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SCIENCE DIRECT®
Crop Protection 22 (2003) 873–881
Crop Protection
www.elsevier.com/locate/cropro

Kava root (*Piper methysticum* L.) as a potential natural herbicide and fungicide

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Received 28 February 2003; received in revised form 25 March 2003; accepted 28 March 2003

Abstract

Experiments were conducted to examine the biological effects of Kava, a perennial pepper plant native to oceanic region on paddy weeds and fungi harmful to plants and crops. Kava showed a strong inhibition on growth of barnyardgrass (*Echinochloa crus-galli*), monochoria (*Monochoria vaginalis*), and knotgrass (*Paspalum distichum* L.), which are among the most harmful paddy weeds. Kava completely controlled emergence of monochoria and barnyardgrass at a treated dose of 0.5 and 1.0 g, respectively. Application of Kava at 1 tonne ha^{-1} 6 d after saturating paddy soil with water was an effective treatment. This caused around 80% reduction of natural paddy weed growth and increased tillering and root number of rice. In addition, Kava significantly inhibited growth of the five fungi: *Fusarium solani, Pyricularia grisea, Rhizopus stolonifer, Taphrina deformans*, and *Thanatephorus cucumeris*. The effect on *R. stolonifer* was the greatest and *T. cucumeris* and *P. grisea* were the second most affected. The inhibition of Kava on paddy weeds was species dependent, proportional to the treated doses and inversely proportional to the time after watering. Kava is a promising material, which might be used as natural herbicide and fungicide in the field to reduce the dependence on synthetic herbicide and fungicide in agricultural production.

Keywords: Barnyardgrass; Fungi; Knotgrass; Inhibition; Monochoria; Species dependent

1. Introduction

The inappropriate use of agrochemicals may give rise to undesirable side effects. There may be a need to develop new management systems to reduce dependence on synthetic herbicide and insecticide based on ecological manipulations (Kohli et al., 1998).

The exploitation of allelopathic plants for weed control has gained in importance (Xuan et al., 2003). There are a number of higher plants, which show suppressive effects on other plants in their vicinity, but only some among them have shown effects on weeds and pathogen. These plants are described in Table 1.

Kava is a perennial pepper plant from the oceanic region. In Vanuatu, 8000 tonne of Kava is produced annually, of which around 3750 tonne is exported. Kava may exert its effects through similar mechanism as many more standard drug therapies. It has been shown that the Kava plant contains 15 lactones also called kavalactones, which are chemicals that can affect the central nervous system. Several other types of tranquilizers and relaxant drugs also act upon this area in the brain. Like many other tranquilizers, the relaxant and mild euphoric effects of Kava occur rapidly after ingestion (Pittler and Edzard, 2000). Kava is commonly used to prepare a traditional beverage and pharmaceutical purposes (Pittler and Edzard, 2000).

Our group conducted this study during 2000–2002 to examine (i) the effect of Kava on the growth of several paddy field weeds in laboratory and greenhouse condition, (ii) application of Kava as a natural herbicide for weed control in paddy soil, and (iii) impact of Kava on fungal growth of some plant diseases.

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0261-2194/03/$ - see front matter
doi:10.1016/S0261-2194(03)00083-8

Table 1
Allelopathic potential of some higher plants on crops, pathogens, and weeds

Plant species	Afflicted species	Phenomenon	Identified constituents	Reference
Alfalfa (*Medicago sativa* L.)	Paddy weeds, rice (*Oryza sativa* L.) plant	Reduced 90% paddy weeds and increased 10% rice yield at 1–2 tonne ha^{-1}	Medercapin, 4-methoxymedicarpin, sativan, 5-methozysativan, saponins, salicylic acid, and gallic acid, *p*-coumaric acid, protocatechuic acid, *p*-hydrobenzoic acid, catechin, vanillic acid, vanillin, syringic acid, and ferulic acid	Dornbos et al. (1990), Nakahisa et al. (1994), Xuan et al. (2002, 2003)
Asparagus (*Asparagus officinalis* L.)	Asparagus, tomato (*Lycopersicon esculentum* Mill), lettuce (*Lactuca sativa* L.)	Germination was inhibited by addition of asparagus root to dry soil	3,4-dihydroxy benzoic acid, 2,6-dihydrobenzoic acid, 3,4-dihydroxy phenylacetic acid, 3,4-methoxyacetophen, and *β*-(*m*-hydroxyphenyl) propionic acid	Shafer and Garrison (1986), Young (1986)
Buckwheat (*Fagopyrum esculentum Moench*)	Paddy weeds	Significantly controlled paddy weeds at 2 tonne ha^{-1}	Palmitic acid, stearic acid, arachidic acid, behenic acid, ferulic acid, caffeic acid, chlorogenic acid	Tsuzuki (2001)
Hairy vetch (*Vicia vilosa* L.)	Upland weeds	A promising cover crops for weed control in fields, grass land, and orchards in the central and southern part of Japan		Fujii (2001)
Neem (*Azadirachta indica* A. *juss*)	*Aspergilus niger*, *Fusarium moniliforma*, *Macrophormina phaseolina*, *Drechlea rostrata* in vitro Tungo baciliform, spherical virus	10% neem oil inhibited growth of these pathogen Neem oil and neem cake reduced rice seedling infection by these pathogen	Nimbin, nimbidin, nimbidol, gedunin, sodium nimbinate, queceretin, salannin, azadirachtin	Koul et al. (1989), Sankaram (1987) Saxena et al. (1985)
Red clover (*Trifolium pratense L.*)	Red clover	Injury by continuous cropping	Methoxybenzoic acid, salicylic acid, *p*-hydroxybenzoic acid, isoflavonoids	Katznelson (1972), Chang et al. (1969)
Pink savory (*Satureja thymbra*)	Soil fungi (*Mucor hiemalis and Penicilium citrinum*)	Strong inhibition on mycelia growth of *M. hiemalis* and *P. citrinum* at 0.25 μm ml^{-1}		Vokou (1997)
Sorghum (*Sorghum biocolor*)	Sorghum shoot fly (*Atherigona soccata*), stem borer (*Chilo partellus*)	Resistance of sorghum to sorghum fly and stem borer on was cultivar dependent		Alborn et al. (1997)
Taro (*Colocasia esculenta Scott*)	Taro	Injury by continuous cropping, 59% tuber yield was reduced at the second year cropping		Tsuzuki et al. (1995)
Velvet bean (*Mucuna prurients*)	Weeds	Strong inhibition on weed growth	L-3, 4-dihydroxyphenylalanine	Fujii (2001), Fujii et al. (1990)

2. Material and methods

Kava was imported from Vanuatu as commercial product derived from the roots of the plant only. These roots were ground into powder for all treatments. Chemical composition of the dried Kava powder includes N: 0.37, P: 0.27, K: 0.63, Mg: 0.07, and Ca: 0.46%.

Knotgrass (*Paspalum distichum* L.) is native to North America and is now spreading widely in tropical areas and is a perennial gramineous weed (Holm et al., 1991). In Japan, it is spreading rapidly from Kanto to the west areas. It is reported to be a difficult to control paddy weed in Japan (Chikara, 2003). The knotgrass growing in the paddy field of Experimental Farm of Agricultural Faculty, Miyazaki University, Japan was cut from the fifth node with average length of 18 cm and weight around 11.9–12.1 g. This part of the weed was transferred to the laboratory for use.

Barnyardgrass (*Echinochloa crus-galli* var. *formosensis* Ohwi.) and monochoria (*Monochoria vaginalis* (Burm.f.) Persil var. *plantaginea* Solms.) are among the world's worst weeds and especially in rice in Japan (Holm et al., 1991). Their seeds were collected from paddy fields in 1999. Empty and underdeveloped seeds were discarded by floating in tap water. The remaining seeds were then air dried and hermetically stored at $-20^{\circ}C$ to keep the seed fresh. Seeds of the barnyardgrass were treated with a solution of H_2SO_4 (90%) for 2 min to loosen the seed coat, and rinsed many times with distilled water. Seed of monochoria was cleaned and placed in a growth chamber (25°C, 4000 lx) in a 200 ml glass pot filled with distilled water, and 20 seeds of rice were added to the pot. After 2 d, these seeds were used in all treatments. The germination of these paddy weed seeds was shown to be $\geqslant 70\%$ (using distilled water).

Paddy soil used in greenhouse experiment (pH: 6.2, total C: 2.21%, total N: 0.17%, CEC: 8.8 meq per 100 g soil; CaO: 91, MgO: 13, K_2O: 17, K_2O_5: 18, SiO_2: 25 mg per 100 g soil, respectively) came from the experimental farm of Miyazaki University where early matured rice (var. Koshihikari) had been cultivated and soil collected from up to a 10 cm depth. The soil was air dried and mixed until treatments were carried out. Commercial heated soil (Yamamune commercial Association, Miyazaki City, Japan, which did not have any microorganisms and weed seeds) was used in laboratory experiment [pH: 6.3; EC ($ms\,cm^{-1}$): 0.45; NO_3–N (mg 100 g dry $soil^{-1}$): 19.1; exchangeable CaO, MgO, K_2O, and available P_2O_3 (mg 100 g dry $soil^{-1}$): 251.7, 76.0, 111.4, and 5.21, respectively].

Five fungal species including rhizopus root (*Rhizopus stolonifer* MAFF305786), pearl leaf curl (*Taphrina deformans* MAFF305614), rice blast (*Pyricularia grisea* MAFF101002), rice sheath blight (*Thanatephorus cucumeris* MAFF305844), and papaya dry root (*Fusarium solani* MAFF306358) were provided by Experimental Station of Miyazaki Prefecture, Japan in October, 2000. *Fusarium solani* is known to cause a variety of diseases on many different hosts, especially on papaya. It was reported to be the most common and widespread species of *Furasium* causing papaya fruit rot. The fungus is also known to cause a rot of young (3–5 cm long) papaya fruits especially during wet weather. The fungus enters the seed cavity through the blossom end where it quickly spreads within the fruit and causes the fruit to abort and fall from the tree (Saxena and Sharma, 1981). *Pyricularia grisea* caused rice blast and it is a problem almost everywhere that rice is grown. This fungal disease is estimated to cause production losses of US$55 million each year in South and Southeast Asia. The losses are even higher in East Asia and other more temperate rice-growing regions around the world (Herdt, 1991). Rhizopus rot, caused by *Rhizopus stolonifer*, can be very destructive to harvested fruit. While it can develop in hail-injured or cracked fruit on the tree, it most commonly affects fruit in storage, during transit, and at the marketplace. Ripe fruit of peaches, nectarines, sweet cherries, and plums are most susceptible. Rhizopus fruit rot is usually of minor importance in the field but can cause important post-harvest losses (Nishijima et al., 1990). *Taphrina deformans* is a fungus, which caused peach leaf curl disease that can result in severe early defoliation and crop loss on nearly all peach and nectarine cultivars (Cheah et al., 1993). *Thanatephorus cucumeris* is a fungus causing sheath blight disease, which is prevalent in all rice-growing countries and can cause significant yield losses (Lin et al., 1995).

2.1. Effects of Kava extracts on growth of knotgrass

2.1.1. Laboratory condition

One hundred grams of Kava powder was added to 1000 ml of distilled water, stored at room temperature for 24 h and then filtered through three layers of filter papers. This solution was set as original dose. Dilution of 1/2, 1/4, 1/8, 1/16, 1/32, and 1/64 (50, 25, 12.5, 6.3, 3.2, and 1.6 $g\,l^{-1}$, respectively) of the original concentration (100 $g\,l^{-1}$) of Kava was made with the Hypunch hydroponic solution at 2 $ml\,l^{-1}$ (Yorkey company, Aichi prefecture, Japan). The dilutions were put in a 200 ml triangular glass pot together with three plants of the knotgrass. Control treatments were hydroponic solution. The dishes were placed in a growth chamber (set at: 27°C, 4000 lx, light time: 7:00–19:00). After 25 d, plant height, radicle length, leaf and radicle number, and dry weight of the weed were measured. The hydroponic dilution and solution were changed every 5 d.

In addition, this experiment was carried out in a greenhouse during August 2001. The average temperature in the greenhouse was about 27.4°C. However, the hydroponic solution was double the strength of that

used in laboratory tests. Dilution of 1/10, 1/20, and 1/40 (10, 5, and 2.5 g l^{-1}) of the original dose with the hydroponic solution was arranged. Seven hundred milliliter of the dilution including the original concentration were added to an 800 ml pot. Fifteen days after transplanting the knotweed into the pots, plant height, radicle length, tiller number and dry weight of the weed were measured. The hydroponic solutions were changed every 5 d. Both laboratory and greenhouse experiments were conducted in a completely randomized design with 3 and 5 replications, respectively.

2.2. Effects of Kava on growth of barnyardgrass and monochoria

2.2.1. Application with different doses

Three grams of calcinated soil was put in a 500 ml plastic pot (diameter: 9 cm) and saturated with tap water. Twenty seeds each of barnyardgrass and monochoria were sown at a 2 cm depth in the soil. The powdered Kava root at 1, 0.5, 0.25, and 0.125 g pot^{-1} were simultaneously applied in the pots, respectively. Control received only tap water. Treatments were placed in a growth chamber (set at: 25°C, 4000 lx, light time: 7:00–19:00). After 15 d, weed plants were counted, and plant height, radicle length, and plant dry weight of the two weeds were determined.

2.2.2. Application with different time of treatments

The same method as described in 2.2.1 experiment was carried out. However, Kava powder at 0.25 g was applied in the pots after 20 seeds of barnyardgrass and monochoria were sown at: 0 (immediately after saturating water), 3, 6, and 9 d later. Control received only tap water. The pots were transferred into a growth chamber (set at: 25°C, 4000 lx, light time: 7:00–19:00). After 15 d, weed plants were counted, plant height, radicle length, and plant dry weight of the two weeds were determined. Experiments 2.2.1 and 2.2.2 were carried out in 2002.

2.3. Effects of Kava on natural weed growth in paddy soil

This experiment was conducted in the greenhouse in April–May 2000. The average temperature was 17°C. Paddy soil were filled in a plastic box (diameter: 19, height: 21 cm) and saturated with tap water. Kava powder at 1 tonne ha^{-1} was applied in the boxes, 6 and 11 d after watering as a single treatment. In addition, the dose 1 tonne ha^{-1} was applied as a split dose at two treatment times. The first time was applied with 0.5 tonne ha^{-1} at 6 and 11 d. The latter was treated in the boxes after 10 and 15 d (including the incorporations of 6–16, 6–21, and 11–21 d, the incorporated 11–26 d was not conducted), respectively. Three rice seedlings (var. Koshihikari) were transplanted into the boxes at 1 d after saturating water. After 31 d, type of paddy weeds, their plant number and dry weight were determined. Rice growth including plant height, tiller and panicle number was measured.

2.4. Effect of Kava on fungal growth

This experiment was conducted in the laboratory during September 2001. Kava powder dried at 40°C for 2 d was extracted with 70% methanol at the ratio of 2 g 10 ml^{-1} for 24 h at room temperature. The solution was filtered by three layers of filter papers and was evaporated until dryness by rotary evaporator under reduced pressure. The residue was well mixed with 10 ml of sterilized water and it was set as original concentration (200 g l^{-1}). Its 1/2, 1/4, and 1/8 dilution (100, 50, and 25 g l^{-1}, respectively) was prepared. One milliliter of these doses was blended with 9 ml of PDA (Potato Dextrose Agar) culture solution (Difco company, Japan) and placed in a 9 cm petri dish, respectively. An aliquot of 0.01 mg spores of the fungi were transplanted in the middle of the dishes, respectively. Control treatment was PDA culture solution only. The dishes were put in a growth chamber (set at: 25°C, 4000 lx, light time: 7:00–19:00). The experiment was arranged in a completely randomized design with three replications. After 1 week, radius length of the fungi growth was determined.

The inhibition percentage of the study was calculated as follows:

Inhibition percentage (%) = [1 − (sample extracts/control)] × 100.

All experiments of this study were carried out with at least 3 replications. Data were analyzed using SAS 6.12 version (SAS Institute, 1997) for ANOVA with the least significant difference (LSD) at the 0.05 probability level.

3. Results and discussion

3.1. Effects of Kava extracts on growth of knotgrass

3.1.1. Laboratory condition

Table 2 showed that at all applied doses, Kava significantly inhibited growth of knotgrass as compared with the control. The inhibitory magnitude of Kava was proportional to the dose applied. Especially, at 25 g l^{-1}, radicle growth and leaf number of the weed were completely suppressed. Table 2 data show, radicle and leaf growth of the knotgrass were the most sensitive to Kava extract. At the highest dose (100 g l^{-1}), Kava controlled around 50% of weed emergence.

3.1.2. Greenhouse condition

At the lowest (2.5 g l^{-1}), except for plant height, Kava extract markedly inhibited growth of knotgrass including radicle length, tiller number and dry weight

Table 2
Growth percentage of knotgrass treated with Kava extract in laboratory and greenhouse condition as compared with the respective control

Concentration ($g l^{-1}$)	Plant height	Radicle length	Leaf number	Radicle number	Dry weight
Laboratory					
0.0	100a(0.0)	100a(0.0)	100a(0.0)	100a(0.0)	100a(0.0)
1.6	86.4b(13.6)	75.8b(24.2)	67.3b(32.7)	55.4b(44.6)	87.0b(13.0)
3.2	59.1cd(40.9)	42.4c(57.6)	46.7c(53.3)	38.4c(61.6)	87.0b(13.0)
6.3	65.2c(34.8)	46.2c(53.8)	53.3c(46.7)	52.4b(47.6)	74.8c(25.2)
12.5	62.8cd(37.2)	19.7d(80.3)	53.3c(46.7)	35.4c(64.6)	87.8b(11.2)
25.0	56.1d(43.9)	0.0e(100.0)	53.3c(46.7)	1.6d(98.4)	39.7e(60.3)
50.0	55.3d(44.7)	0.0e(100.0)	0.0d(100.0)	0.0d(100.0)	56.5d(43.5)
100.0	55.3d(44.7)	0.0e(100.0)	0.0d(100.0)	0.0d(100.0)	32.1f(67.9)
LSD(0.05)	8.0	4.6	12.2	6.5	5.8
CV%	6.8	7.5	15.0	10.7	4.7
Concentration ($g l^{-1}$)	Plant height	Radicle length	Tiller number	Dry weight	
Greenhouse					
0.0	100a(0.0)	100a(0.0)	100a(0.0)	100a(0.0)	
2.5	93.1ab(6.9)	54.1b(45.9)	80.2b(19.8)	76.2b(23.8)	
5.0	87.5b(12.5)	46.2b(53.8)	77.2b(22.8)	74.1bc(25.9)	
10.0	65.6c(34.4)	32.8c(67.2)	47.1c(52.9)	69.1c(30.9)	
LSD(0.05)	8.6	8.7	8.7	6.3	
CV%	5.3	8.0	6.1	4.2	

Column with the same letter is not significantly different at $P = 0.05$.
Value in the parentheses are inhibition percentage over control.

(Table 2). At the dose of $5.0\,g\,l^{-1}$, growth of the weed was slightly reduced than that of the $2.5\,g\,l^{-1}$. However, at the strongest applied dose ($10\,g\,l^{-1}$), emergence of knotgrass was significantly suppressed as compared with other doses and the control. However, there was no remarkable reduction between dry weights of the two dose 5 and $10\,g\,l^{-1}$. Radicle length and tiller number were sequentially the most sensitive to Kava extract (Table 2).

Results in this experiment indicated that Kava extract resulted in strong inhibition on the growth of knotgrass. The magnitude of Kava on the weed growth was proportional to the dose applied. Radicle, leaf and tiller growth of knotgrass were the most sensitive to the inhibition of Kava.

3.2. Effects of Kava on growth of barnyardgrass and monochoria

3.2.1. Application with different doses

Results in Table 3 showed that at the lowest application (0.125 g), only plant height of barnyardgrass was significantly reduced (31.7% of inhibition) whereas radicle length was markedly stimulated (20% of stimulation) as compared with control. At higher dose (0.25 g), growth of barnyardgrass was significantly suppressed as compared with both control and the lowest dose (Table 3). At the highest concentration (1.0 g), emergence of barnyardgrass was completely controlled (100% of inhibition).

Table 3
Growth percentage of barnyardgrass and monochoria treated with different concentration of Kava as compared with the respective control

Concentration (g)	Weed number	Plant height	Radicle length	Dry weight
Barnyardgrass				
0.0	100.0a(0.0)	100.0a(0.0)	100.0b(0.0)	100.0a(0.0)
0.125	100.5a(−0.5)	68.3b(31.7)	120.0a(−20.0)	98.5a(1.5)
0.25	67.5b(22.5)	23.3c(76.7)	52.7c(47.3)	55.1b(44.9)
0.5	41.7c(58.3)	5.1d(94.9)	26.1d(73.9)	0.3c(99.7)
1.0	0.0d(100.0)	0.0e(100.0)	0.0e(100.0)	0.0c(100.0)
LSD (0.05)	5.8	3.4	6.0	4.7
CV%	6.3	4.7	5.4	5.1
Monochoria				
0.0	100.0a(0.0)	100.0a(0.0)	100.0b(0.0)	100.0a(0.0)
0.125	103.4a(−3.4)	98.3a(1.7)	113.0a(−13.0)	100.0a(0.0)
0.25	50.8b(49.2)	30.5b(69.5)	48.1c(51.9)	34.7(65.3)
0.5	0.0c(100.0)	0.0c(100.0)	0.0d(100.0)	0.0(100.0)
1.0	0.0c(100.0)	0.0c(100.0)	0.0d(100.0)	0.0(100.0)
LSD (0.05)	5.8	7.5	3.2	7.0
CV%	6.3	9.1	3.4	8.0

Column with the same letter is not significantly different ($P = 0.05$).
Numbers in the parentheses indicates inhibition percentage over control.
Values in the parentheses with (−) indicate promotion percentage over control.

The lowest dose did not show any significant impact on monochoria growth (Table 3). However, at 0.25 g, Kava reduced more than 50% emergence of monochoria.

At 0.5 and 1.0 g, there was no emergence of monochoria (100% of inhibition). Results in Table 3 specified that Kava could markedly control growth of barnyardgrass and monochoria at the dose of 0.25 g. However, Kava showed a stronger effect on the growth of monochoria than that of barnyardgrass. In addition, the inhibitory effect of Kava on these paddy weeds was proportional to the increase of applied dose.

3.2.2. Application with different time of treatments

Table 4 showed that when Kava was applied immediately after watering it achieved significant weed control of both barnyardgrass and monochoria. At this time, a roughly 50% emergence of these weeds were reduced except for the weed number of barnyardgrass. Plant height of the two weeds and radicle length of monochoria were the most affected (79.5%, 80.0%, and 71.5% of inhibition). At 3 d after saturating water, the weed number of barnyardgrass was not markedly suppressed, but emergence of monochoria and plant height, radicle length and dry weight of barnyardgrass were significantly inhibited as compared with control. However, the reduction percentage was lower than those at 0 d (immediately after watering). At 6 d after pouring water, the inhibitory magnitude of Kava on the two weeds was significantly weaker than that at the 3 d (Table 4). At 9 d, weed number of the two weeds and radicle length of monochoria had no effects as compared with the control. The suppressive degree of Kava on barnyardgrass and monochoria was markedly less effective than that at 6 d.

Results of this experiment indicated that Kava appeared to have the strongest effect on barnyardgrass and monochoria growth at 0–3 d after saturating water to the soil. The inhibitory magnitude of Kava on these weeds was inversely proportional to the treated time after applying water to the soil.

Table 4
Growth percentage of barnyardgrass and monochoria with different treated time of Kava as compared with the respective control

Treated time (d)	Weed number	Plant height	Radicle length	Dry weight
Barnyardgrass				
Control	100.0a(0.0)	100.0a(0.0)	100.0a(0.0)	100.0a(0.0)
0	76.7b(23.3)	20.5e(79.5)	54.2d(45.8)	58.2d(41.8)
3	92.7a(1.3)	34.5d(65.5)	51.2d(48.8)	58.2d(41.8)
6	92.7a(1.3)	45.1c(54.9)	68.5c(31.5)	78.2c(21.8)
9	95.5a(0.5)	77.5b(22.5)	82.3b(17.7)	89.2b(10.8)
LSD (0.05)	9.5	7.0	8.3	10.0
CV%	5.7	6.9	6.4	7.1
Monochoria				
Control	100.0ab(0.0)	100.0a(0.0)	100.0a(0.0)	100.0a(0.0)
0	40.7d(59.3)	20.0d(80.0)	28.5d(71.5)	57.7d(42.3)
3	74.5c(25.5)	38.2c(61.8)	43.6c(56.4)	67.7c(32.3)
6	96.1b(3.9)	72.1b(27.9)	76.4b(23.6)	67.7c(32.3)
9	101.8a(−1.8)	74.5b(25.5)	102.5a(−2.5)	74.9b(25.1)
LSD (0.05)	5.2	6.7	3.6	7.1
CV%	3.5	11.2	2.8	5.3

Column with the same letter is not significantly different ($P = 0.05$).
Numbers in the parentheses indicates inhibition percentage over control.
Values in the parentheses with (−) indicate promotion percentage over control.

3.3. Application of Kava in paddy soil

3.3.1. Effects of Kava on natural weed growth in paddy soil

In the untreated control plots, emergence of six major paddy weeds in paddy field were observed including barnyardgrass (*Echinochloa crus-galli*), needle spikerush (*Eleocharis acicularis*), kayatsurigusa (*Cyperus microiria*), spike-flowered rotala (*Rotala indica*), water starwort (*Callitricle verna*), and monochoria (*Monochoria vaginalis*). At 6 d after watering, growth of barnyardgrass was completely controlled by Kava (Table 5). At 11 and the two times of treatments of 11–21 d, plant number of this weed was strongly reduced as compared with control. However, at 6–16 d, there was no effect on barnyardgrass growth and at 6–21 d, plant number of this weed was increased. Table 5 showed that treatment at 6 d after watering was the most effective to growth of the six major paddy weeds than other treatments.

Application at 3 d after watering recorded the strongest weed control (78.7%) shown by total plant numbers, which was significantly reduced as compared with the other treatment times. Later applications showed reduction of weed number and the 6–16 d period was noted to have the greatest impact (48.1% of inhibition) and the 6–21 d period was the second most effective (47.2% of inhibition) (Table 5).

Dry weight of paddy weeds were significantly decreased by all treatments and at the 6 d, dry weight of the weeds was drastically reduced (86.3% of inhibition). Application of Kava at 6–16 d was the second most effective for weed control in paddy soil (66.3% of inhibition). Treatments at 11 and 6–21 d had an identical magnitude of paddy weed control (56.8%) while the 11–21 d was the least effective.

3.3.2. Effects of Kava on rice growth

Table 6 showed no significant difference of rice plant height as compared with control. However, Kava showed a slight inhibition on plant height of rice (roughly 10%) as compared with control, but no significant difference among treatments was found (Table 6).

At 6–21 d Kava increased tiller number of rice (35.0%) with the 6 d was the second most effective (21%). The application at 6–21 d significantly promoted

Table 5
Effects of Kava with different time of treatment on natural weed growth in paddy soil

Treated time	Type of paddy weeds (plant)								Total dry weight (g)
	A	B	C	D	E	F	G	Total plant number	
Control	0.7	94.7	58.3	15.7	21.7	28.3	15.3	234.7a(0.0)	0.95a(0.0)
6 days[a]	0.0	11.0	27.0	0.7	2.0	7.7	2.0	50.0c(78.7)	0.13e(86.3)
11 days[a]	0.5	71.0	47.5	4.5	4.5	23.5	3.0	154.5b(34.2)	0.41c(56.8)
6–16days[b]	0.7	58.0	36.0	3.7	4.3	13.0	6.0	121.7b(48.1)	0.32d(66.3)
6–21 days[b]	1.0	34.3	5.3	8.3	10.0	23.3	8.3	124.0b(47.2)	0.41c(56.8)
11–21 days[b]	0.3	26.7	52.7	9.3	11.0	28.0	12.3	140.3b(40.2)	0.56b(41.1)
LSD (0.05)								36.9	0.07
CV%								15.7	7.9

Column with the same letter is not significantly different ($P = 0.05$)
Numbers in the parentheses indicates inhibition percentage over control
Values in the parentheses with (−) indicate promotion percentage over control
[a] Treated one time with 1 tonne ha^{-1}.
[b] Treated two times with 0.5 tonne ha^{-1}, respectively. A: *Echinochloa crus-galli*, B: *Eleocharis acicularis*, C: *Cyperus microiria*, D: *Rotala indica*, E: *Callitriche verna*, F: *Monochoria vaginalis*, G: Other weeds.

Table 6
Effects of Kava with different time of treatment on rice growth in paddy soil

Treated time	Rice growth		
	Plant height (cm)	Tiller number (plant)	Panicle number (plant)
Control	29.9a(0.0)	14.3d(0.0)	22.3ab(0.0)
6 days[a]	26.8a(10.4)	17.3ab(−21.0)	27.7a(−24.2)
11 days[a]	26.8a(10.4)	14.6cd(−2.1)	21.3b(4.5)
6–16 days[b]	26.6a(11.0)	16.7bc(−17.0)	24.7ab(−11.0)
6–21 days[b]	26.9a(10.0)	19.3a(−35.0)	22.7ab(−2.0)
11–21 days[b]	27.1a(9.4)	15.7bcd(−9.8)	22.0b(1.3)
LSD (0.05)	5.3	2.2	5.4
CV%	10.8	7.5	12.8

Column with the same letter is not significantly different ($P = 0.05$).
Numbers in the parentheses indicates inhibition percentage over control.
Values in the parentheses with (−) indicate promotion percentage over control.
[a] Treated one time with 1 tonne ha^{-1}.
[b] Treated two times with 0.5 tonne ha^{-1}, respectively.

tiller number of rice (17%), but treatments at 11 and 11–21 d recorded less impact (Table 6). In addition, treatment at the 6 d had the most stimulative effect on panicle number of rice (24.2%) and the 6–16 d was the second most strongest (however, it was not significantly increased as compared with the control). Other treatments either had a very slight increase or reduction of panicle number (Table 6).

Observations in these experiments suggested that the application of Kava with 1 tonne ha^{-1} at 6 d after watering gained the greatest weed control (roughly 80% weed reduction) and significant increase of tiller and panicle number (about 20%). The second most effective was at 6–16 d (with 0.5 tonne ha^{-1}application of Kava, respectively) caused approximately 50% weed control and approximately 10% growth of tiller and panicle number (Tables 5 and 6). It agreed with results in Table 3 that the weed control magnitude of Kava was inversely proportional to the time after saturating water in paddy soil.

3.3.3. *Effect of Kava on the fungal growth*

Results in Table 7 indicate that Kava appeared to have the strongest effect on *R. stolonifer* growth. At the dose of 100 g l^{-1} and original concentration (200 g l^{-1}), Kava completely inhibited emergence of this fungus (Table 7). At 50 and 25 g l^{-1}, Kava also recorded the highest suppression on *R. stolonifer* than the other fungi studied (85.5% and 44.0% of inhibition, respectively). At the original dose, *T. cucumeris* and *P. grisea* were sequentially the most sensitive to Kava (87.7% and 85.8% of inhibition, respectively). Growth of *T. deformans* and *F. solani* were strongly reduced as compared with control (71.6% and 61.2%), but they were less sensitive to Kava effect than those of *R. stolonifer*, *T. cucumeris* and *F. solani* (Table 7). At this dose, except for *T. cucumeris* and *P. grisea*, the impact of Kava on *R. stolonifer, F. solani* and *T. deformans* was species dependent.

Observations in this experiment showed that the suppression of Kava on the five fungi studied was proportional to the applied dose. At the weakest dilution, Kava gave around 25–45% growth reduction of these harmful fungi (Table 7). At the dose of 100 g l^{-1}), the inhibition was fluctuated around 55–100%. At the original concentration (200 g l^{-1}), Kava entirely inhibited *R. stolonifer* growth. However, this dose gave only 61.2% decrease of *F. solani*. The magnitude of Kava inhibition on individual fungi appeared to be species dependent and more work will be needed on the other species.

Table 7
Growth percentage of fungi treated with Kava extract as compared with the respective control

Dose ($g l^{-1}$)	Fungi species					LSD (0.05) between row
	Fusarium solani	*Pyricularia grisea*	*Rhizopus stolonifer*	*Taphrina row deformans*	*Thanatephorus cucumeris*	
0.0	100.0a(0.0)	100.0a(0.0)	100.0a(0.0)	100.0a(0.0)	100.0a(0.0)	0.0
25.0	74.2b(25.8)	71.4b(28.6)	56.0b(44.0)	69.5b(30.5)	73.9b(26.1)	13.6
50.0	60.1c(39.9)	57.2c(42.8)	14.5c(85.5)	58.3b(41.7)	63.7c(36.3)	20.0
100.0	56.7c(43.3)	35.6d(64.4)	0.0d(100.0)	33.1c(66.9)	43.3d(56.7)	9.6
200.0	38.8d(61.2)	14.2e(85.8)	0.0d(100.0)	28.4c(71.6)	12.3e(87.7)	7.4
LSD (0.05)	11.1	7.8	7.3	11.5	8.6	
CV%	9.3	7.7	11.7	10.9	8.0	

Column with the same letter is not significantly different ($P = 0.05$).
Values in the parentheses indicate inhibition percentage over control.

4. Conclusion

Findings in this study confirmed that Kava root had strong allelopathic activity, with significant inhibition on barnyardgrass, monochoria and knotgrass as well as five harmful fungi. Kava might be a promising material to biologically control the fast expansion of these paddy weeds. The inhibitory magnitude of Kava to paddy weeds was proportional to applied dose and was inversely proportional to the time after saturating water to the soil. Specifically, Kava could completely control growth of barnyardgrass and monochoria at 1.0 and 0.5 g in bioassays, respectively. Kava also exhibited a strong inhibition on natural weed growth in paddy soil and the application of 1 tonne ha^{-1} at 6 d after watering showed the most effective weed control and increased rice yield. Results in this study indicated that the effect of Kava on paddy weed and fungi growth was species dependent. Kava seemed to be a promising material and might be used as potential natural herbicide and pathogen control to reduce the dependence on synthetic herbicide and pesticide in agriculture practice. However, in March 2002 the US Food and Drug Administration (FDA) warned persons who have liver damage or who are taking medications that impair liver function to check with a doctor before taking Kava. Liver-related risks associated with the use of Kava have prompted regulatory agencies in other countries, including Germany, Switzerland, France, Canada, and the United Kingdom, to take action ranging from warning consumers about the potential risks of Kava use to removing Kava-containing products from the marketplace. Although liver damage appears to be rare, FDA believes consumers should be informed of this potential risk (FDA, 2002). Therefore, Kava and other natural products, which showed strong weed reduction but are toxic, might affect the quality agricultural products and this matter need evaluation. In addition, research on the efficacy of Kava with different applied dose and time of treatments on other specific paddy weeds and harmful plant pathogens should be further examined. The isolation and characterization of growth inhibitors, which might be responsible for the strong allelopathic potential of Kava, is needed.

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