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EVALUATION OF ALLELOPATHIC POTENTIAL OF RICE LANDRACES (*ORYZA SATIVA* L.) ON THE GROWTH OF BARNYARDGRASS (*ECHINOCHLOA CRUS-GALLI* P.BEAUV) IN DIFFERENT SCREENING CONDITIONS

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Abstract

The objectives of this study were to evaluate allelopathic potential of the total 51 Vietnamese rice landraces (*Oryza sativa* L.) collected from different ecosystems on the growth of barnyardgrass (*Echinochloa crus-galli*) in the different screening conditions. In laboratory screening, Nanh chon, Lua Tho, Nang Quat Bien, Ble Blau and Vang Thom landraces exhibited the greatest weed suppressing against the shoot length (SL) and root length (RL) of barnyardgrass by over 60%. In greenhouse, 5 landraces, Vang Quat Bien, Nanh Chon, Lua Tho, Bulu Pan dark, Huong Chiem and Nang Quat Vang revealed significant inhibition from 60.0% - 70.0% on SL of barnyardgrass. In field trial, 8 landraces demonstrated SL inhibition over 70.0%. The highest average inhibition (AI) was found in 3 rice landraces including Ble Blau do, Huong Chiem and Vang Quat Bien by over 50.0%. Rice allelopathic activity is landraces ─ dependent and varietal groups ─ dependent, of which the traditional none sticky group landraces (TNS) were the highest, followed by the improved varieties (IV), while the least was the traditional sticky landraces (TS). The correlation coefficient showed strikingly different allelopathic potential values in laboratory – greenhouse and laboratory ─ field and field ─ greenhouse screenings. The results have provided useful information to further develop allelopathic rice lines via breeding program for sustainable weed management in this country.

Key words: Allelopathy, E*chinochloa crus-galli*, Weed inhibition, Landrace.

Introduction

Rice (*O. sativa* L.) is one of the most important cash crops which is providing daily food for more than 90 million persons in this country. Rice is grown approximately 82% of the arable land and plays a key role in the economy of the country. According to the report of MARD (2015), the total rice growing areas were approximately 7.83 million/ha in 2015, increased by 18.7 thousand ha to compare to 2014, producing a total of 45.2 million tons of milled rice, equivalent to 5.7 ton/ha on average. Vietnam is currently one of the biggest rice exporters in the world. However, most of rice production has been exported to the developing countries (Khanh *et al*., 2013).

Rice in this country is being coped with both abiotic and biotic stresses causing low rice yield compared to other rice-producing countries. Among the adverse factors, weed infestation is one of the most challenges to rice production in this country. It is considered a major biotic limitation and persistent problem, leading to severe economic losses (about 46% rice yield reduction in Mekong Delta) (Chin, 2001). Synthetic herbicides use can reduce time-spent for weed control and stabilize rice production. Nevertheless, intensive herbicide application in rice production also has potential drawbacks. Apart from its cost, overuse herbicides are being encountered with negative problems in this country such as environmental contaminants, unsafe agricultural products, weed-resistant herbicides, and human health concerns. Herbicide application for weed managerment only in rice was significantly enhanced from the early 1990, and strikingly increased ≈ 42.000 ton/year in 2012, equivalent to 300 million USD (ILS, 2013). Therefore, improvement of both rice quality and yield as well as minimizing the overuse of synthetic herbicides are an imperative work. Biological weed management through the use of allelopathy may effect a yield improvement without environmental cost, which is one of the most important considerations for scientists working to secure the world's food supply for coming generations (Khanh *et al.*, 2013).

Allelopathy is a biological phenomenon, simply understood as the ability of plant to suppress or stimulate growth of nearby other plants in the environment by chemical means. Much worldwide attention has been paid on plant allelopathy research since raising the evidence of allelopathy use as a biological tool to reduce weed growth and protect crops against interference of weeds and increased crop yields (Berendji *et al*., 2008; Anuar *et al*., 2015; Shah *et al*., 2016; Basharat *et al*., 2017). Allelopathic research on rice was initially launched in the early 1970s and has been widely studied in many countries in the world. Dilday *et al.*, (1994) screened over 10.000 rice lines for allelopathic potential on ducksalad [*Heteranthera limosa* (Sw.) Willd.]. Olofsdotter *et al.*, (1997) reported that 45 out of 1000 screened rice varieties revealed promising allelopathic activity against one or more paddy weeds. About 20-40% of thousands rice varieties in Egypt showed strong allelopathic activity against indicator plants (Hassan *et al*., 1998). To date, over 16.000 rice varieties collected from 99 countries have been screened for their allelopathic potential. It is possible to use allelopathic rice varieties as an ideal allelopathic component to control weeds via plant breeding (Khanh *et al*., 2013).

Rice allelopathy research has only been performed sporadically in Vietnam, of which Chau *et al.*, (2008) and Khanh *et al.*, (2009) evaluated the 92 Vietnamese rice varieties in bioassay and reported out of 16 varieties obtained high allelopathic properties against the growth of lettuce (*Lactuca sativa*), kale (*Brassica oleracea*) and barnyardgrass. There are thousands of rice landraces including native and local rice varieties which have not been screened for their allelopathic potential. Hence, the main objectives of this study were to evaluate allelopathic potential of 51 Vietnamese rice landraces against the growth of barnyardgrass in the differential screening conditions (laboratory, greenhouse and field). The variation of correlation among rice landraces based on the values of shoot length (SL), root length (RL) and dry weight (DW) between laboratory-greenhouse, laboratory-field and greenhouse-field screenings were also assessed.

Materials and Methods

Materials and germination test: The 51 rice landraces were collected from some specific provinces in the North Vietnam in 2014. Rice landraces were classified into 3 types based on the different varietal groups of their origins and habitats: (i) traditional none-sticky (TNS) (27 landraces); (ii) improved varieties (IV) (14 landraces); and traditional sticky (TS) (10 landraces). Barnyardgrass seeds collected in paddy field in 2015 were used as the indicator plant. The Empty and undeveloped seeds were discarded by floating in tap water. The remaining seeds were air-dried and then hermetically stored at –20ºC. Before performing the experiment, the rice and barnyardgrass seeds were incubated at 40ºC in oven–dried for 5 days to break seed dormancy. Barnyardgrass seeds were then sterilized with 1% sodium hypochlorite for 30 min and rinsed several times with distilled water. In germination check, germination ratio of seeds was randomly examined and shown to be over 90%.

Laboratory bioassay: The rice landraces were screened in the laboratory condition for their allelopathic potential against the growth of barnyardgrass following to the method of Khanh *et al.*, (2013). Briefly, 20 seeds of each rice landraces were evenly sown in a Petri dish (9 cm in diameter) lined with filter paper (Whatman No.42) and added 10 ml of distilled water. After 2 days, 20 seeds of barnyardgrass were evenly inter-planted between the rice seeds. The Petri dishes were then transferred into a growth chamber (25ºC, 4000 lux, lighted time: 9.00 –17.00, humidity: 75%). After 7 days, the number of germinating barnyardgrass seeds was counted, and the SL and RL were recorded. The seedlings of barnyarngrass were kept in oven at 60ºC for 5 days to determine the dry weight.

Greenhouse screening: All rice landraces were simultaneously examined in a greenhouse following by the method of Khanh *et al.,* (2009) with some modifications. Ten seeds were planted in a Petri dish (9 cm in diameter) lined with the double water-wetted filter paper. The Petri dishes were transferred into the growth chamber (28ºC, 4000 lux, lighted time: 9.00-17.00, humidity: 75%) 3 days for germination. A set of plastic trays included a small pots (38 mL, 5 cm in diameter) and big pots (70 mL, 7 cm in diameter) were used. The hole at bottom of each pot was wrapped by a plastic label to prevent water leaking out from the interstice of trays' holes. Simultaneously, the small pot was discretely cut from the set of tray, and inserted in a big pot, then filled with a wet soil media (pH 4.5-5.8, EC 1.0±0.2, N 1100± 100 mg/kg, P_2O_5 400±100 mg/kg). One finest healthy seedling amongst 10 germinated rice seedlings of each rice landrace was selected and transplanted at the center of the inserted small pot-tray by hand. The trays planted rice seedlings were then transferred to greenhouse in spring season of 2014. Greenhouse temperature was set around 25 – 30º C by water cooling system and tap water was provided every 2 day to all pots. After 28 days of growing, 12 healthy seeds of barnyardgrass were evenly transplanted around the rice plant. The pots planted with barnyardgrass seeds only were used as the controls. Fourteen days after barnyardgrass transplanted, they were cut at bottom soil surface. Allelopathic values based on SL and DW of barnyardgrass were determined.

Field screening: Field screening was performed at the Experimental Farm of Agricultural Genetics Insitute in the summer season 2015. The method was carried out following the report of Ahn *et al.*, (2005). Rice seeds were soaked in tap water for 2 days and treated with a fungicidal chemical at 0.05% for 24 h, then grown in seedling beds for 20 days. The paddy field was divided in plots with 3.3 m^2 in area. Each plot was well covered by the nylon for anti-penetration from other plots. One seedling of each rice landrace was transplanted by hand in the plots (30 x 15 cm in density). Two weeks after grown, 25 days-old barnyardgrass plants taken from the seed beds were inter-planted in 5 rows across the rice rows. No herbicide was applied. The pesticides were used following the conventional method of rice cultivation in Vietnam. The plots planted with barnyardgrass seedlings only were used as the controls. Measurement was recorded 60 days after planted. Barnyardgrass plants from each row were harvested and measured. The biomass of weeds naturally grown in other experimental plots in each rice landrace was also collected by hand in the area of 50 x 50 cm^2. For DW, barnyardgrass seedlings were kept in oven–dried at 60ºC for 5 days and weighted. Additionally, the inhibition percentage (%) between treatment and the control was calculated by the equation:

$$\text{Inhibition (\%)} = \frac{\text{(Control-rice variety treatment)}}{\text{Control}} \times 100$$

The inhibition magnitudes against barnyardgrass growth including the SL, DW of the sampled barnyardgrass were recorded as an average inhibition (AI).

Statistical analyses: The laboratory bioassay was conducted with three replications. Greenhouse and field experiments were carried out in a completely randomized design with 3 replications. The analysis of variance for all data was recorded using the general linear model procedure of the statistical analysis system program (SAS Institute, 2011) and pooled mean values were separated on the basis of the least significant differences (LSD) at the 0.05 probability level. Correlation coefficient between laboratory-field, laboratory-greenhouse and greenhouse-field among the landraces were calculated. The inhibition against SL and DW of barnyardgrass were presented as the allelopathic factors.

Results

Allelopathic potential among rice landraces in laboratory condition: For GI, Vang Quat Bien revealed the greatest inhibition (30.1%), followed by Lua Tho (29.2%) and other 6 landraces: Nang Thom, Nanh Chon, Bot Bui SoMS16, Nang Quat Vang, Nang Thom Nhem and BT landraces showed inhibition by range from 20.0% to 28.0%, respectively. Seventeen landraces exhibited negligible inhibition by less than 3.0%. For SL inhibition, 3 rice landraces, Nanh Chon (61.4%), Lua Tho (61.0%) and Vang Quat Bien (62.2%) showed the highest suppression. Four landraces: Nang Quat Vang, Vang Thom and Tau Huong had shown inhibition by over 50%. While, allelopathic effects on 7 landraces varied from 40.0 % to 47.0%, while 18 landraces showed medium SL inhibition ranging from 10.0% to 20.0%. For RL inhibition, 2 rice landraces Ble Blau do and Vang Thom had exhibited the strongest suppression by 61.3% and 62.5%, respectively. Six landraces suppressed the RL from 50.0% to 59.0%, respectively. There were 23 landraces having allelopathic effects fluctuating from 20.0% to 47.0% and 6 landraces showed negligible inhibition less than 5.0% (Table 1).

For DW, Vang Thom exposed the highest inhibition (39.0%), followed by Nang Quat Vang (37.0%) and Lua Tho (36.4%) , the next was Vang Quat Bien (35.8%), Nanh Chon (35.6%), Bot Bui So MS16 (32.6%) and Tep Hang Som (30.1%), respectively. Eight landraces disclosed inhibitory effects from 20.0% to 29.0%, while 15 landraces revealed DW inhibition lower than 10.0%, after all, Than Nong Duoi was the lowest DW inhibition by 0.5%.

In general, all landraces have shown allelopathic effects on G, SL, RL and DW of barnyardgrass growth. For average inhibition (AI), based on the values of G, SL, RL and DW, 5 landraces have exerted inhibition over 40.0%. Among them, Lua Tho and Nanh Chon displayed the greatest allelopathic effect by 45.2% and 43.8%, respectively, followed by Vang Quat Bien (42.9%), Nang Quat Vang (42.4%), Vang Thom (42.1%). AI suppression ranged from 31.0 %-38.0% in 8 landraces. Seven landrace was lower inhibition by 10.0%.

On the other hand, amongst the varietal groups for AI values: it showed that TNS (2.0% - 45.2%), TS (3.3% - 14.7%) and IV (2.6% - 22.0%), respectively. Also, total inhibition factors among the landrace were ranked: RL (26.9%) > SL (24.3%) > DW (15.7%) > G (10.2%), respectively (Table 1).

Allelopathic potential of the landraces in greenhouse condition: The greatest SL inhibition was Vang Quat Bien (70.4%). Five landraces showed SL inhibition by over 60.0%, of which the potent SL inhibition was observed in Nanh Chon (65.3%) and Lua Tho (65.1%), followed by Bulu Pan dark (64.2%), Huong Chiem (63.2%), and the last was Nang Quat Vang (60.8%), respectively. Seven landraces showed SL suppression ranging from 51.4% to 59.7%. Six landraces exhibited SL inhibition over 40.0%. Similarly, 10 landraces exhibited SL inhibition by over 30.0%. The other landraces had SL inhibition from 15.0% to 29.0% (Table 2).

It noted that all landraces demonstrated SL inhibition with a wide range from 15.6% to 70.4%. For DW suppression, Vang Quat Bien exerted the maximum inhibition by 41.2%, followed by Huong Chiem (40.4%). While, BT09 displayed the lowest DW inhibition (0.7%). There were 11 landraces showed allelopathic effects from 30.1% to 39.6%, respectively. Thirteen landraces showed DW reduction by over 20.0%. The inhibition of the other landraces was fluctuated from 0.7% to 19.6%. For AI, Vang Quat Bien the highest suppression by 55.8% was shown. Three landraces have had a similar AI inhibition viz. Lua Tho (51.9%), Huong Chiem (51.8%) and Bulu Pan dark (51.9%), respectively. Eight landraces had medium AI inhibition from 41.9% to 49.0%.

Also, 7 landraces exhibited AI inhibition over 30.0%, while, three landraces demonstrated low and negligible AI inhibition as BT09 (8.2%); BT (11.9%) and Ba Bui Son (12.0%), respectively. In total SL showed higher inhibition than DW by the values 36.1% and 28.1% (Table 2).

Allelopathic potential of rice landraces in field screening: The observation showed that all landraces inhibited growth of barnyardgrass in the field with a wide range. For SL inhibition, Huong Chiem was the greatest (77.4%), followed by Bulu Pan dark (76.7%), Ble Blau do (75.8%), Vang Thom (75.5%), Bao Thai (75.45%), Vang Quat Bien (72.3%), Nang Quat Vang (70.3%) and Lua Tho (70.0%), respectively. SL inhibition over 60.0% was found in 4 landraces including Nanh Chon, Nang Thom Nhem, Tau Huong and Bong Sen MS42, respectively. The medium SL suppression over 50.0% was observed in 8 landraces. Two landraces, G59 Nep Man and Nep 352 showed the least SL inhibition viz. 4.2%, while 29 landraces exhibited wide range SL inhibition ranging from 10.0% to 49.9%, respectively.

For allelopathic effect of reducing P of barnyardgrass comparing with the controls, 11 landraces exhibited significant inhibitory effects by over 40.0%, of which Lua Tho was the highest (49.1%), followed by Thoc Te L931 (46.3%), Ble Blau do (46.2%). Contrarily, Nep Xiem and Nep 352 indicated the lowest allelopathic effects by the values 4.5% and 3.5%, respectively. Nine landraces reduced barnyardgrass panicles by over 30.0%, while 17 landraces showed P reduction from 20.0% to 30.0% . To monitor the DW inhibition, 6 landraces exposed significant suppression over 50.0%, of which Nanh Chon (59.2%) was the highest, followed by Bong Sen MS42 (55.3%), Vang Quat Bien (52.5%), respectively. There were 16 landraces showing low allelopathic effects by lower 20.0%, Nep 352 (6.5%), G59 Nep Man (9.5%) and Nep Xiem (11.2%) were the lowest. DW inhibition ranged from 40.0% to 49.0% were attained in 7 landraces. The 20 landraces exhibited DW suppression ranged from 20.0% to ≈ 40.0%. For DWB inhibition, 3 landraces Mot Bui Nam, Ble Blau do and Huong Chiem showing the maximum effects of inhibition by 51.3%, 50.6% and 52.3%, respectively .The ten landraces showed DWB reduction from 40.4% to 49.3%. The neligible allelopathic effect of DWB was found in several landraces including Nep 352 (4.5%), G59 Nep Man (5.8%) and Nep Xiem (9.5%).

Table 1. The inhibition effects of 51 rice landraces against the growth of barnyardgrass in laboratory condition.

No.	Rice landraces	Inhibition (%)					
		G	SL	RL	DW	AI	Group
1.	Nang Thom	25.1	42.6	32.7	26.1	31.6	TNS
2.	Tep Hang Som	15.7	40.6	40.7	30.1	31.8	TNS
3.	Nanh Chon	27.8	61.4	50.7	35.6	43.9	TNS
4.	Mot Bui Nam	17.1	37.2	27.1	29.7	27.8	TNS
5.	Bot Bui So MS16	28.0	47.7	28.2	32.6	34.1	TNS
6.	Lua Tho	29.2	61.0	54.3	36.4	45.2	TNS
7.	Huong Lai De Lai	6.8	6.0	9.5	4.2	6.6	TNS
8.	Than Nong Duoi	2.5	1.6	3.4	0.5	2.0	TNS
9.	Nang Quat Vang	21.8	50.8	59.4	37.6	42.4	TNS
10.	Ba Bui Son	5.4	10.6	1.0	3.6	5.2	TNS
11.	Nang Thom Nhem	24.1	46.3	50.7	28.3	37.4	TNS
12.	Vang Thom	15.8	51.1	62.5	39.0	42.1	TNS
13.	Vang Quat Bien	30.1	62.2	43.5	35.8	42.9	TNS
14.	Tau Huong	19.1	51.4	47.5	29.4	36.9	TNS
15.	Huong Dong 12	2.1	17.9	18.0	15.2	13.3	TNS
16.	Bong Sen MS42	11.5	40.4	20.2	19.4	22.9	TNS
17.	Ble Blau do	23.1	45.5	58.4	28.3	38.8	TNS
18.	Huong Chiem	16.9	50.9	55.2	30.1	38.3	TNS
19.	Bulu Pan dark	10.0	46.2	61.3	36.5	38.5	TNS
20.	G176 Khau Boong Duong	1.5	7.2	6.1	1.0	4.0	TNS
21.	Lua Den	2.5	16.1	6.0	2.5	6.8	TNS
22.	Thoc Te Duoi Bo	6.1	12.3	31.2	10.7	15.1	TNS
23.	Bao thai	0.5	30.1	26.7	15.6	18.2	TNS
24.	Moc Tuyen	2.3	10.1	22.1	1.7	9.1	TNS
25.	Xe Liem Man Te	0.5	10.6	8.1	1.5	5.2	TNS
26.	Thoc Te L931	5.2	17.6	42.0	1.2	16.5	TNS
27.	Pke Chong po	1.5	22.6	46.5	17.4	22.0	TNS
28.	BT	2.1	4.1	12.5	1.9	5.2	IV
29.	KD	3.6	3.5	4.6	0.7	3.1	IV
30.	G170 OM504	6.2	7.5	4.2	1.3	4.8	IV
31.	G243-N22	1.5	14.7	18.6	10.0	11.2	IV
32.	G22 Trung Trang TQ	2.4	3.0	4.7	0.6	2.7	IV
33.	G133-A330	3.4	19.7	20.2	10.5	13.5	IV
34.	GL106 (Gia Loc)	9.5	18.1	14.6	16.2	14.6	IV
35.	G233	2.0	21.2	1.9	12.6	9.4	IV
36.	G168 OM1490	1.5	19.0	13.8	19.1	13.4	IV
37.	HT9	2.4	19.7	14.8	12.3	12.3	IV
38.	SH8	8.1	15.2	42.5	20.1	21.5	IV
39.	BT09	10.5	2.1	30.1	11.5	13.6	IV
40.	J02	12.7	8.6	7.3	1.7	7.6	IV
41.	Khang Dan Dot Bien	20.4	18.2	38.1	21.5	24.6	IV
42.	Nep Thanh Tam	15.4	17.1	34.9	22.2	22.4	TS
43.	Nep Tu Le	10.5	20.1	18.2	14.6	15.9	TS
44.	G45 Nep Cuc	8.1	9.2	27.9	10.0	13.8	TS
45.	G59 Nep Man	2.5	2.4	16.5	0.7	5.5	TS
46.	Nep Xiem	16.1	13.2	15.6	10.3	13.8	TS
47.	Nep Hoa Vang	2.8	25.1	31.7	17.2	19.2	TS
48.	Nep 352	6.1	23.2	22.3	18.6	17.6	TS
49.	Nep Muong Trang	6.5	16.4	15.6	10.0	12.1	TS
50.	Nep Meo	1.5	13.7	21.7	0.7	9.4	TS
51.	Nep 97	14.7	26.8	26.9	8.2	19.2	TS
	Total inhibition	10.2	24.3	26.9	15.7	19.3	
	$LSD_{(0.05)}$	12.2	15.1	17.5	13.2	14.3	

G: Germination; SL: Shoot length; RL: Root length; DW: Dry weight; AI: Average inhibition; TNS: Traditional non-sticky rice; IV: Improved varieties; TS: Traditional sticky

Table 2. The inhibition effects of 51 rice landraces against barnyardgrass in greenhouse condition.

No.	Rice landraces	Inhibition (%)			
		SL	DW	AI	Group
1.	Nang Thom	43.2	29.9	36.6	TNS
2.	Tep Hang Som	40.8	28.5	34.7	TNS
3.	Nanh Chon	65.3	30.1	47.7	TNS
4.	Mot Bui Nam	40.8	28.9	34.9	TNS
5.	Bot Bui So MS16	51.2	34.3	42.8	TNS
6.	Lua Tho	65.1	38.6	51.9	TNS
7.	Huong Lai De Lai	19.2	12.6	15.9	TNS
8.	Than Nong Duoi	18.8	12.7	15.8	TNS
9.	Nang Quat Vang	60.8	37.1	49.0	TNS
10.	Ba Bui Son	16.3	7.6	12.0	TNS
11.	Nang Thom Nhem	51.6	32.1	41.9	TNS
12.	Vang Thom	59.7	36.8	48.3	TNS
13.	Vang Quat Bien	70.4	41.2	55.8	TNS
14.	Tau Huong	58.7	34.6	46.7	TNS
15.	Huong Dong 12	19.1	10.2	14.7	TNS
16.	Bong Sen MS42	48.2	20.7	34.5	TNS
17.	Ble Blau do	51.4	36.3	43.9	TNS
18.	Huong Chiem	63.2	40.4	51.8	TNS
19.	Bulu Pan dark	64.2	39.6	51.9	TNS
20.	G176 Khau Boong Duong	20.5	14.3	17.4	TNS
21.	Lua Den	30.4	20.1	25.3	TNS
22.	Thoc Te Duoi Bo	25.3	15.7	20.5	TNS
23.	Bao thai	54.6	38.5	46.6	TNS
24.	Moc Tuyen	28.7	20.0	24.4	TNS
25.	Xe Liem Man Te	18.1	10.0	14.1	TNS
26.	Thoc Te L931	29.4	18.6	24.0	TNS
27.	Pke Chong po	34.5	25.4	30.0	TNS
28.	BT	15.6	8.2	11.9	IV
29.	KD	17.4	10.1	13.8	IV
30.	G170 OM504	25.1	16.5	20.8	IV
31.	G243-N22	30.7	22.3	26.5	IV
32.	G22 Trung Trang TQ	18.4	10.4	14.4	IV
33.	G133-A330	35.2	21.4	28.3	IV
34.	GL106 (Gia Loc)	36.7	22.3	29.5	IV
35.	G233	45.2	30.1	37.7	IV
36.	G168 OM1490	36.7	25.6	31.2	IV
37.	HT9	40.4	19.5	30.0	IV
38.	SH8	45.3	25.6	35.5	IV
39.	BT09	15.7	0.7	8.2	IV
40.	J02	25.1	13.9	19.5	IV
41.	Khang Dan Dot Bien	35.2	21.8	28.5	IV
42.	Nep Thanh Tam	25.5	15.6	20.6	TS
43.	Nep Tu Le	27.6	15.8	21.7	TS
44.	G45 Nep Cuc	21.3	14.7	18.0	TS
45.	G59 Nep Man	20.3	12.1	16.2	TS
46.	Nep Xiem	23.4	11.5	17.5	TS
47.	Nep Hoa Vang	30.2	19.3	24.8	TS
48.	Nep 352	32.5	15.1	23.8	TS
49.	Nep Muong Trang	35.6	19.6	27.6	TS
50.	Nep Meo	20.7	12.4	16.6	TS
51.	Nep 97	29.5	13.1	21.3	TS
	Total inhibition	36.1	21.8	28.9	
	LSD $_{(0.05)}$	23.2	18.1	-	

RL: Root length; DW: Dry weight; AI: Average inhibition; TNS: Traditional non-sticky rice; IV: Improved varieties; TS: Traditional sticky.

Table 3. The inhibition effects of 51 rice landraces against barnyardgrass and weeds biomass in field condition.

No.	Rice landraces	Inhibition (%)					
		SL	P	DW	DWB	AI	Group
1.	Nang Thom	51.3	20.4	35.4	30.3	34.4	TNS
2.	Tep Hang Som	54.2	16.6	36.5	35.8	35.8	TNS
3.	Nanh Chon	69.1	37.5	59.2	45.9	52.9	TNS
4.	Mot Bui Nam	50.4	25.0	39.6	51.3	41.6	TNS
5.	Bot Bui So MS16	53.2	38.4	40.2	28.7	40.1	TNS
6.	Lua Tho	70	49.1	37.2	30.1	46.6	TNS
7.	Huong Lai De Lai	30.5	23.4	17.6	23.2	23.7	TNS
8.	Than Nong Duoi	29.2	12.3	19.1	28.4	22.3	TNS
9.	Nang Quat Vang	70.3	41.6	50.0	45.2	51.8	TNS
10.	Ba Bui Son	25.6	16.6	16.7	25.4	21.1	TNS
11.	Nang Thom Nhem	65.1	38.2	40.5	39.3	45.8	TNS
12.	Vang Thom	75.4	40.0	51.2	41.6	52.1	TNS
13.	Vang Quat Bien	72.3	42.4	52.5	45.6	53.2	TNS
14.	Tau Huong	68.7	43.2	45.7	40.4	49.5	TNS
15.	Huong Dong 12	30.2	14.3	21.2	25.2	22.7	TNS
16.	Bong Sen MS42	60.2	32.1	55.3	48.2	49.0	TNS
17.	Ble Blau do	75.8	46.2	45.4	50.6	54.5	TNS
18.	Huong Chiem	77.4	43.5	41.2	52.3	53.6	TNS
19.	Bulu Pan dark	76.7	43.2	39.4	49.3	52.2	TNS
20.	G176 Khau Boong Duong	41.6	29.7	30.0	20.1	30.4	TNS
21.	Lua Den	45.2	18.7	21.5	19.7	26.3	TNS
22.	Thoc Te Duoi Bo	46.8	32.5	25.1	24.6	32.3	TNS
23.	Bao thai	75.4	40.2	50.1	43.2	52.2	TNS
24.	Moc Tuyen	45.6	20.5	28.7	30.5	31.3	TNS
25.	Xe Liem Man Te	36.4	19.2	20.3	21.6	24.4	TNS
26.	Thoc Te L931	55.2	46.3	40.1	42	45.9	TNS
27.	Pke Chong po	38.7	23.5	19.2	17.5	24.7	TNS
28.	BT	30.5	25.4	15.3	12.5	20.9	IV
29.	KD	28.7	17.8	16.3	16.4	19.8	IV
30.	G170 OM504	25.3	13.2	13.2	15.1	16.7	IV
31.	G243-N22	39.2	25.6	18.5	18.7	25.5	IV
32.	G22 Trung Trang TQ	34.3	21.7	15.6	14	21.4	IV
33.	G133-A330	40.5	26.4	21.1	22.3	27.6	IV
34.	GL106 (Gia Loc)	41.4	21.2	25.8	23.1	27.9	IV
35.	G233	50.2	32.1	21.2	18.9	30.6	IV
36.	G168 OM1490	41.4	28.2	19.4	21.1	27.5	IV
37.	HT9	42.6	30.0	21.5	17.8	28.0	IV
38.	SH8	49.6	29.8	18.5	20.4	29.6	IV
39.	BT09	20.5	18.9	13.2	16.7	17.3	IV
40.	J02	36.8	17.7	16.5	20.4	22.9	IV
41.	Khang Dan Dot Bien	42.3	21.5	23.4	23.2	27.6	IV
42.	Nep Thanh Tam	45.6	25.7	31.2	32.4	33.7	TS
43.	Nep Tu Le	50.1	32.4	32.5	30.1	36.3	TS
44.	G45 Nep Cuc	55.3	36.8	38.2	40.1	42.6	TS
45.	G59 Nep Man	4.2	7.1	9.5	5.8	6.7	TS
46.	Nep Xiem	10.0	4.5	11.2	9.5	8.8	TS
47.	Nep Hoa Vang	25.9	42.1	49.4	38.9	39.1	TS
48.	Nep 352	4.2	3.5	6.5	4.5	4.7	TS
49.	Nep Muong Trang	20.1	22.7	41.3	25.1	27.3	TS
50.	Nep Meo	23.5	18.7	20.3	16.1	19.7	TS
51.	Nep 97	31.2	24.8	18.6	19.8	23.6	TS
	Total inhibition	44.7	27.4	29.3	28.2	32.4	
	LSD $_{(0.05)}$	24.2	28.0	25.6	29.2	-	

SL: Shoot length; P: Panicles; DW: Dry weight; DWB: Dry weight of biomass; AI: Average inhibition; TNS: Traditional non-sticky rice; IV: Improved varieties; TS: Traditional sticky

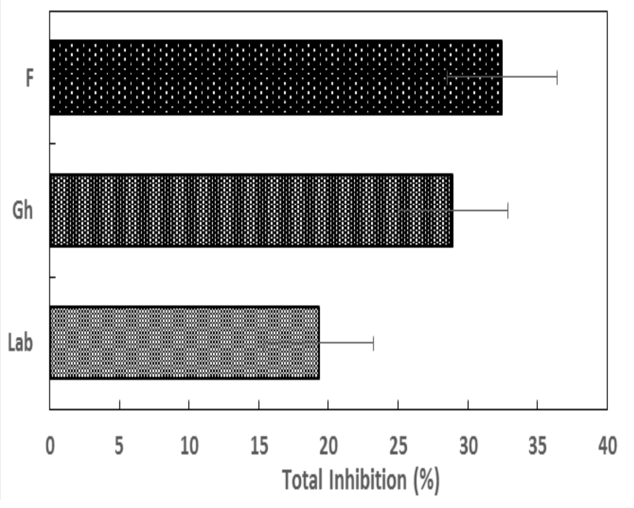

Fig. 1. Total average allelopathic potential of rice landraces with differently varietal groups against the growth of barnyardgrass in laboratory, greenhouse and field conditions.

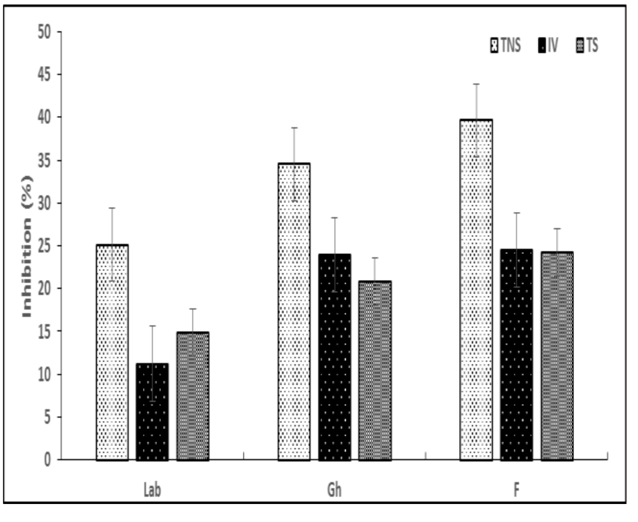

Fig. 2. Comparison of weed suppressing among rice landraces-varietal groups against barnyardgrass in laboratory, greenhouse and field screenings. TNS: Traditional none-sticky landraces; IV: Improved varieties (landraces); TS: Traditional sticky landraces; Lab: Laboratory; Gh: Greenhouse; F: Field.

For AI, there were 8 landraces showing high inhibition, of which Ble Blau was the highest by 54.5%. Huong Chiem and Vang Quat Bien showed similar AI values by 53.0%. The magnitude of AI was ranged from 20.9% to 49.5%, except for 7 landraces were AI was lower than 20.0%. There was not much significant difference between the total inhibition of P (27.5%), DW (29.3%) and DWB (28.2%), except for SL was 44.7% (Table 3).

Comparison of allelopathic potential of the landraces among the different screening conditions: Generally, total average inhibition (TAI) in field condition showed the highest by 32.4%, followed by TAI in greenhouse was 28.9% and the lowest TAI was monitored in laboratory by 19.3%, respectively (Fig. 1.).

The AI of varietal groups included TNS, T and IV, were calculated and compared. The results of AI among varietal group in laboratory condition showed as order: TNS landraces (25.1%) > TS (14.8%) > IV (11.2%). Similarly, AI of greenhouse condition was: TNS (34.5%) >IV (23.9%)>TS (20.7%). In field condition, the values of AI were as follows: TNS was the highest (39.6%). However, the AI values of IV and TS were not significantly different by (24.5%) and (24.2%), respectively (Fig. 2.). The order of rice landraces based on the varietal groups observed in all the screened conditions should be ranked as: TS < IV <TNS.

The correlation coefficient among rice landraces based on the values SL, and DW between the differential screening conditions: laboratory-greenhouse, laboratory - field and greenhouse-field screenings were analyzed and shown in Fig.3. The allelopathic effects reducing SL and DW of barnyardgrass were used as the allelopathic factors to compare allelopathic potential among the rice lanraces.

For SL, correlation coefficient showed strikingly different values which implied the inhibitory percentage between laboratory – greenhouse and laboratory – field and field – greenhouse by the in turn of the values r^2=0.86, r^2=0.59 and r^2=0.66, respectively. Similarly, the DW factors between laboratory-greenhouse, laboratory-field and field – greenhouse were also found markedly different with the values r^2 = 0.68, r^2 = 0.47 and r^2=0.50, respectively. The different correlation was also significantly changed between field- greenhouse screenings based on the DW and SL inhibition values were r^2 = 0.50 and r^2 = 0.66, respectively (Fig. 3.).

Discussion

Based on the results of allelopathic potential of varietal rice groups they were ranked as TNS >IV>TS. The current results were agreed with our previous reports that TNS had possessed the highest allelopathic potential (Khanh *et al*., 2009). The IV landraces are elite lines with high yielding potential. Therefore, they often show feeble allelopathic potential due to the lack of selection pressure for allelopathic traits during breeding. In bioassay test, 5 rice landraces, Lua Tho, Nanh Chon, Vang Quat Bien, Nang Quat Vang and Vang Thom revealed the highest allelopathic potential by over 40.0%. It was observed that total inhibition of RL against barnyardgrass was higher than that of SL which agreed with the previous studies of Olofsdotter & Navarez, (1996) and He *et al.*, (2012) who reported that allelopathic potential of rice noticeably suppressed root rather than shoot growth of the indicator plants. It indicated that the higher inhibition of roots may be due to their negative effects from intimate contact with the treated filter paper. Moreover, the other explanations may be related to the use of different screening methods which possibly leads to obtain different results. For example, some methods applied either aqueous or different chemical solvent extract of rice leaf, shoot and root or the mixture of rice residues showing different inhibitory magnitudes of rice seed exudation (Jung *et al*., 2004).

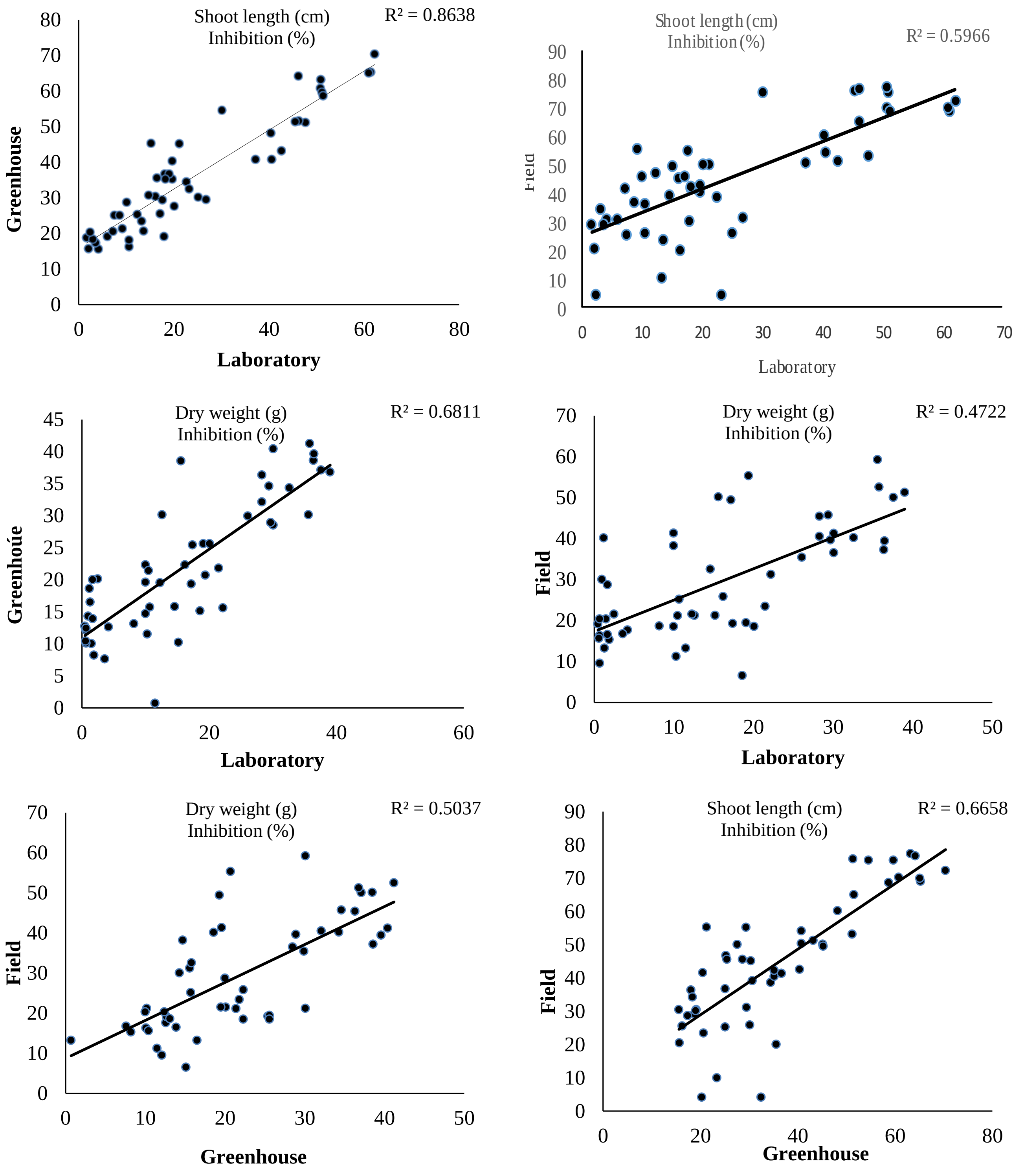

Fig. 3. Correlation coefficient of rice landraces against SL and DW of barnyardgrass in differential screening conditions.

A clear allelopathic evidence in plants has been recently found by releasing phytotoxic (allelochemicals) into environment to suppress nearby the other plants. For instance, several allelochemicals of rice were determined by releasing during its growth such as cytokinins, momilactones (A and B), phenolic acids which have been responsible for weed suppressing (Kato-Noguchi & Ino, 2005). Therefore, the screening methods by root exudates should be performed to evaluate allelopathic potential of rice. It is a better way to record the actual allelopathy potential of rice than any use of organic solvents extract rice residues.

In greenhouse condition, root exudates "double pots" screening method was applied. This method is simple and reliable in assessing allelopathic potential of rice landraces and can be examined in limited time and space all year round. In laboratory and greenhouse screenings, the competitive factors for growth resources such as humidity, water, light and temperature were partly controlled. Therefore, the actual allelopathic potential of rice landraces could be obtained.

Generally, the results in this study revealed that the rice landraces have had a spectrum variation of allelopathic potential in the differential screening conditions. The landraces with the different varietal groups such as TNS, IV and TS disclosed higher weed suppression in field than that monitored in laboratory and greenhouse (Fig.2). It can be explained due to indistinguishability between the allelopathy and resource competition factors because rice is influenced by a series of plant physiologies, plant-plant-environment interactions.

The results of this study showed that the same landrace, however, demonstrated differently allelopathic potential values. The key reason may be justified due to the dissimilar time of rice grown which may release more allelochemicals to inhibit growth of indicator plant, led to attain the different result, such as bioassay test (7 days), greenhouse (50 days) and field (80 days). Moreover, some researches reported that allelopathic rice causes weed-suppressing at its early developmental stage, hence, weeding in the first 30 days following transplanting is important (Hisashi & Ino, 2001).Better comprehending on the nature of interactions between allelopathic rice and weeds might ameliorate the ability of rice plants to compete and reduce the use of synthetic herbicides (Olofsdotter *et al*., 2002; He *et al*., 2012). In the fact that the research of allelopathy has emerged much controversy on the paucity of evidence of chemical pathways, even though numerous allelochemicals have been found in rice plants. Also, the chemical interactions between the tested allelopathic plants and the donors are still obscured.

In this study, based on the phenotype characteristics of landraces, we have observed that high tiller capacity, erect leaves and grain seed weight have shown higher allelopathic potential than the lower tiller and grain seeds landraces. It was consisted with the report of Ahn *et al.*, (2005), who suggested the traits of allelopathic potential varieties, is directly proportion with high yield, strong tillers, high plant height and sufficient height and leaf areas. Our findings have revealed that almost Vietnamese rice landraces exerted allelopathic potential against growth of barnyardgrass with landrace-dependent and varietal group-dependent and significantly influenced by the screening methods applied and environment grown. To the best our knowledge, thousands of worldwide rice landraces have been assessed for their allelopathic potential by either screening with different methods or isolating allelochemicals from rice residues and root exudates (Berendji *et al*., 2008; Khanh *et al*., 2013). However, rice allelopathic potential has still endured and encountered with much controversy about whether the role of allelopathy and actual modes of allelochemicals in bioassays or natural settings, especially the paucity of evidence of allelochemical interactions because competition and allelopathy factors are arduous to separate under field conditions. Nevertheless, for more accuracy in evaluating allelopathic potential of rice landraces, laboratory screening is indispensable for initial allelopathic evaluation, then need to be further validated in greenhouse and field screenings before any conclusion can be made.

The slope of the regression line based on SL and DW values was strikingly different between laboratory-field, laboratory-greenhouse and field- greenhouse performances. It implies that the experimental conditions involved in the factors of high allelopathic effects and the resource competitions. Moreover, the role of allelopathy in rice-weed interference is often neglected with sceptics attributing any influence of one plant on another plant in its vicinity to competition (Khanh *et al*., 2013).

Conclusions

In conclusions, our findings have pointed out that a wide variation allelopathic potential of Vietnamese rice landraces with the landrace-dependent, varietal groups-dependent and significantly influenced by the screening method applied and environment interactions. The current research has found some landraces with high allelopathic potential, a useful information for further allelochemicals identification and breeding program to develop the acceptable- allelopathic traits rice lines to sustainably control weed in this country.

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