



# Impact of low-temperature, overcast and rainy weather during the reproductive growth stage on lodging resistance of rice

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## Introduction

Rice is the most important staple food crop in China and Asia. Lodging of rice stems destroys the photosynthetic capacity of the canopy, which greatly affects grain filling. This effect causes yield loss, a decline in grain quality, and increases in harvest costs, severely limiting the balanced yield increases for rice in large areas.

The reproductive growth stage is a critical period for the formation and plumpness of rice stems, especially from panicle initiation to heading stage.

Research has shown that low light promotes internode elongation and reduces culm wall thickness. This reduction results in fragile supporting tissue and low stem strength, thus aggravating lodging.

In our research, we will systematically investigated how low-temperature, overcast and rainy weather impact the reproductive growth stage, rice stem strength and the associated differences between varieties.



Table 2 Comparison of characteristics related to lodging among different varieties from 2012 to 2014.

Varieties	Year	WP(g.cm)	FW(g)	SL(cm)	M(g.cm)	BS(g.mm <sup>-2</sup> )	Z(mm <sup>3</sup> )	LI(%)	LR(%)
Yliangyou2	2012	2890.2a	25.4b	113.7a	1752.6b	997.3b	18.0a	164.9a	29.8a
	2013	3193.2a	28.6a	111.8a	2219.5a	1144.8a	19.5a	144.1b	1.37b
	2014	2551.7b	23.0b	110.9a	1485.4c	911.8b	16.4a	172.0a	0.31b
Ilyou084	2012	2992.2a	26.6a	112.4a	1490.7a	644.8ab	23.1a	201.0b	75.2a
	2013	3032.5a	27.5a	110.4ab	1726.0a	908.2a	19.8a	176.8b	64.6a
	2014	2663.1a	24.7a	107.8b	1125.6b	546.3b	20.7a	236.6a	61.0a
Wuyunjing23	2012	1937.6a	20.5a	94.4b	1896.6a	1922.7b	9.9a	102.6a	0.9b
	2013	1508.8b	18.2a	82.7c	1956.9a	2320.9a	8.4b	77.3b	0b
	2014	1891.7a	18.9a	99.8a	1576.3b	2220.8ab	7.1c	120.8a	10.6a
W3668	2012	1536.9a	15.1a	101.6b	772.9a	1149.4c	6.7a	200.4a	61.4a
	2013	1343.0a	14.3ab	94.0c	827.5a	1672.4a	5.0b	162.5b	76.8a
	2014	1320.9a	12.3b	107.1a	643.5b	1443.8b	4.5c	205.0a	91.2a
Significance									
Y		7.8**	12.0**	48.7*	44.0**	21.3**	5.5*	36.7**	0.5ns
V		241.4*	175.5**	230.4**	147.1**	211.6**	178.2**	121.8**	45.5**
Y*V		7.2**	3.5*	22.9**	3.5*	2.5ns	1.3ns	1.3ns	2.0ns

## Materials and methods

Year: 2012- 2014

Cultivar: Y liangyou 2 (*Indica* hybrid rice, lodging-resistant)

Ilyou084 (*Indica* hybrid rice, lodging- susceptible)

Wuyunjing23 (*japonica* rice, lodging-resistant)

W3668 (*japonica* rice, lodging-susceptible)

Table 1 Nitrogen (N) application treatments during field experiments (kg N ha<sup>-1</sup>).

Nitrogen application (kg N ha <sup>-1</sup> )	Base-tiller fertilizer		Panicle fertilizer	
	Basal	Tillering	Panicle initiation	Spikelet differentiation
270	67.5	67.5	81	54

Calculation of Mechanical Parameters:

1、 Breaking moment by whole plant(WP, g cm) :

$$WP=SL \times FW;$$

2、 Breaking strength(M, g cm) :  $M = F \times L/4,$

3、 Cross section modulus (Z, mm<sup>3</sup>):  $Z=\pi/32 \times (a_1^3b_1 - a_2^3b_2)/a_1$

4、 Bending stress(BS, g mm<sup>-2</sup>):  $BS=M/Z$

5、 Lodging Index(LI, %):  $LI=WP/M$

6、 Lodging Rate(LR, %), representing the percentage of lodging plants in all the plants.

## Results & Discussion

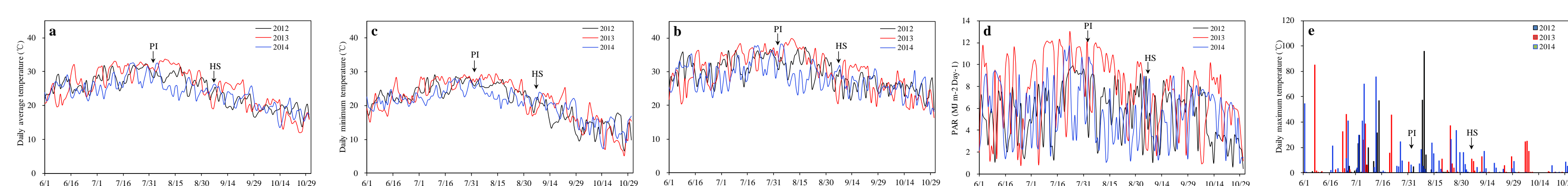


Fig.1. Daily average temperature(a), Daily maximum temperature(b), Daily minimum temperature(c), PAR(d) and Precipitation(e) during the whole rice growth stage from June to October in 2012, 2013 and 2014. Data were collected by the Danyang Meteorological station. PI and HS indicate panicle imitation stage and heading stage, respectively.

Table 1 Average temperature, maximum and minimum temperatures, and photosynthetically active radiation (PAR), precipitation and days of rainfall at Danyang from 2011 and 2015.

Growth stages	TS -PI					PI-HS					HS-MS				
	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Average temperature (° C)	27.8	29.0	30.1	26.8	26.9	26.7	27.8	29	24.6	26.1	19.4	19.6	20.4	19.4	20.7
Maximum temperature (° C)	32.2	32.4	33.1	32.6	32.1	30.8	31.4	33.7	28.3	27.7	28.7	27.5	27.5	25.7	26.4
Minimum temperature (° C)	21.8	23.0	23.7	21.4	20.2	20.5	22.8	19.4	21.4	24.1	12.3	11.7	12.0	9.9	13.8
PAR (MJ m <sup>-2</sup> day <sup>-1</sup> )	5.3	12.0	8.9	6.1	7.1	5.2	6.6	8.6	4.4	8.5	3.6	5.3	5.5	5.3	7.5
Precipitation (mm)	260.2	192.0	142.8	338.6	287.5	249.6	171.7	72.9	185.9	0	41.8	1.0	113.3	72.1	38.4
Days of rainfall	21	12	7	20	20	21	5	6	20	0	11	1	12	19	12

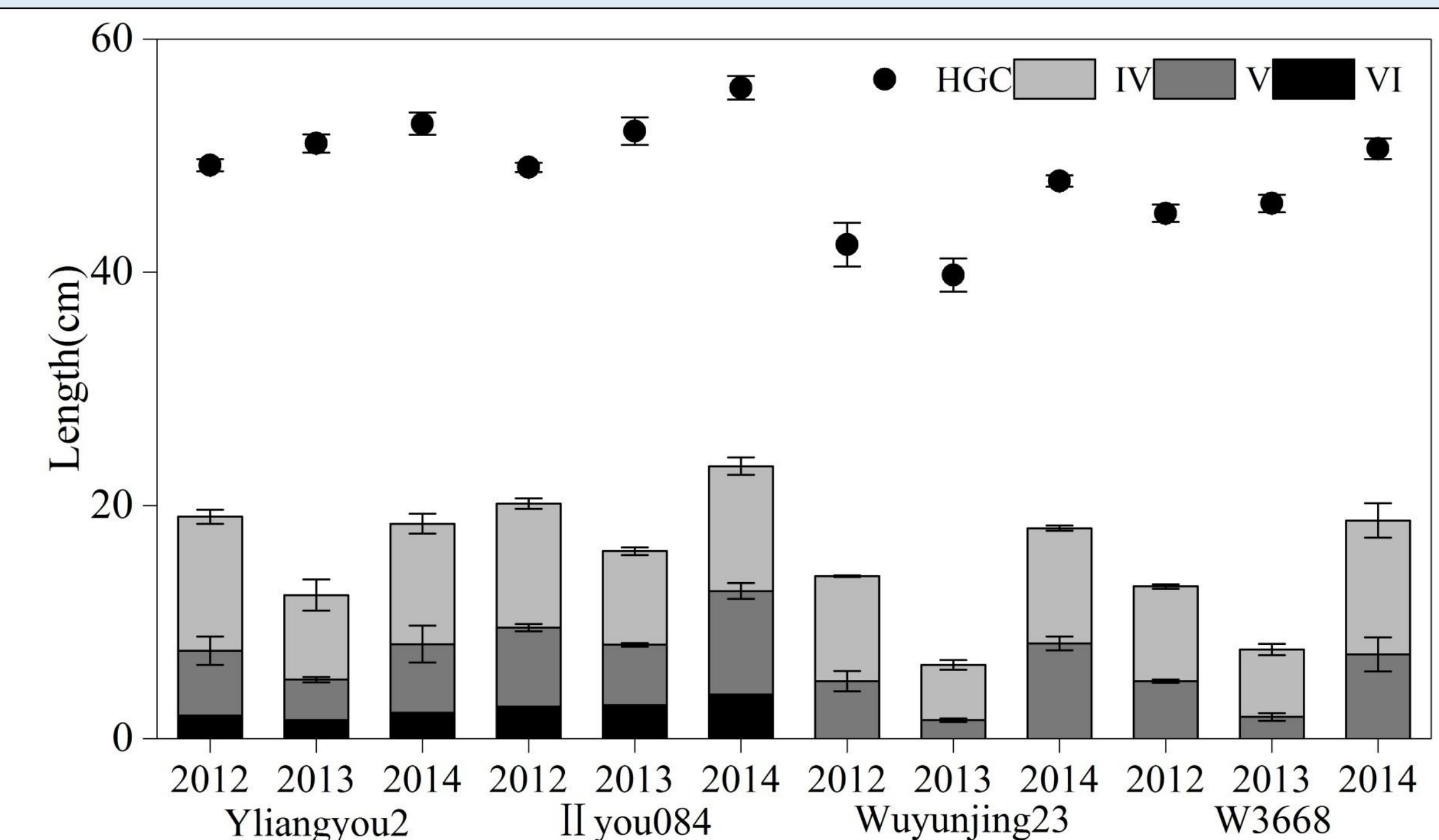


Fig. 2 Configuration of internodes of different varieties from 2012 to 2014. The uppermost internode was named I; others were followed by II-VI.

Table 3 NSC, cellulose, lignin content and total content of SC (cellulose and lignin) in basal internode culms and leaf sheaths among different varieties.

Varieties	Year	Culm (mg/cm)				Leaf sheath (mg/cm)			
		NSC	Cellulose	Lignin	SC	NSC	Cellulose	Lignin	SC
Yliangyou2	2012	2.59b	7.24a	3.20b	10.44a	1.67ab	3.90b	2.01a	5.44ab
	2013	3.50b	7.62a	4.53a	12.15a	1.02b	3.59b	1.84a	5.43b
	2014	5.09a	7.04a	2.49b	9.54a	2.24a	5.49a	2.01a	7.50a
Ilyou084	2012	1.41b	5.75a	3.87a	9.62a	0.51b	1.66a	1.28a	2.94a
	2013	7.13a	5.23a	3.71a	8.94a	0.47b	1.93a	1.06a	2.99a
	2014	4.00ab	5.87a	2.19b	8.07a	1.17a	2.55a	1.42a	3.97a
Wuyunjing23	2012	1.74a	4.46b	2.78a	7.24b	2.22a	5.94a	3.91b	9.85b
	2013	0.75b	5.48a	2.64a	8.12a	0.77b	6.64a	3.91b	10.55ab
	2014	0.75b	4.50b	2.58a	7.08b	0.90b	6.62a	4.89a	11.50a
W3668	2012	1.86b	3.89ab	1.75a	5.64ab	0.83a	3.10a	2.03a	5.12a
	2013	3.77a	4.49a	2.04a	6.54a	0.66a	4.37a	2.43a	6.81a
	2014	1.11b	3.35b	1.65a	5.00b	0.63a	3.74a	2.69a	6.43a
Y		5.3*	1.1ns	47.9**	6.6**	11.0**	4.3*	6.8**	5.2*
V		8.9**	24.8**	72.3**	38.2**	17.6**	46.3**	128.5**	71.6**
Y*V		4.1**	0.7ns	14.4**	0.9ns	7.3**	1.5ns	1.9ns	0.8ns

## Conclusions

◆ Reduction in lodging resistance under Low-temperature, overcast and rainy weather is a comprehensive effect from morphology to physiology.

◆ yield and lodging resistance of indica rice are more significantly affected by extreme weather.