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Studies of Organic Forage Production System for Animal Production in Korea

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한국의 가축 생산성 향상을 위한 유기조사료 생산체계에 관한 연구

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Organic forage production system is one of the most important aspects in organic livestock production. Animals in the organic farming system are also essential for manure to be used for organic forage production. Both organic forage and animals are essential to maintain the cycle of organic agriculture system. In this paper we introduce the organic forage production system in Korea. Summer and winter crops are getting popular in Korea because of their high forage yield and cultivation in double cropping systems. Common cropping system for forage production in Korea is the double cropping system with legume and grass mixture. Forage sorghum and sudangrass are the most popular ones of annual summer forage corps because of their high production with low cost in the double cropping systems. In the mixture of forage crops, inter cropping is more suitable in the corn and sorghum cropping system because of high lodging resistance and forage yield, and low weed population. Forage sorghum and sudangrass are difficult to preserve as direct-cut silage due to the fact that its high moisture content causes excessive fermentation during ensiling. Corn grain addition to sorghum silage could be recommended as the most effective treatment for increasing quality and reducing production cost. It is recommended that corn grain could be added up to 10% of total amount of silage. And agriculture by-products also can be added at the time of ensiling to minimize losses of effluent and have the additional advantage of increasing quality. Agriculture by-products as silage supplements increased DM content and quality, and decreased the production cost of sorghum silage. Field pre-wilting treatment of forage crops also increased DM content and quality of the silage. Wilting sorghum ×sudangrass hybrid before ensiling was the effective method for reducing effluent

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and increasing pH and forage quality more than direct cut silage. Optimum pre-wilting period of sudangrass silage was 1 or 2 days. In organic forage, the most important factor is the enhancement of organic forage sufficiency in relation to the environmental-friendly and organic livestock. Consequently, there are many possibilities for animal production and organic forage production in Korea. No forages no cattle concept should be emphasized in organic farming system.

Key words : *by-product, cropping system, forage quality, production cost, livestock*

Introduction

The human population has been increasing tremendously in the past half century, and agriculture production has been intensified through the abundant use of inorganic fertilizer, the practice of monoculture, and the use of chemicals. Some argue that such a system of production is not sustainable because it leads to degradation of the earth's environment. Thus, they offer organic agriculture as an alternative. Undoubtedly, human survival depends on agricultural production being increased and the earth's environment being sustained. Whether agriculture production will continue to employ the present intensive system, or move to organic farming, or use a combination of the two, it will definitely have significant effects in the future(Kim, 2011; Kim et al., 2006; 2007; 2010; 2011; Kwon et al., 2006).

In Korea, organic agriculture as well as environment-friendly agriculture is important for several reasons: for air purification, water quality and conservation, soil conservation and improvement, organic waste digestion, and biodiversity conservation. This is the reason why environment-friendly agriculture and organic farming increased in Korea, and now consumers are also interested in environment-friendly and organic products for human health and well-being.

Korean beef cattle and dairy cattle are the primary ruminant livestock in Korea, and it is also important because of the increasing demand for beef and milk. Therefore, organic forage production system for organic ruminant livestock production is one of the most important aspects in organic agriculture, because organic feed is the key in producing organic animals. But organic animals are also essential for producing manure to be used for organic farming. Therefore, both organic plants and organic animals are essential to maintain their cycle for organic agriculture system.

The objectives of this paper are to discusses: 1) the current situation of organic livestock production, 2) forage production and the cost of organic forage, 3) organic forage production system, 4) requirement and production area of organic forage for livestock production, and 5)

new technology of forage production and utilization in Korea.

1. Current situation of organic livestock production

The total number of environment-friendly livestock farms including organic and non-antibiotics livestock farms were 9,267 in 2012. And the number of animal was increasing very rapidly year by year (Table 1). Total amount of production in the environmental-friendly livestock production was 569 thousand MT in 2012 (Table 1). Fig. 1 indicates that the organic livestock farm had been tied up since 2005, but agriculture farm was increased with 16,733 farms. The organic livestock's environment is pretty limited compared to the organic agriculture in Korea. Owing to the shortage of organic forage, it is difficult to increase organic farming in Korea.

Table 1. The status of environment-friendly livestock from 2005 to 2012

Item	2005	2006	2007	2008	2009	2010	2011	2012
No. of certified farm	18	68	763	2,904	4,441	6,345	7,720	9,267
No. of certified animal (×1,000)	45	197	18,103	38,769	60,357	86,348	105,777	125,205
Production(MT)	256	1,671	13,562	148,286	309,546	404,196	480,916	569,639

MT = metric ton.
Source: MAFRA(2013).

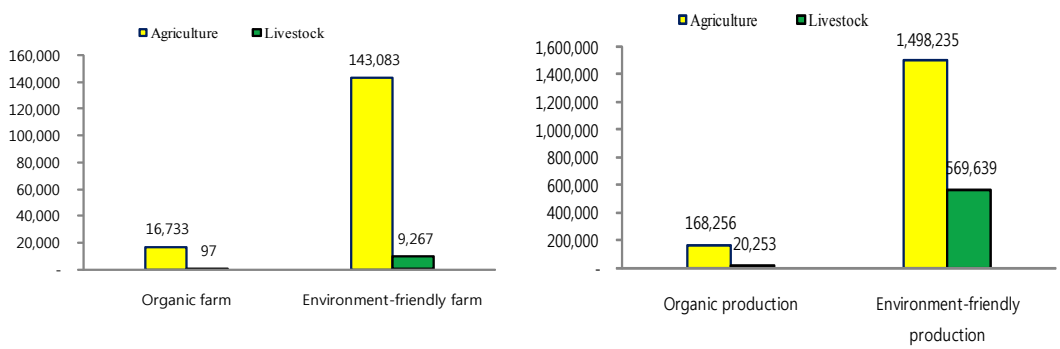

Fig. 1. Comparison of agriculture and livestock in organic farm
Source: MAFRA(2013).

2. Forage production and the cost of organic forage in Korea

The primary feeds for livestock in Korea are concentrates and rice straw. Recently, however,

the supply of domestic good quality forages is increasing rapidly, particularly in winter (Italian ryegrass, rye, oats, forage barley and so on) (Seo, 2006; 2009).

Summer and winter crops are getting popular among forage crops because of their high production yield and cultivation in double cropping systems in Korea. The importance of cropping system for the enhancement of soil quality and forage production has long been recognized in agriculture. Common cropping system in Korea is the double cropping system with legume and grass mixture (Kim et al., 2001; Park et al., 2009).

One of prerequisites for organic livestock production is to secure the use of organic feeds. It is assumed that due to the use of chemical fertilizers and pesticides, conventional cropping system achieves the higher productivity than organic system, while organic production practices cost less than conventional ones (Kim et al., 2007). Thus, a study was aimed to investigate and compare the productivity and production cost between conventional and organic silage crops in Korea.

Table 2. Comparison of forage yield and production cost between conventional and organic forages

Forage crops	Forage yield(kg/ha)		Production cost(won/kg DM)		Difference	
	Conventional(A)	Organic(B)	Conventional(C)	Organic(D)	A-B(kg/ha)	D-C(won)
Corn	14,265	8,965	222	334	5,300	112
Sorghum	23,780	17,719	110	149	6,061	40
Sudangrass	20,867	15,260	131	176	5,607	45
Rye	10,373	10,038	184	196	335	12
Italian ryegrass	6,148	5,283	291	347	865	56
Oat	5,251	4,862	273	316	389	43
Crimson clover	4,201	3,571	317	402	630	85
Red clover	3,438	2,732	391	529	706	138
Hairy vetch	5,198	4,870	386	394	328	8

Source: Kim et al.(2007), Kim(2011).

Table 2 shows that in summer crops, the forage production of organic corn, sorghum and sudangrass were 14,265, 23,781 and 20,867 kg/ha, respectively. The production cost of corn, sorghum and sudangrass were estimated 334, 149 and 176 won/kg DM, respectively. However, the production of in winter crops were lower than the summer crops, showing that the produc-

tion of organic rye, Italian ryegrass and oats were 10,038, 5,283 and 4,862 kg/ha, respectively. The production cost of rye, Italian ryegrass and oats were 196, 347 and 316 won/kg DM, respectively. And the forage production of crimson clover, red clover and hairy vetch were 3,571, 2,732 and 4,870 kg/ha, respectively. The production cost of crimson clover, red clover and hairy vetch were 402, 529 and 394 won/kg DM, respectively.

In comparison between conventional and organic forage, the production of organic forage was lower than that of the conventional forage, while the production cost of organic forage was higher than conventional forage (Table 2).

3. Organic forage production system in Korea

The production of organic sorghum and rye, and sudangrass and rye in the double cropping system were higher than others in using two cropping systems followed by the production of organic sorghum and hairy vetch, and sorghum and crimson clover (Table 3).

Table 3. Organic forage production of winter and summer crops at two cropping systems

Cropping system	Summer crops(A) (kg/ha)	Winter crops(B) (kg/ha)	Total yield (A+B)	Index	Cropping system	Winter crops(C) (kg/ha)	Total yield (A+C)	Index
Corn	9,441	-	9,441	100			9,441	100
Sorghum	17,719	-	17,719	188			17,719	188
Sudangrass	15,260	-	15,260	162			15,260	162
Corn+Rye	8,965	9,538	18,503	196	Corn+Crimson	3,571	12,536	133
Sorghum+Rye	17,719	9,538	27,257	289	Sorghum+Crimson	3,571	21,290	226
Sudangrass+Rye	15,260	9,538	24,798	263	Sudangrass+Crimson	3,571	18,831	199
Corn+IRG	8,965	5,283	14,248	151	Corn+Red	2,732	11,697	124
Sorghum+IRG	17,719	5,283	23,002	244	Sorghum+Red	2,732	20,451	217
Sudangrass+IRG	15,260	5,283	20,543	218	Sudangrass+Red	2,732	17,992	191
Corn+Oat	8,965	4,862	13,827	146	Corn+HV	5,198	14,163	150
Sorghum+Oat	17,719	4,862	22,581	239	Sorghum+HV	5,198	22,917	243
Sudangrass+Oat	15,260	4,862	20,122	213	Sudangrass+NV	5,198	20,458	217

Corn: monoculture=late maturity, two cropping system=early maturity. Index: corn monoculture=control. Sudangrass=sorghum×sudangrass, IRG=Italian ryegrass, Crimson=crimson clover, Red=red clover, HV=hairy vetch.

Source: Kim(2011).

4. Requirement and production area of organic forage for livestock production

Table 4 shows forage requirements for Hanwoo beef cattle and dairy cattle in Korea. First, the area needed for the organic forage production for 20 Hanwoo cattle ranged from 1.87 to 4.28 ha in two cropping systems using sorghum and grass, or sorghum and legumes.

For finishing Hanwoo, the area needed for organic forage production for 20 heads was from 1.89 to 2.94 ha in two cropping systems using corn and grass, or corn and legume. And the area needed for organic forage production for 70 heads of dairy cattle was from 18.78 to 28.15 ha in two cropping systems using corn and grass, or corn and legume.

Table 4. Requirements and production area of organic forage in Hanwoo and dairy cattle

Cropping system	Forage yield (kg/ha)	Effective forage yield[1] (kg/ha)	OFPIA(ha)	Cropping system	Forage yield (kg/ha)	Effective forage yield[1] (kg/ha)	OFPIA(ha)	
			Hanwoo (250kg/ 17head)[2]				Hanwoo (400kg/ 17head)[3]	Dairy (680kg/ 34head)[4]
Dry field								
Sorghum+Rye	27,257	20,443	1.87	Corn+Rye	18,503	13,877	1.89	18.78
Sorghum+IRG	23,002	17,252	2.22	Corn+IRG	14,248	10,686	2.46	24.39
Sorghum+Oat	22,581	16,936	2.26	Corn+Oat	13,827	10,370	2.53	25.13
Sorghum+Crimson	21,290	15,968	2.40	Corn+Crimson	12,536	9,402	2.80	27.73
Sorghum+HV	20,451	15,338	2.49	Corn+HV	14,163	10,622	2.47	24.53
Rice paddy field								
Straw+Rye	13,989	10,492	3.65	Straw+Rye	13,989	10,492	2.51	24.84
Straw+IRG	13,134	9,850	3.89	Straw+IRG	13,134	9,850	2.67	26.46
Straw+Barley	11,919	8,939	4.28	Straw+Barley	11,919	8,939	2.94	28.15

[1] Effective forage yield= forage yield × 0.25 (Harvest and feeding loss=25%).

[2] Growing Hanwoo(250kg); feed requirement=7.5 kg/head/day, 2,738 kg/head/365days, forage requirement (forage:concentrate=70:30)=1,916 kg/head/365days, 38,320 kg/20heads/365days.

[3] Finishing Hanwoo(400kg); feed requirement=12 kg/head/day, 4,380 kg/head/365days, forage requirement (forage:concentrate=30:70)=1,314 kg/head/365days, 26,280 kg/20heads/365days.

[4] Lactating dairy cattle(680kg); feed requirement=20 kg/head/day, 7,446 kg/head/365days, forage requirement (forage:concentrate=60:40)=3,723 kg/head/365days, 260,610 kg/70heads/365days.

[5] OFPIA=organic forage production index area.

Source: Kim(2011); Kim et al.(2011).

5. Application of forage production and utilization for organic livestock production in Korea

5.1. Effects of single inter- and mixed cropping on organic forage production

A study was conducted to compare forage production between cropping treatments using corn and sorghum (Table 5). Lodging resistance at inter-cropping was higher than sorghum single and mixed cropping due to the thicker stem diameter. Total dry matter content at the inter-cropping was higher than the mixed cropping. In fresh and dry matter (DM) yields, the yield of the inter cropping was highest among cropping systems.

Table 5. Effects of the single, inter- and mixed cropping on agronomic characteristics and forage production of corn and sorghum

Cropping	LR	Plant height		Stem diameter		DM	Forage yield		
		Corn	Sorghum	Corn	Sorghum		Fresh	DM	Index
	(1-9)[1)]	------- cm -------		------- cm -------		-%-	------- kg/ha -------		
Corn single	1	324	-	2.0	-	23.7	72,566	17,198	100
Sorghum single	4	-	288	-	0.8	20.3	74,303	15,084	87
Inter cropping	1	314	301	1.9	1.1	22.2	110,803	24,598	143
Mixed cropping	3	284	308	1.7	1.0	20.9	94,100	19,667	130
Mean						21.8	87,943	19,137	
P-value						0.246	0.0001	0.0378	

[1)] Rating: 1=outstanding, 9=poor, LR=lodging resistance, DM=dry matter.
Source: Kim et al.(2006).

In the study, weed population and vegetation were also investigated (Table 6). Main weeds at corn and sorghum fields were found to be barnyard grass (*Echinochloa crusgall*), velvetleaf (*Abutilon avicennae*), crabgrass (*Digitatia saguinalis*), and redroot pigweed (*Amaranthus retro-flexus*). Weed population was lower in the inter- and mixed croppings than the corn single cropping. Therefore, it is concluded that the inter-cropping is more suitable for corn and sorghum production because of the higher lodging resistance and forage yield, and the lower weed population.

Table 6. Effects of the single, inter- and mixed croppings of corn and sorghum on weed population and vegetation

Weed species	Population and vegetation of weed				P-value
	Corn	Sorghum	Inter-cropping	Mixed cropping	
	Population, kg DM/ha, (%)				
Echinochloa crusgalli	397 (35.3)	388 (40.4)	311 (26.8)	272 (30.3)	
Abutilon avicennae	68 (6.0)	128 (13.4)	191 (16.5)	190 (21.2)	
Digitatia saguinalis	327 (29.1)	238 (24.8)	430 (37.1)	220 (24.5)	
Amaranthus retroflexus	270 (24.0)	138 (14.4)	148 (12.8)	153 (17.0)	
Others	63 (5.6)	67 (7.0)	78 (6.8)	63 (7.1)	
Total	1,124 (100)	959 (100)	1,159 (100)	899 (100)	0.0378

Source: Kim et al.(2006).

5.2. Effects of pre-wilting and agriculture by-products supplementation on the silage quality of organic forage

Pre-wilted sorghum×sudangrass hybrid silage showed lower pH than direct cut silage (control) because of the higher moisture content of control silage (Table 7). The DM content of sorghum× sudangrass hybrid silage with pre-wilting was high above 25.1% after 1 day wilting, while that of control was 17.6%. And the effluent of wilted silage was decreased with prolonged wilting period, but direct cut silage produced the effluent of 183 mL/kg. Crude protein and ether extract contents in the wilted silages were decreased, while crude ash was increased with prolonged wilting period. The silages with pre-wilting had higher acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents than control, while non-fiber carbohydrate (NFC) showed the opposite results.

Lactic and total organic acids were increased with wilting. The palatability of silage with 2 days wilting using with dairy goats was highest among the silages. The experiment results indicated that the pre-wilting sorghum×sudangrass hybrid silage could be recommended as an effective method for reducing effluent and pH, and increasing forage quality comparing with direct cut silage. Optimum pre-wilting day of sorghum×sudangrass hybrid silage may be 1 day.

Table 7. Effects of pre-wilting on the forage and silage quality of organic sorghum×sudangrass silage

Pre-wilting days	CP (%)	EE (%)	ash (%)	NDF (%)	ADF (%)	NFC (%)	TDN (%)	DM (%)	pH (1:5)	Organic acid(%)			
										Lactic	Acetic	Butyric	Total
0 day	10.2	3.2	8.9	64.7	42.8	13.0	55.1	17.6	4.30	3.61	0.20	0.01	3.82
0.5 day	9.8	2.9	9.7	68.5	43.8	9.1	54.3	22.7	3.99	3.51	0.23	0.00	3.74
1 day	9.6	2.6	10.2	68.3	43.5	9.4	54.5	25.1	3.85	5.58	0.26	0.00	5.84
2 days	9.0	1.9	10.0	69.1	44.1	9.2	54.0	25.6	3.79	5.50	0.20	0.00	5.70
3 days	9.0	1.8	10.6	70.3	44.0	8.4	54.1	26.9	3.79	5.02	0.21	0.00	5.22
Mean	9.5	2.5	9.9	68.2	43.7	9.8	54.4	23.6	3.95	4.64	0.22	0.00	4.86
LSD(0.05)	NS	0.24	0.87	1.33	NS	1.70	NS	2.7	0.19	0.97	NS	NS	0.15

CP=crude protein; EE=ether extract; ash=crude ash; NDF=neutral detergent fiber; ADF=acid detergent fiber; NFC=non fiber carbohydrate; TDN=total digestible nutrients; DM=dry matter.
Source: Lim et al.(2009).

Table 8. Effect of agriculture by-products on the forage and silage quality of organic sorghum×sudangrass silage

Treatment	DM (%)	pH (1:5)	CP (%)	EE (%)	CA (%)	NFC (%)	NDF (%)	ADF (%)	TDN (%)	LAC (%)	ACE (%)	BUT (%)
Control	15.7^{c}	4.94^{a}	12.2^{b}	3.6^{c}	13.3^{a}	9.0^{c}	61.8^{a}	40.6^{a}	63.7^{d}	4.90^{d}	0.27^{a}	0.01
Crushed rice	25.8^{b}	3.61^{d}	10.1^{c}	2.9^{c}	6.9^{d}	24.9^{a}	55.1^{b}	24.7^{d}	68.6^{a}	5.85^{b}	0.15^{b}	0.01
Rice bran	25.5^{b}	3.75^{cd}	12.0^{b}	13.4^{a}	7.8^{d}	12.7^{b}	54.1^{b}	26.1^{b}	68.2^{bc}	4.36^{e}	0.14^{b}	0.01
Wheat bran	27.5^{a}	3.99^{b}	14.2^{a}	2.7^{c}	11.8^{c}	24.8^{a}	46.5^{c}	26.6^{b}	68.0^{c}	5.45^{c}	0.15^{b}	0.02
Green grain of rice	25.1^{b}	4.88^{bc}	14.1^{a}	5.5^{b}	9.2^{c}	22.5^{a}	48.7^{c}	25.0^{cd}	68.5^{ab}	6.36^{a}	0.17^{b}	0.02

DM=dry matter; CP=crude protein; EE=ether extract; CA=crude ash; NFC=non fiber carbohydrate; NDF=neutral detergent fiber; ADF=acid detergent fiber; TDN=total digestible nutrients; LAC=lactic acid; ACE=acetic acid; and BUT=butyric acid.
$^{a, b, c, d}$ means in the same column with different superscripts differ significantly ($p<0.05$).
Source: Kim et al.(2010).

Sorghum×sudangrass silages added with by-products had low pH values, while sorghum×sudangrass silage (control) had a high pH value because of its high moisture content (Table 8). Silages added with by-products had lower ADF and NDF contents than control silage, while

NFC, TDN and lactic acid contents showed the opposite results. The lactic acid of the silages added with crushed rice and green grain of rice were higher than other treatments as well as high DM, NFC and TDN. The silages added with crushed rice and green grain of rice can be recommended as the most effective treatments for increasing forage quality and DM content of sorghum×sudangrass silage.

Although whole crop barley (*Hordeum vulgare* L.) is now widely grown as a silage crop in Korea, forage production and silage quality of that for organic farm have not been published. Therefore, in Table 9 a study was conducted to investigate the effect of harvest stage on forage production and quality of organic barley, and the effect of field wilting and crushed rice supplementation on shortening of harvest date and improvement of forage quality. The pH of the silage harvested at milking stage showed about 4.00 which was lower than the silages harvested at other times. The crude protein and TDN contents were decreased as harvest stage prolonged, while, NDF and ADF contents were increased. Field wilting and crushed rice treatments decreased NDF and ADF contents, and increased TDN content.

Lactic and total organic acids contents of the silage harvested at milking stage were highest, and butyric acid content of the silage harvested at the same stage was lowest. The improved quality of silages by field wilting and crushed rice addition was observed at heading stage. The experiment results indicate that the optimum harvest stage of organic barley silage was milking stage. The field wilting and crushed rice addition could be recommended as effective methods for shortening harvest date and increasing forage quality of organic barley silage.

Table 9. Effects of harvest stage, wilting and crushed rice addition on the chemical composition of organic whole crop barley silage

Harvest Stage	Wilting and crushed rice	CP (%)	NDF (%)	ADF (%)	TDN (%)	DM (%)	pH (1:5)	Organic acid (%)			
								Lactic	Acetic	Butyric	Total
Heading Stage	Control	16.8	54.7	37.8	59.0	12.7	5.06	1.73	2.90	2.13	6.76
	Wilting	16.3	35.4	26.6	60.8	19.1	4.42	7.84	2.02	0.89	10.75
	CR 10%	17.4	52.8	35.5	67.1	14.9	4.76	6.39	1.87	1.58	9.84
	CR 15%	16.1	36.0	27.6	67.9	18.6	4.57	6.71	1.91	1.88	10.50
	Mean	16.6	44.7	31.9	63.7	16.3	4.70	5.67	2.18	1.62	9.46

Harvest Stage	Wilting and crushed rice	CP (%)	NDF (%)	ADF (%)	TDN (%)	DM (%)	pH (1:5)	Organic acid (%)			
								Lactic	Acetic	Butyric	Total
Milking stage	Control	15.4	56.6	45.5	53.0	21.7	3.92	10.13	1.59	0.58	12.30
	Wilting	15.3	54.9	36.0	60.5	29.0	4.03	9.80	1.30	0.15	11.24
	CR 10%	14.1	52.9	34.8	62.5	25.5	4.15	7.85	2.28	0.54	10.67
	CR 15%	13.0	38.2	22.6	69.8	27.6	4.02	6.76	1.22	0.36	8.34
	Mean	14.5	50.6	34.7	61.4	25.9	4.03	8.64	1.60	0.41	10.64
Yellow stage	Control	10.7	59.7	42.5	55.3	27.9	5.58	0.43	1.61	1.40	3.44
	Wilting	12.2	48.8	35.0	55.5	48.4	6.17	0.50	0.86	0.27	1.63
	CR 10%	11.5	55.4	41.5	56.1	31.0	5.14	1.07	1.51	0.80	3.39
	CR 15%	12.2	48.8	35.0	61.2	38.9	4.59	1.64	1.04	0.36	4.03
	Mean	11.3	56.0	40.3	57.1	36.5	5.37	0.91	1.25	0.71	2.87
LSD(0.05)											
Harvest stage (H)		0.47	1.62	1.37	1.08	0.91	0.15	0.58	0.48	0.32	0.94
Wilting and CR (W)		0.54	1.87	1.59	1.25	1.05	0.18	0.67	0.56	0.36	NS
H×W		***	***	***	***	***	***	***	NS	NS	***

CR=crushed rice addition. H×W =interactions between harvest stage, and wilting and crushed rice addition. Source: Kim et al.(2010).

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