

## Allelopathic effects of rice cultivars on barnyardgrass growth to reduce the herbicide dose

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### ABSTRACT

In lab studies, we compared the weed suppression abilities of 3 rice varieties [cv. Koukishumuchi (allelopathic), cv. Dongjinbyeo (non-allelopathic) and cv. K21 (newly bred potent allelopathic)] on barnyardgrass and thereby to reduce the herbicide rates. Kouketsumochi variety caused maximum weed suppression, while, Dongjinbyeo was least effective. The allelopathic suppression effects of Koukishumuchi, K21 and Dongjinbyeo on barnyardgrass height were 45%, 31% and 20%, and on fresh weight 35%, 30% and 20%, respectively. These effects were converted into herbicide rate as per equation of toxicity regression. To inhibit the plant height and fresh weight, the toxicity regression values of Kouketsumochi were 10.6 mg/L and 8.4 mg/L, K21 (6.3 mg/L and 6.9 mg/L) and Dongjinbyeo (3.7 mg/L and 4.0 mg/L) respectively. By comparing the LD<sub>50</sub> value with no rice, herbicide rate was reduced by 18-48%; with rice Kouketsumochi and K21, reduced the herbicide rates by 36% and 17%, respectively than Dongjinbyeo. Thus, the rice cultivars with allelopathic potential reduced the herbicide dose for weed management and promoting an eco-friendly rice cropping system.

**Key Words:** Barnyardgrass, herbicide rates, rice allelopathy, rice varieties, weed suppression.

### INTRODUCTION

Rice is a staple food in the world, especially in Asia. However, weeds are the major constraints in these areas. Due to shortage of labour and increase in labour costs, availability of herbicides, changes in planting pattern from transplanting to direct sowing, the rice production became highly dependent on herbicides (18). However, continuous application of herbicides has resulted in some undesirable problems. Among them, environmental contamination and development of herbicides resistant weeds are especially serious (<http://www.weedscience.org>). For sustainable agricultural development, it is necessary to find an alternative method for weed control, hence, all countries are doing research to meet the requirements of sustainable agricultural development. Allelopathy in rice may be the potent supplemental methods to develop a sustainable agricultural system.

Barnyardgrass (*Echinochloa crus-galli* L.) is world worst weed found not only in rice, but also in other crops in moist and fertile soils (7). It can produce over 1.0 million seeds and absorbs 80 % soil nitrogen (7). Hence, in this study, barnyardgrass was used as a

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target plant and the efficient and sensitive dosage LD<sub>50</sub> (50% lethal dosage) was determined for the rice cultivars with allelopathic effect, to use allelopathic cultivars for weed management in rice production. Minimum lethal dosage (MLD) and 50% lethal dosage (LD<sub>50</sub>) evaluates the bioactivity of herbicide on target plant and index of relative toxicity to indicate the bioactivity of two herbicides (2,10,21).

The allelopathic potential of rice has received great attention, after Dilday *et al.* (3) identified rice cultivars allelopathic to duckweed [*Heteranthera limosa* (Sw.) Willd]. The use of allelopathic crops can definitely reduce the herbicides consumption, thus decreasing the cost of weed control. Further allelopathy technology, which is a seed-based technology, is more easily transferable to the low-input management systems prevailing in most Asian rice-farming systems. Kim *et al.* (18) reported that Kouketsumochi, an allelopathic cultivar, reduced the density and growth of barnyardgrass than Donjinbyeo cultivar, when herbicide was not applied. Similar efforts had been done to identify and develop weed-suppressive rice in upland rice and wild rice species (4,5,6,8,11,14,15,19).

Since 1990s, herbicides mixture of bensulfuron-methyl and butachlor are used to control grasses and broadleaved weeds in rice. Bensulfuronmethyl, as ALS inhibitor herbicide, is a sulfonylurea type which has been intensively used in the world since 1990. Currently, ALS inhibitor resistant weeds are increasing more rapidly than any other herbicide mode of action (Source: Dr. Ian Heap, <http://www.weedscience.com>). While, butachlor is achloroacetamides type herbicides, considered as cell division inhibitor (20). Barnyardgrass evolved resistance to butachlor in China (12,13), but the resistance mechanism is unknown. Mixing of herbicides with different modes of action is main method to delay the development of resistance and may reduce the herbicide use.

This study aimed to determine how the potent allelopathic effect of rice cultivar can reduce the herbicide rates and suppress the growth of barnyardgrass in laboratory conditions.

## MATERIALS METHODS

The 3-rice cultivars viz., Kouketsumochi (allelopathic), Dongjinbyeo (non-allelopathic) and K21 were used as test plant to evaluate their allelopathic effect on Barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.) weed. K21 is a newly bred potent allelopathic rice cultivar developed from Donjinbyeo (female parent) and Koukishumochi (male parent) in Korea (19). Herbicide applied was mixture of butachlor 2.5% and bensulfuronmethyl 0.17% with commercial name manduri, [HiTek Co., Ltd., Dongbu, Seoul, Korea] widely used in Korea at 800 g (ai) per hectare in rice crop. The soil was used from rice field with adequate fertility and pH 4.5-5.8. The study was done in pots (10 cm dia and 7 cm deep).

### Combined effects of allelopathic rice cultivars and herbicide on barnyardgrass

The experimental treatments consisted of two factors: (i). 3 rice cultivars [Kouketsumochi (allelopathic), Dongjinbyeo (non-allelopathic) and K21] grown with barnyardgrass and (ii). herbicide rates 4 (0, 15, 30 and 60 g ha<sup>-1</sup>). Barnyardgrass was grown alone without herbicide as control. The treatments were replicated thrice in completely randomized design.

The pots were filled with the 200 g soil per pot. Fifteen rice seeds and 20 barnyardgrass seeds were sown at 0.5 cm depth in each pot. Herbicide was applied on the soil surface 2 days after sowing. The soil was maintained at saturated soil moisture content in first 5 days and then 30 ml water was added daily during the study period. The pots were placed in growth chamber [25 °C, 14 h light and at 22 °C, 10 h dark]. After 14 days of herbicide application, the height and fresh weight of 5 or 10 barnyardgrass per pot were measured to calculate the inhibitory rate.

#### **Herbicide bioassay for toxicity regression equation**

The treatment consisted of (i). Herbicide rates 5 (0,1.25,2.5,5.0 and 10 mg L<sup>-1</sup>), (ii). Rice cultivars 3 (Kouketsumochi, Dongjinbyeo and K21), (iii). Barnyardgrass alone without herbicide as control. The pots were filled with 200 g soil. The treatments were replicated thrice in complete randomized design. In (i). Twenty pre-germinated weed seeds were sown per pot, while in (ii) ten pre-germinated seeds of 3 rice cultivars and 20 pre-germinated seeds of weed were sown per pot, respectively. The soil was maintained at saturated soil moisture content in first 5 days and then 30 ml water was added daily. The pots were placed in growth chamber [25 °C, 14 h light and 22 °C, 10 h dark]. After 14 days, height and fresh weight of 10 weed plants were measured to calculate the inhibitory rate and to set up a toxicity regression equation.

#### **Allelopathic potential of rice cultivars**

The experiment was done in pots as per Herbicide bioassay. The treatments consisted of (i). Rice cultivars + barnyardgrass and (ii). Barnyardgrass alone [control]. The treatments were replicated thrice in complete randomized design. Fifteen rice seeds and 25 barnyardgrass seeds were sown per pot. Five days after sowing, the small or late germinated seedlings were removed to keep 10 rice and 10 weed seedlings per pot for (i) Treatment and 10 weed seedlings for for (ii) Treatment. Then rice and barnyard grass were grown for 2-weeks in growth chamber [25 °C, 14 h light and 22 °C, 10 h dark]. Thereafter plant height and fresh weight of barnyardgrass were measured.

**Data analysis:** The allelopathic effects of various herbicide rates and rice cultivars were evaluated on the barnyardgrass by IR (inhibitory rate), and analysis of variance was done by DPS (6.5) programme. IR was calculated as under:

$$IR = 100 \times (1 - tr/ck).$$

Where, tr: (treatment) is barnyardgrass grown with rice or herbicide applied; ck: (control) no herbicide applied and barnyardgrass grown alone.

The equation of toxicity regression was set up as under:

$$Y = ax + b,$$

Where, Y: Inhibitory rate, X: Herbicide rates.

Then equation of toxicity regression, LD<sub>50</sub> was calculated to compare, how much rate of herbicide was reduced. IR was converted into the relative herbicide rate as per the toxicity regression equation of herbicide.

## RESULTS AND DISCUSSION

### Herbicide rates and rice cultivars

The rice cultivars had different suppressive effects on barnyardgrass and reduced its growth (Table 1). When herbicide was not applied, Kouketsumochi proved most allelopathic, followed by its descendant of K21, while Dongjingbyeo was least allelopathic. The Kouketsumochi, K21 and Dongjingbyeo decreased the weed height by 44.27, 26.93, and 21.12% and weed fresh weight by 32.7, 24.67 and 6.87% respectively. When barnyardgrass was grown alone and herbicide was applied, the herbicide at 15, 30, 60 g/ha reduced the weed height by 19.80, 30.48, and 43.28% and fresh weight by 49.56, 54.91 and 73.79%, respectively (Table 1). There was significant interaction between the herbicide rates and rice cultivars i.e. herbicide bioactivity varied with different rice cultivars (Figure 1).

Table 1. Effects of rice varieties and herbicides rates on growth of barnyardgrass at 14 days after herbicide application

Treatments	Plant height (%)	Fresh weight (%)
<b>Rice varieties</b>		
Control	0.0 d	0.0 d
Koukishumuchi	44.27 a	32.78 a
K-21	26.93 b	24.67 b
Dongjinbyeo	21.12 c	6.87 c
Mean	23.08	16.08
LSD 0.05	14.63	4.11
<b>Herbicide rate (a.i.g ha<sup>-1</sup>)</b>		
0	0.0 d	0.0 c
15	19.80 c	49.56 b
30	30.48 b	54.91 b
60	43.28 a	73.79 a
Mean	23.39	44.57
LSD 0.05	22.06	20.46

\*Plant height and weight of barnyardgrass with no rice and no herbicide. Data with same letter represent no significant difference at 5% level.

### Rice cultivars and herbicide combined effects

When herbicide was used with or without rice, the weed growth reduction was similar at various herbicide rates (Figure 1). Lower herbicide rates had less effect on weed height and weight i.e. the bioactivity was dependent on herbicide rates. But all cultivars reduced the height and fresh weight of barnyardgrass over no-rice, especially under lower herbicide rates (viz., 15 and 30 g a.i. ha<sup>-1</sup>) (Tables 2 and 3). This suggested that rice cultivars influenced the weed suppression. When herbicide was used without rice pot, the herbicide LD<sub>50</sub> on plant height and fresh weight of weed was 11.83 and 12.6 mg L<sup>-1</sup>, respectively. However, when herbicide was used with rice cultivars, the LD<sub>50</sub> values for plant height and fresh weight of weed decreased to 5.1 and 6.48 mg L<sup>-1</sup> for Kouketsumochi, 5.87 and 8.51 mg L<sup>-1</sup> for K21, 7.82 and 10.26 mg L<sup>-1</sup> for Dongjinbyeo, respectively. Therefore, herbicide rate was reduced (34 to 56.9%) than without rice for weed plant

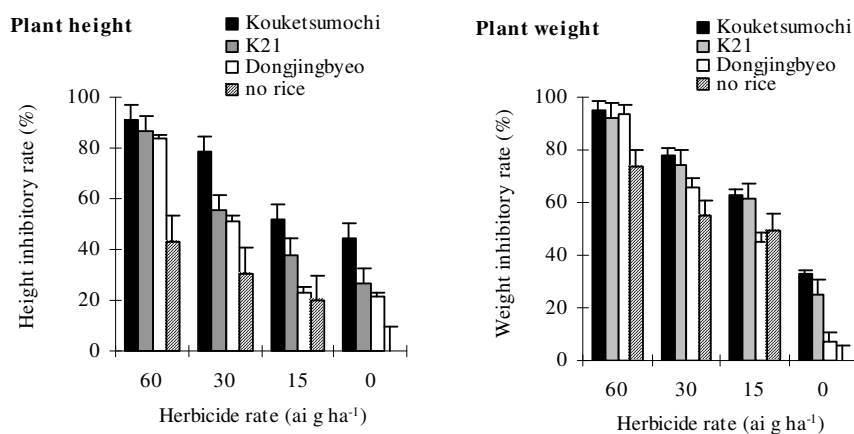


Figure 1. Effects of rice cultivars and herbicide rates on the height and fresh weight of barnyardgrass. a.i : Active ingredient

Table 2. Effects of rice varieties and herbicide rates on plant height (cm)

Rice varieties	Herbicide rate (a.i.g ha <sup>-1</sup> )				LSD 0.05
	0	15	30	60	
Control	0.0 d	19.81 c	30.48 d	43.28 c	10.67
Koukishumuchi	44.27 a	52.0 a	78.53 a	90.88 a	7.73
K-21	26.93 b	38.09 b	55.76 b	86.39 ab	11.16
Dongjinbyeo	21.12 c	22.98 c	51.07 c	83.53 b	1.86
LSD 0.05	5.80	3.18	4.70	4.49	-

Data with same letter in column represent no significant difference at 5% level.

Table 3. Effects of rice varieties and herbicide rates on fresh weight (g/plant)

Rice varieties	Herbicide rate (a.i.g ha <sup>-1</sup> )				LSD 0.05
	0	15	30	60	
Control	0.0 d	49.56 b	54.91 c	73.79 b	5.35
Koukishumuchi	32.78 a	62.64 a	77.91 a	95.12 a	15.27
K-21	24.67 b	61.09 a	74.10 a	92.14 a	13.01
Dongjinbyeo	6.87 c	44.80 b	65.53 b	93.25 a	20.73
LSD 0.05	6.87	1.55	3.81	1.11	-

Data with same letter in column represent no significant difference at 5% level.

height and fresh weight, 34.9 and 36.8% for Koketsumochi and about 17.1 and 24.9% for K21 lower than the non-allelopathic rice cultivar, Dongjinbyeo (Tables 4 and 5). These results indicate that allelopathic rice cultivars could reduce the herbicide dose. Thus with these cultivars, herbicide rate to control the barnyardgrass may be reduced.

Table 4. Herbicide toxicity regression equation and effects of reduced herbicide rates on plant height of barnyardgrass

Treatment	Toxicity regression equations $Y=aX+b$ ( $R^2$ )	LD <sub>50</sub> (mg L <sup>-1</sup> )	Reduced rate of herbicide (%)	
			I*	II**
Herbicide	$Y = 3.4434x + 9.2337$ (0.9645)	11.83		
Herbicide+ K21	$Y = 6.7336x + 10.499$ (0.8693)	5.87	50.38	24.94
Herbicide+ Dongjinbyeo	$Y = 5.5278x + 6.7988$ (0.8951)	7.82	33.90	-
Herbicide+ Kouketsumochi	$Y = 7.207x + 13.27$ (0.8876)	5.10	56.89	34.78

\* Reduced rate I: reduced rate of LD<sub>50</sub> compared to the herbicide LD<sub>50</sub>;

\*\* Reduced rate II: reduced rate of LD<sub>50</sub> compared to LD<sub>50</sub> of Dongjinbyeo.

Table 5. Herbicide toxicity regression equation and effect of reduced herbicide rates on fresh weight of barnyardgrass

Treatment	Toxicity regression equation $Y=aX+b$ ( $R^2$ )	LD <sub>50</sub> (mg L <sup>-1</sup> )	Reduced rate of herbicide (%)	
			I*	II**
Herbicide	$Y = 3.4459x + 6.5697$ (0.9673)	12.60		
Herbicide+ K21	$Y = 6.209x - 2.8357$ (0.9299)	8.51	32.46	17.06
Herbicide+ Dongjinbyeo	$Y = 5.223x - 3.5762$ (0.954)	10.26	18.57	-
Herbicide+ Kouketsumochi	$Y = 6.158x + 10.098$ (0.8508)	6.48	48.57	36.84

\* Reduced rate I: reduced rate of LD<sub>50</sub> compared to the herbicide LD<sub>50</sub>;

\*\* Reduced rate II: reduced rate of LD<sub>50</sub> compared to LD<sub>50</sub> of Dongjinbyeo.

### Rice cultivars

When herbicide was not applied, weed suppression potential of these rice cultivars varied (Figures 2 and 3). Kouketsumochi was the most allelopathic rice cultivar; followed by K21, while Dongjinbyeo was the least one. The allelopathic suppression effect of Kouketsumochi, K21 and Dongjinbyeo on barnyardgrass height was about 45.8%, 31% and 22%, respectively, while suppression effect on barnyardgrass fresh weight was 35.4%, 30.5% and 20.4%, respectively (Table 6). These allelopathic suppression effects were converted into herbicide rates as per the toxicity regression equation (Tables 4 and 5). For plant height and weight, the values of Kouketsumochi's effect were equated to herbicide as 10.6 mg/L and 8.4 mg/L, 6.3 mg/L and 6.9 mg/L for K21, and 3.7 mg/L and 4.0 mg/L for Dongjinbyeo, respectively (Table 6). The results again proved that a potent allelopathic rice cultivar could greatly reduce the herbicide rate for weed control, which may be economical.

Barnyardgrass is found not only in rice, but also in other crops in moist and fertile soils (7). Minimum lethal dosage (MLD) and 50% lethal dosage (LD<sub>50</sub>) evaluates the bioactivity of herbicide on target plant and index of relative toxicity to indicate the bioactivity of two herbicides (2,10,21). In this study, barnyardgrass was used as a target plant and the efficient and sensitive dosage LD<sub>50</sub> was introduced to determine the rice cultivars with allelopathic effect, which is representative and has actual guidance to apply allelopathic cultivars for weed management in rice production.

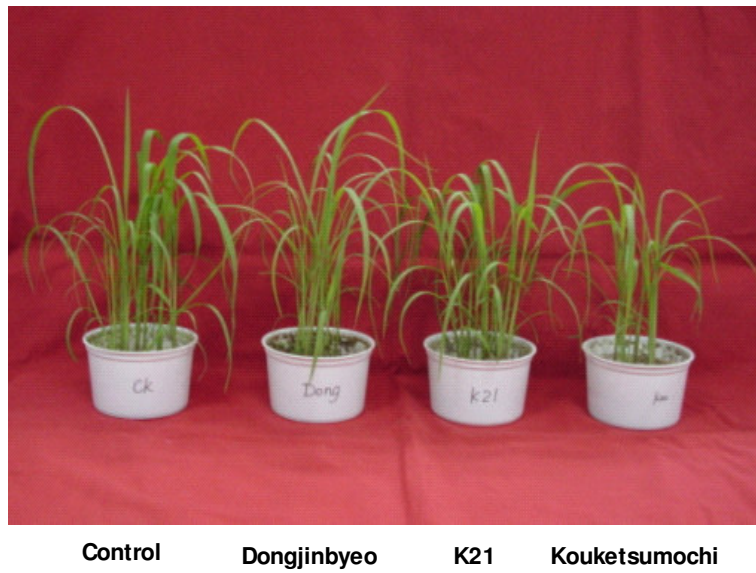


Figure 2. Allelopathic effects of rice cultivars on the growth of barnyardgrass. Control indicates barnyardgrass grown alone. Rice cultivars indicate barnyardgrass grown with each rice cultivar and then rice was cut and removed.

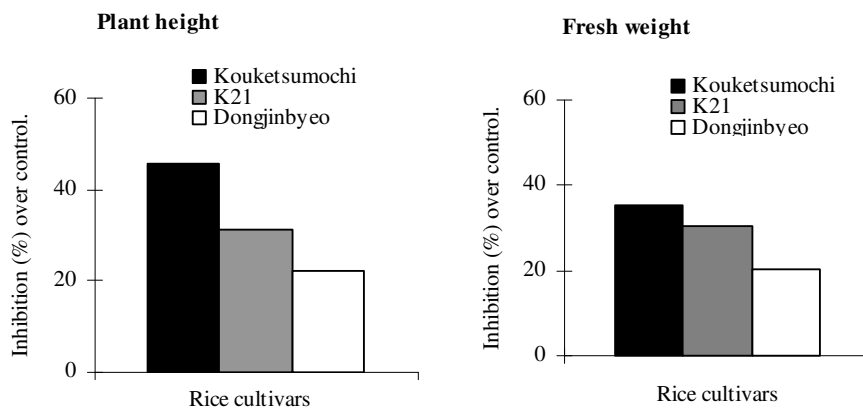


Figure 3. Inhibitory effects of rice cultivars on plant height and fresh weight of barnyardgrass.

Table 6. Inhibitory effects of Test rice cultivars on growth of barnyardgrass seedlings

Rice varieties	Plant height		Fresh Weight	
	Inhibition (%)	Herbicide amount (mgL-1)	Inhibition (%)	Herbicide amount (mgL-1)
Kouketsumochi	45.79	10.61	35.37	8.36
K 21	31.04	6.33	30.51	6.95
Dongjinbyeo	21.99	3.70	20.36	4.00

Weed growth reduction by rice could be due to rice-weed competition and /or inhibitory allelopathic effects. Bastiaans *et al.* (1) reported that plant height was major trait determining competitive ability in plants, followed by early growth rate and rate of tillering.

Applying herbicides at lower rates than recommended by manufacturer may increase the economic returns in rice production (16,17). Gealy *et al.* (9) reported that, with or without propanil, high competitive cultivars, PI312777, Guichao and Teqing, caused more suppression of barnyardgrass and consequently increased rice grain yields than U.S. cultivars, Kaybonner, Lemont and Cypress, which gave higher net returns than commercial cultivars. Although this experiment was done in laboratory, but we found that weed-suppressive rice cultivars, Kouketsumochi and its progeny, reduced the herbicide rate (34.8 and 24.9% in weed plant height, respectively). Thus, combining weed-suppressive rice cultivars with reduced herbicide rates could be an economical alternative to herbicide-intensive weed management programmes and this will lead to more eco-friendly rice cultivation.

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