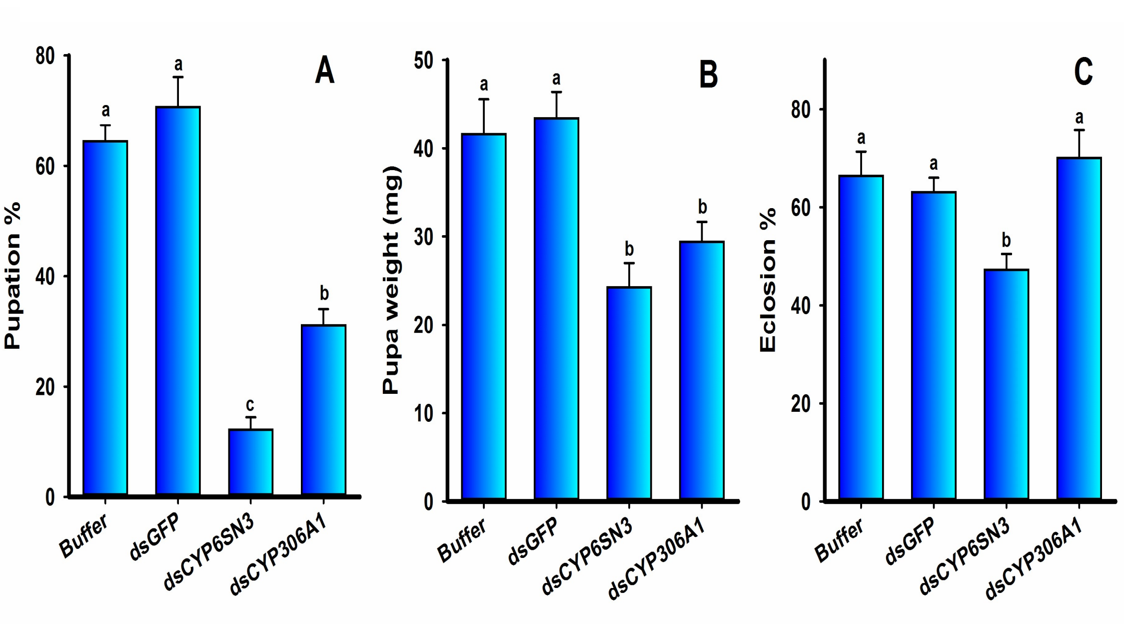


The expression levels of *CsCYP6SN3* and *CsCYP306A1* in 3rd larvae of SSB (*Chilo suppressalis*) were significantly inhibited after feeding on vetiver.

(Lu et al., IJBM, 2022)

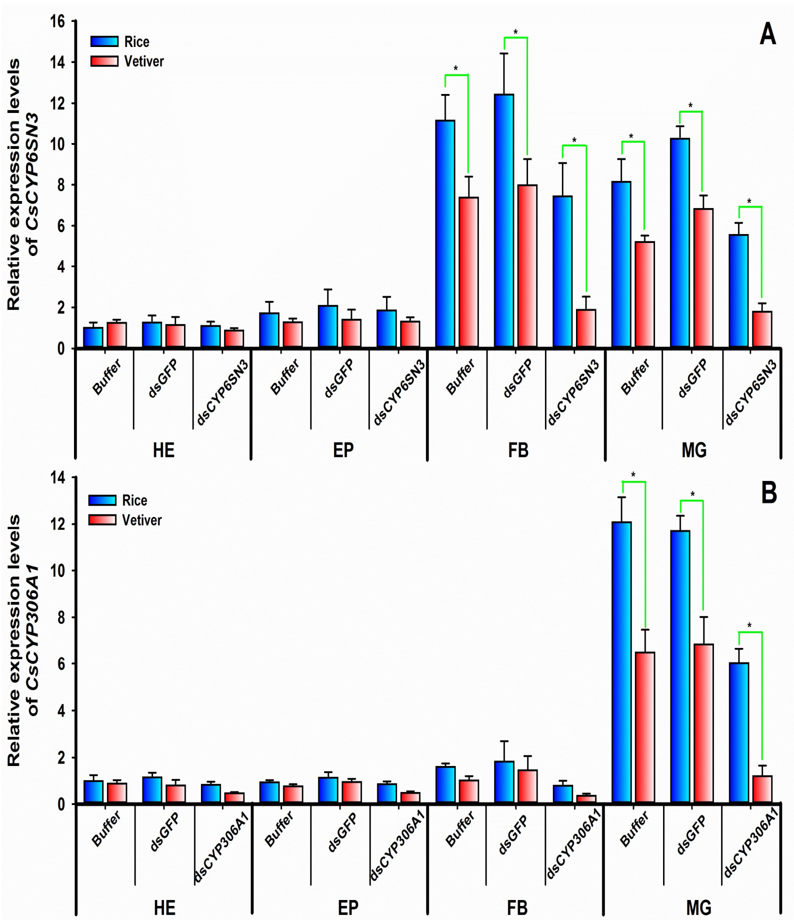
CYP6SN3 and *CYP306A1* involved in the lethal effect of SSB caused by vetiver grass

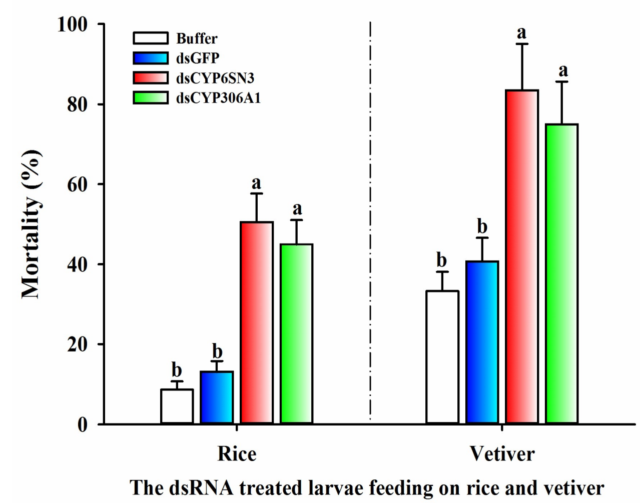




RNA interference showed that silencing *CsCYP6SN3* and *CsCYP306A1* genes dramatically reduced the pupation rate and pupa weight.

CYP6SN3 and *CYP306A1* involved in the lethal effect of SSB caused by vetiver grass



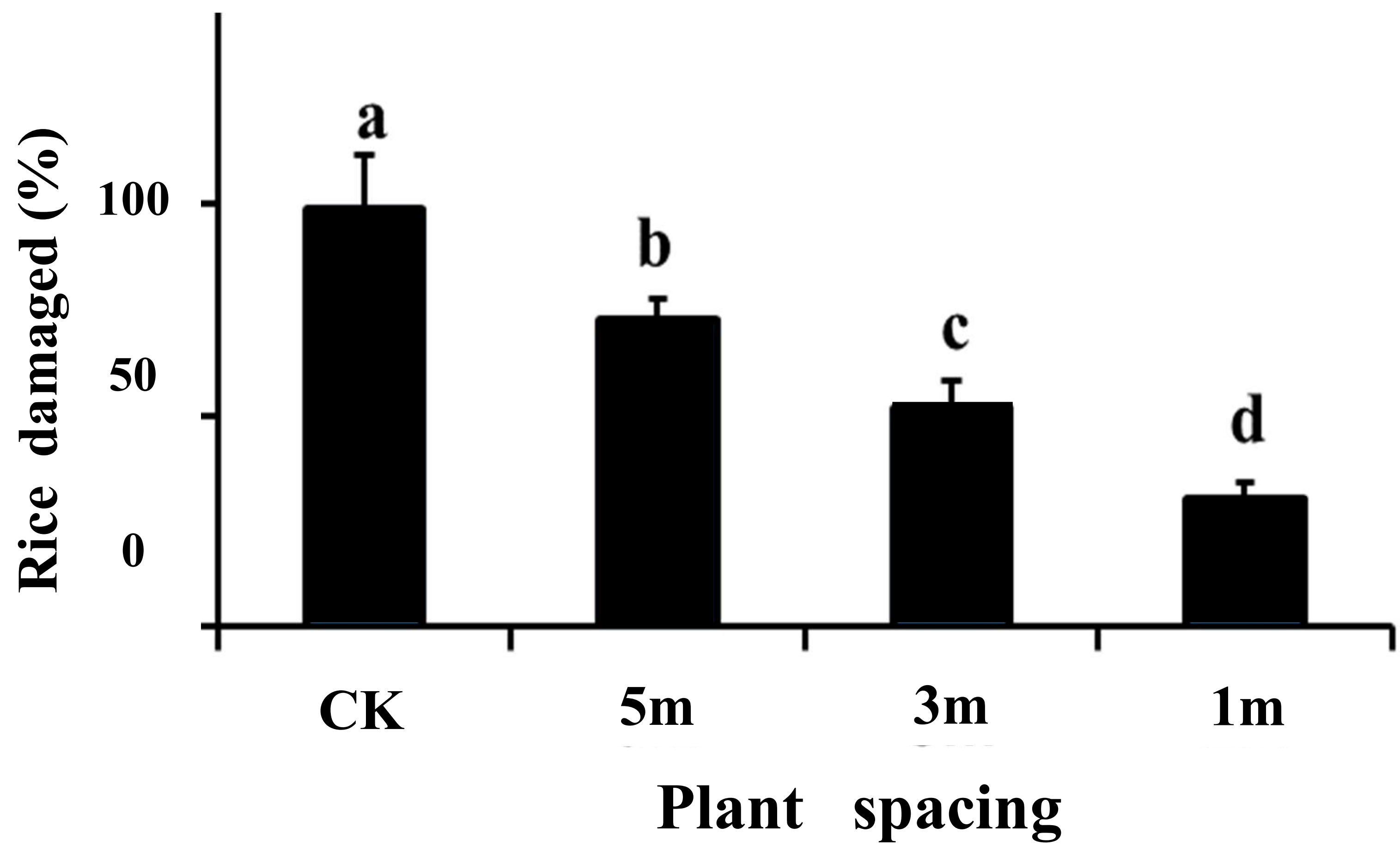


Feeding on vetiver after silencing *CsCYP6SN3* and *CsCYP306A1* led to higher mortality compared with feeding on rice.

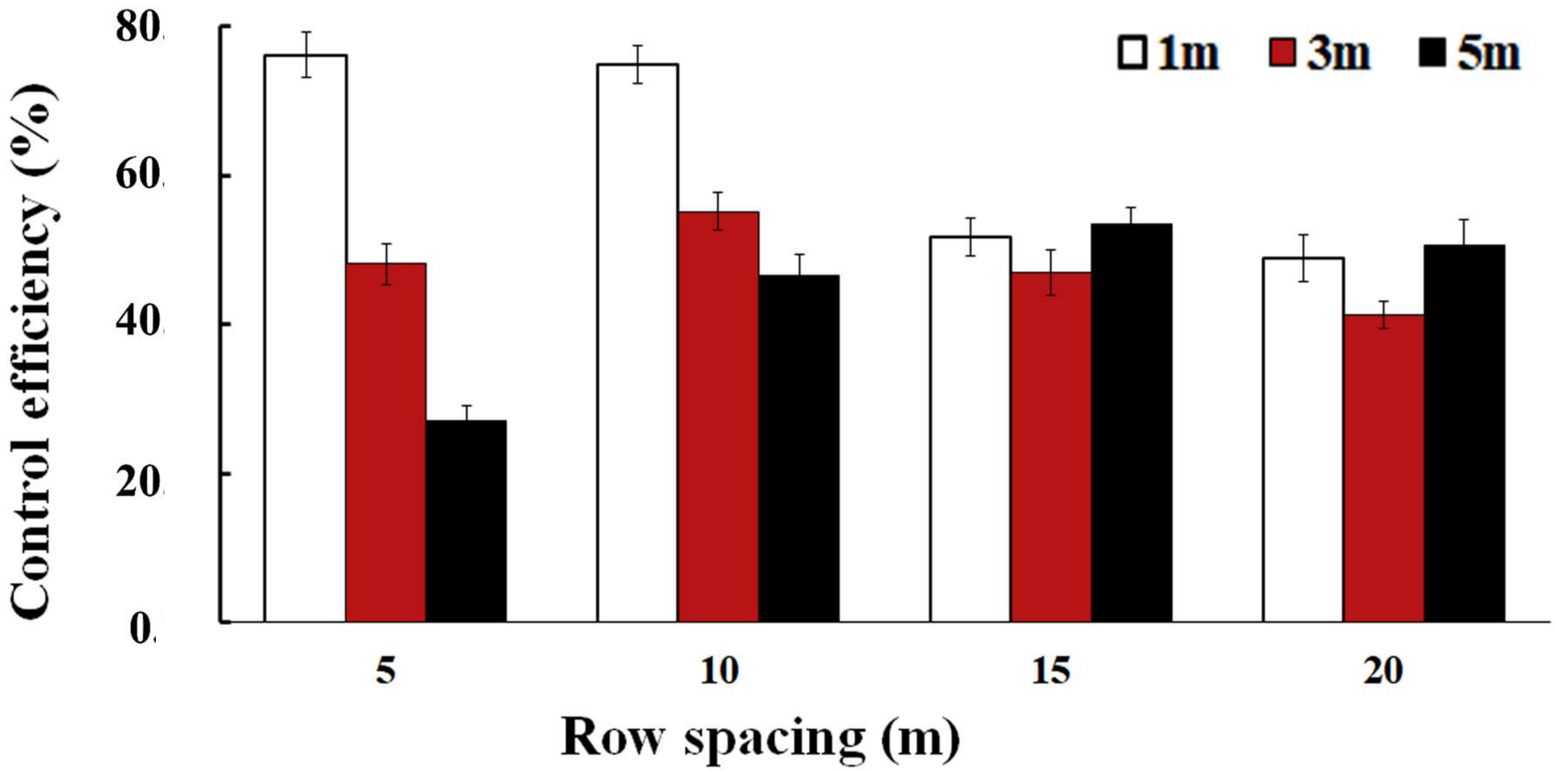
Three

How to apply vetiver to control stem borers ?

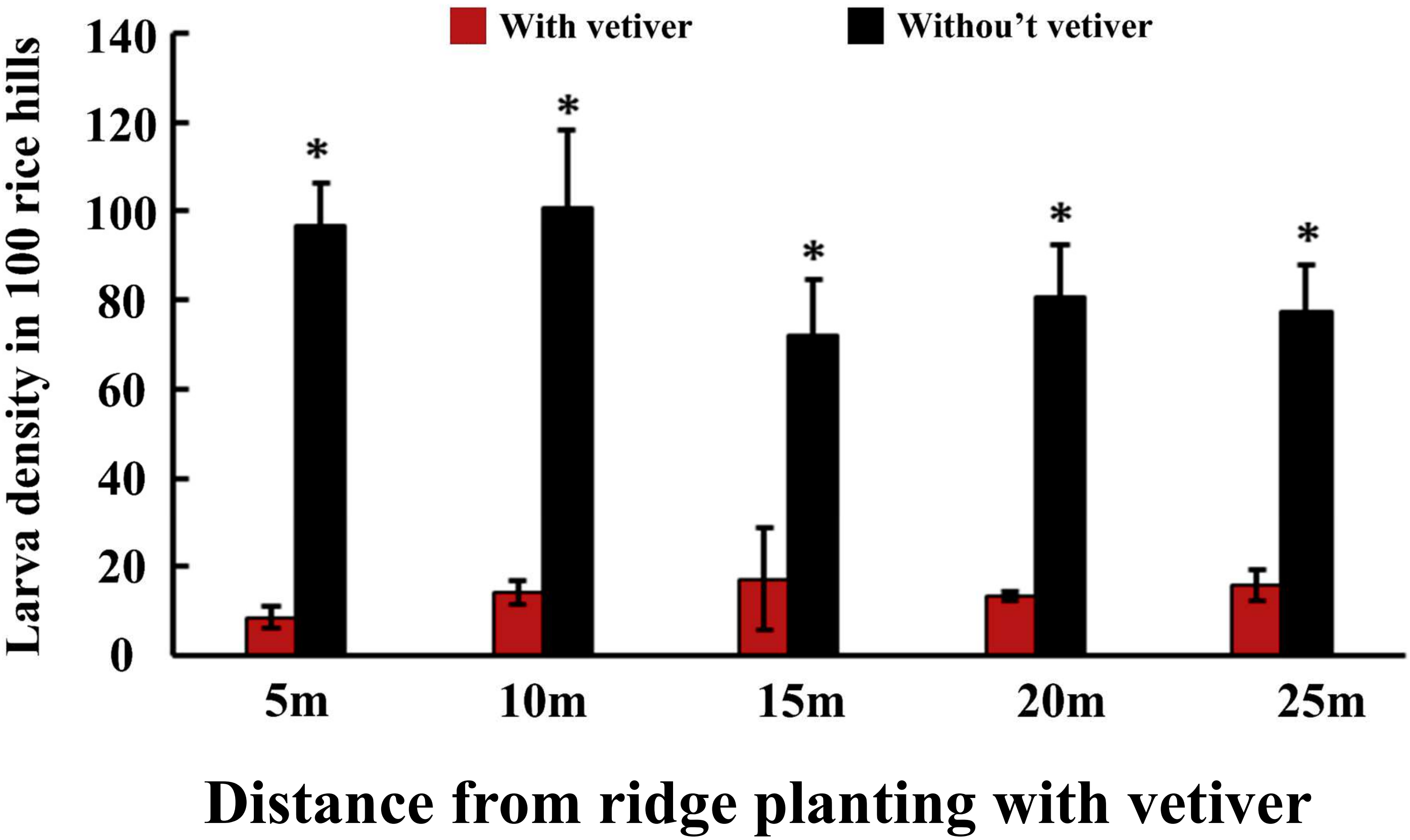
Control efficiency of SSB by planting vetiver at different spaces



Control efficiency of SSB by planting vetiver at different row spaces



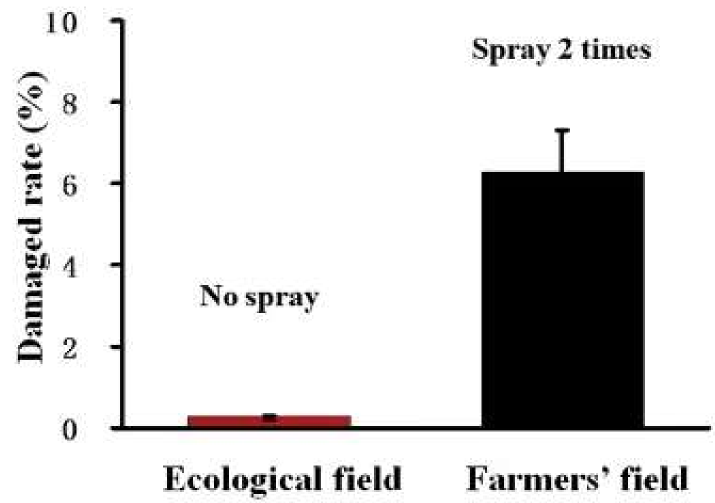
Larva overwintered within rice straw in fields



Vetiver + technology

Trichogramma sp
(150,000 /ha)

Sex pheromone trap
(15-20 traps/ha)



Four

How to scaleup
the application by farmers ?

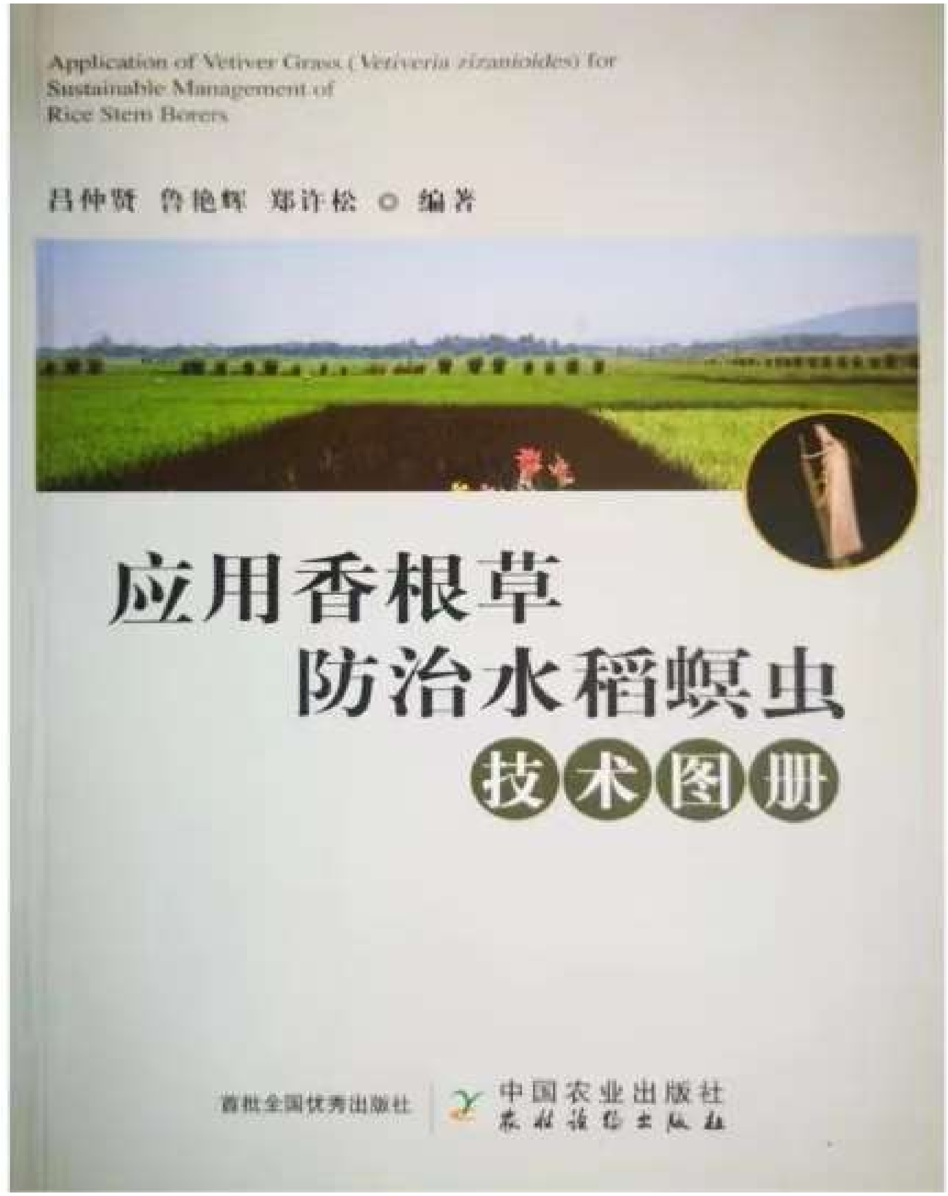
Standardization of vetiver technology

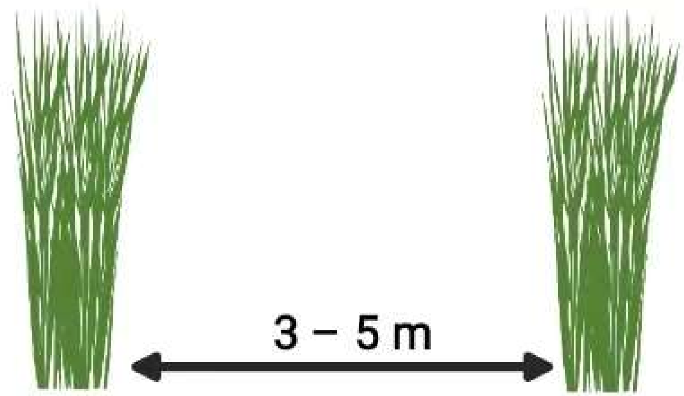
Transplanting : March to June

Plant spacing: 3-5m

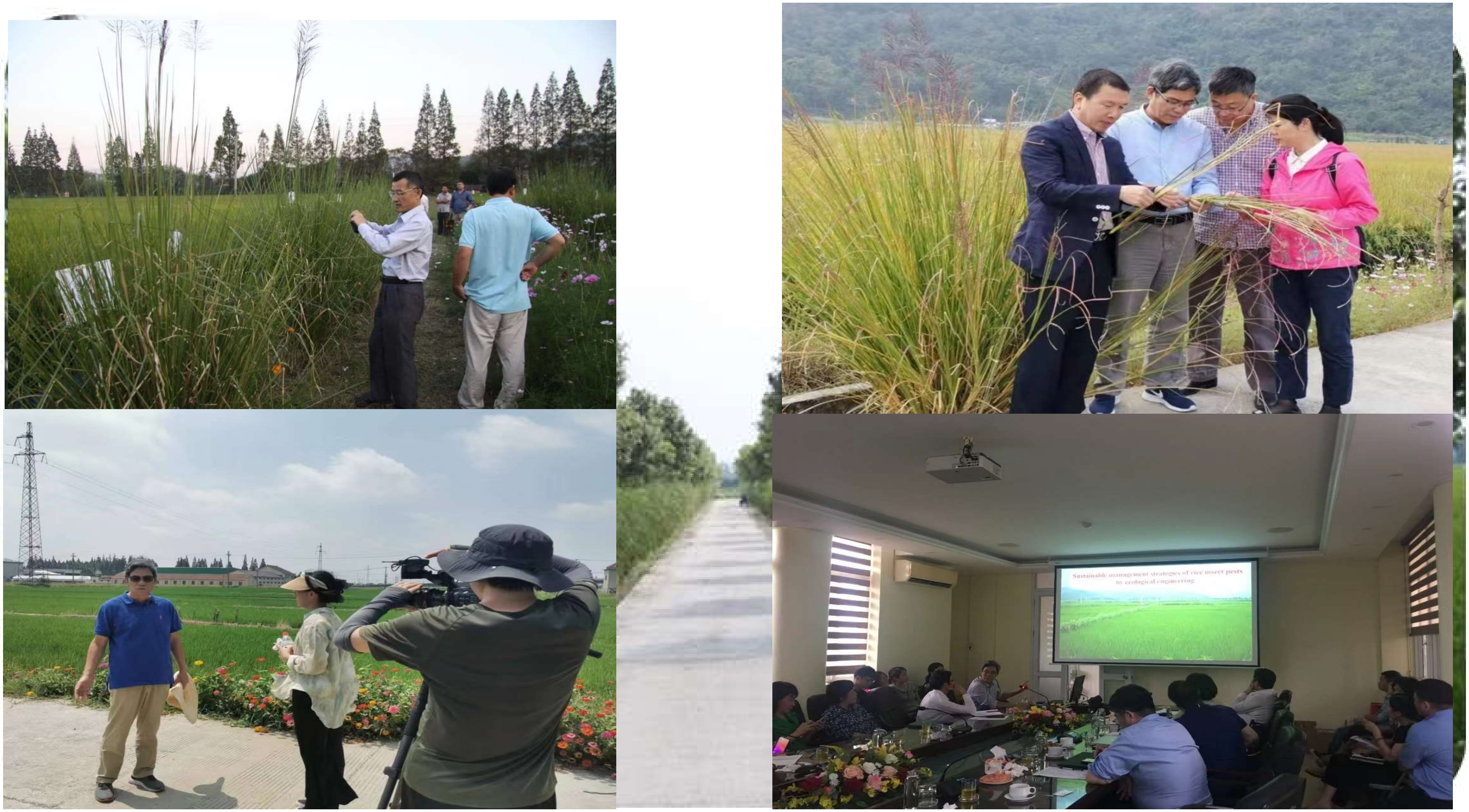
N fertilization: 10g/hill

Cutting strew: after rice harvest




3 – 5 m

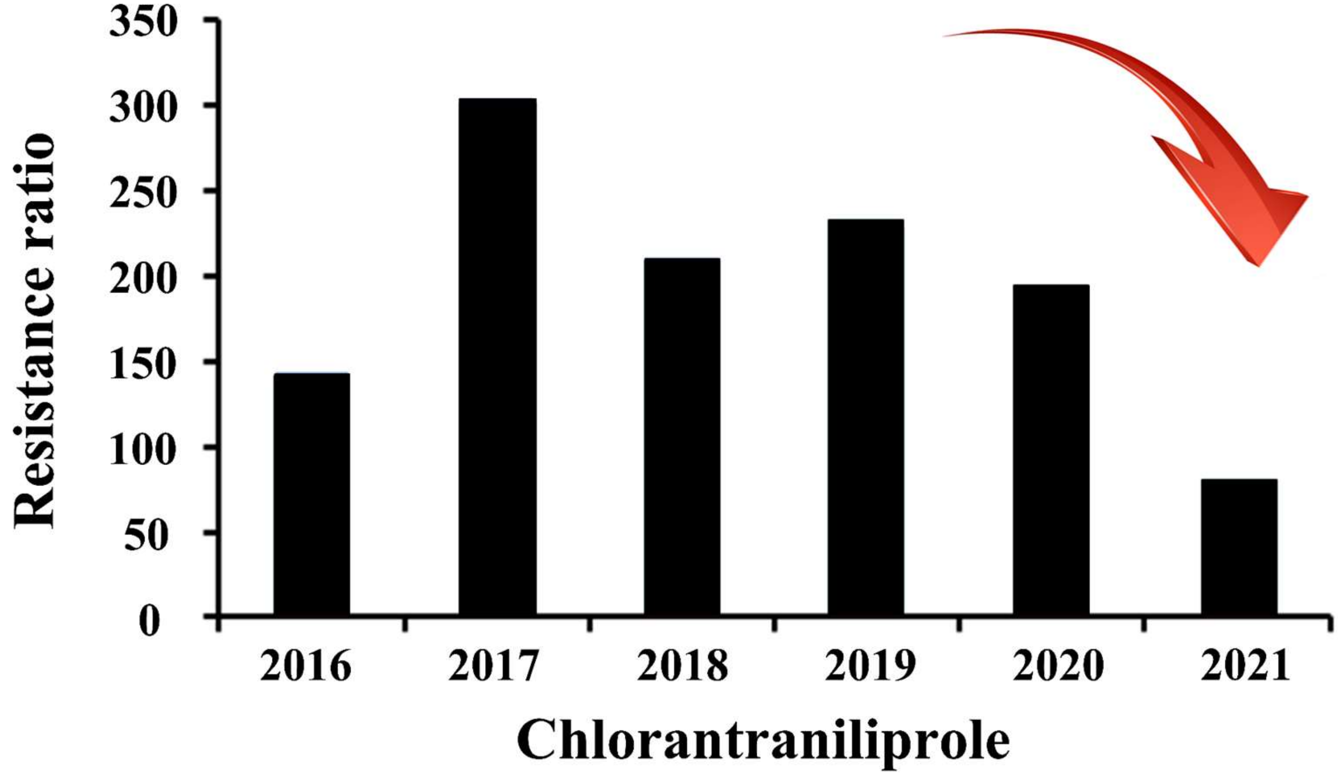
Demonstration and farmer training in field



Official recommendation of vetiver technology by MARA since 2013

An estimated 270,000 hectares of rice fields by using vetiver to control SSB in 15 provinces in China

Resistance of SBB to dominant insecticide decreased by using vetiver as trap plants



Thank you