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Allelopathic potential of yellow cosmos (*Cosmos sulphureus*) and royal poinciana (*Delonix regia*) on weedy rice (*Oryza sativa* f. *spontanea* WR20)

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ABSTRACT

This study evaluates environmentally friendly methods for controlling weedy rice (Oryza sativa f. spontanea) to reduce reliance on chemical herbicides. Extracts from Cosmos sulphureus (yellow cosmos - YCL) and Delonix regia (royal poinciana - RPL) leaves were tested at concentrations of 0.015, 0.075, 0.15, and 0.3 g fresh weight/mL for 48 hours. Pre-soaked weedy rice (WR20) seeds were treated, and stem and root lengths were measured 7 days post-treatment. At 0.3 g fresh weight/mL, YCL extract completely inhibited WR20 growth, while RPL extract inhibited root and stem by 71% and 75%, respectively. WR20 seeds soaked for 96 hours before YCL treatment showed the highest inhibition. For RPL, 48-hour soaking yielded the highest root inhibition, and 96-hour soaking the highest stem inhibition. Evaluating effects on OM18 cultivated rice revealed YCL extract at 0.3 g fresh weight/mL inhibited roots (45.41%) and stems (1.72%) at 2 days post-treatment, with full recovery by 7 days. However, RPL extraction proportionally impacted OM18's roots (33.35–100%) and stems (33.10–80.10%). These findings suggest that using YCL and RPL extracts for weedy rice management is promising, particularly when combined with strategic timing of rice planting to minimize damage.

1. INTRODUCTION

Weedy rice (*Oryza sativa* f. *spontanea*) is a pervasive weed species that severely impacts global rice production. Due to its widespread distribution and adaptability, weedy rice poses a significant threat to agricultural systems in various rice-growing regions, particularly in Asia. Countries such as China, India, Bangladesh, Indonesia, the Philippines, and Thailand face persistent challenges from weedy rice infestations (Shrestha et al., 2019; Juliano et al., 2020; Kimwemwe et al., 2023). In the Mekong Delta, rice (*Oryza sativa*) is the dominant crop, covering approximately 1,418.2 thousand hectares, which represents 79.28% of the total rice cultivation area during the Summer-Autumn crop of 2023. (General Department Statistics, 2023). The increasing invasion of weedy rice and its adverse effects are closely linked to the continued practice of direct-seeded rice cultivation. Over 90% of the rice-growing area in the Mekong Delta uses this method, which, combined with intensive agricultural practices, has led to the robust growth and spread of weedy rice (Nguyen et al., 2023). This situation negatively impacts the quality, productivity, and income of local farmers and affects Viet Nam's total rice exports.

The global challenge of managing weedy rice through chemical methods is exacerbated by its genetic similarity to cultivated rice (*Oryza sativa* L.), often rendering these methods ineffective. Additionally, the extensive use of chemical herbicides has contributed to the development of

herbicide resistance, posing significant threats to rice quality, farmer livelihoods, human health, and the environment. Active ingredients such as Bentazone, Bispyribac-sodium (Begum et al., 2008), Florpyrauxifen-benzyl (Miller & Norsworthy, 2018), and Penoxsulam (Schaedler et al., 2013) have been used to manage weeds due to their resistance to ALS inhibitors. However, their effectiveness has diminished over time as resistance and cross-resistance has developed across weed populations worldwide. This issue is particularly pronounced in Viet Nam, where studies have documented growing resistance of barnyard grass (*Echinochloa spp*.) to commonly used herbicides like quinclorac (Nguyen et al., 2019). Le et al. (2018) also found that *Echinochloa crus-galli* in the Mekong Delta exhibited resistance to bispyribac, penoxsulam, and quinclorac, with an average resistance score of 3.4 and significant costs associated with weed management.

Many studies have demonstrated the efficacy of plant extracts in inhibiting weed growth. For instance, *Cosmos bipinnatus* leaf extract effectively inhibits the root and stem length of *Echinochloa colona* L. and *Echinochloa crus-galli* L. (Nguyen et al., 2024), and *Cosmos sulphureus* significantly reduces the quantity of buds, leaf length, and stem and root length of *Cyperus rotundus* (Respatie et al., 2019). Similarly, Rawal and Pawar (2017) found that *Delonix regia* leaf extract at a 20% concentration inhibits root length and shoot growth of *Vigna radiata* by 74.62% and 76.43%, respectively.

This study aimed to evaluate the effectiveness of *Cosmos sulphureus* (yellow cosmos - YCL) and *Delonix regia* (royal poinciana - RPL) extracts on weedy rice and their possible application for environmentally friendly wet rice cultivation. By investigating the potential of these extracts to inhibit weedy rice growth, this research seeks to provide sustainable and eco-friendly solutions for weedy rice management.

2. MATERIALS AND METHOD

2.1. Materials

The weedy rice (Line of WR20) was provided by the Biotechnology Laboratory in Plant Protection, ATL 5.19, CTU. YCL was planted at the greenhouse of the College of Agriculture, Can Tho University (CoA, CTU) and collect at 60 days after germination. The RPL were collected in the campus of CTU at flowering time.

Chemicals used in extracting the extract include: methanol CH_3OH (MeOH) (Fisher chemical USA, distributed by VietChem company Can Tho branch), and distilled water. Experimental equipment: Yamato low pressure solvent recovery machine (Yamato Neocool Circulator CF302L, Yamato Rotary Evaporator RE301, Yamato Water Bath BM510, Yamato. T. Suzuki, Japan).

2.2. Method

2.2.1. Extraction of YCL and RPL leaves using methanol (MeOH) solvent

Soaking 100 g of fresh sample (YCL/ RPL) with 1 L of cold MeOH (60% concentration) for 48 hours, then filtered through filter paper, the extract was collected and stored in the cool compartment of the refrigerator. The remaining residue was soaked in 0.5 L of cold MeOH (100%) for the next 48 hours. The second extract was then filtered through filter paper again; these two filtrates were mixed to collect 1.5 L of extract, then evaporated at 40 ^{0}C using a rotary evaporator (Yamato Neocool Circulator CF302L, Yamato Rotary Evaporator RE301, Yamato Water Bath BM510, Yamato. T. Suzuki, Japan) to collect extract containing water and metabolomic compounds including allelochemicals (300 mL) (Ho et al., 2008).

2.2.2. Evaluation of the inhibitory ability of YCL and RPL extracts on WR20

The WR20 weedy rice seeds were surface sterilized with 0.1% $HgCl_2$ for 5 minutes and then rinsed five times with sterile distilled water before the experiment.

Ten WR20 weedy rice seeds were placed in Petri dishes (Ø = 4 cm) and soaked in 3 mL of distilled water for 144 hours under laboratory conditions at 25°C in the dark. At 0, 48, and 96 hours after soaking in distilled water, the distilled water was replaced with 3 mL of extract solution (either YCL extract or RPL extract) at concentrations of 0.015, 0.075, 0.15, and 0.3 g fresh weight/mL for a 48-hour soaking period, as shown in Table 1. The control treatment was soaked in distilled water for 144 hours.

After treatment, the WR20 seeds were placed on sterile filter paper in Petri dishes (Ø = 10 cm) and moistened with 4 mL of sterile distilled water under laboratory temperature and light conditions. The experiment was arranged in a completely randomized design, with each treatment consisting of one concentration of extract at a specific time

point. Each treatment had three replicates, with each replicate containing 10 WR20 seeds. The length of the shoots and roots of WR20 was measured after 7 days of treatment (DPT) using an electronic caliper.

Table 1. Treatments

Treatments	Soaking before (hours)	Extraction time (hours)	Soaking after (hours)
Control (H_20)	144	0	0
V1-x	0	48	96
V2-x	48	48	48
V3-x	96	48	0

Note: - Soaking before and soaking after: Time to soak in distilled water BEFORE and AFTER soaking in the extract.

- V is the type of extract, x is the concentration of the extract to be used such as 0.015, 0.075, 0.15, and 0.3 g fresh weight/mL

2.2.3. Evaluation of the effects of YCL and RPL extracts on OM18 rice

The experimental layout method was carried out according to the description of Ho et al., (2008). The experiment was arranged in a completely randomized manner, each treatment was repeated three times with each replication being 10 newly germinated seeds of OM18 rice cultivar.

Using a micropipette, 3 mL of concentration extract (0.015; 0.075; 0.15 and 0.3 g of fresh sample/mL) was filtered with a filter with a hole size of 0.45µm and inserted evenly on absorbent paper placed in a petri dish (Ø = 90 mm). Next, each of these petri dishes is placed in the fume hood (25 ˚C) until the extraction fluid has evaporated completely. These petri dishes are further moistened with 4 ml of Tween 20 solution (0.05%). Place 10 newly germinated seeds of OM18 rice cultivar in the prepared petri dishes above, cover the dishes and cover with food wrap film. The experiment was arranged under stable temperature conditions at 25^0C, with a dark cover. The stem and root length of OM18 rice were measured at 2 and 7 DPT using an electronic ruler; Efficacy calculation according to Abbott's formula (1925).

Calculate effectiveness according to Abbott's formula (1925). SPSS software (version 20) was used to analyze the data.

3. RESULTS AND DISCUSSION

3.1. Effect of YCL extract on the growth and development of WR20

Table 2 and Figure 1 shows the inhibitory effect of YCL extract on the development of roots and WR20 stems at the time of 7 DPT. The results showed that there was a marked difference in inhibitory efficacy between the concentrations of the extracts and the time of soaking in water before soaking the extracts. At concentrations of 0.015 and 0.075 g of fresh sample/mL, YCL had no significant inhibitory effect on both WR20 roots and stems (0.00%). However, at a concentration of 0.15 g of fresh sample/mL, the inhibitory effect increased significantly, reaching 56.57% for roots and 59.95% for stems. At the concentration of 0.30 g of fresh sample/mL, YCL achieved the maximum inhibitory effect, reaching 100% for both roots and stems.

Table 2. Inhibitory effect of YCL extract on roots and stems development at 7 DPT

Empirical combination		Inhibition efficacy (%)	
		Roots	Stems
YCL concentration (g of fresh sample/mL) (A)	**0.015**	0.00^c	0.00^c
	0.075	0.00^c	0.00^c
	0.15	56.57^b	59.95^b
	0.30	100.00^a	100.00^a
Time to soak in distilled before soaking in the extract (hours) (B)	**0**	25.00^c	25.00^c
	48	30.51^b	31.70^b
	96	36.92^a	38.26^a
F (A)		**	**
F (B)		**	**
F AxB		**	**
CV (%)		0.25	0.35

*Note: Data are converted to Arcsin($x^{1/2}$) before statistical processing. Means in the same column followed by the same letter are not different at the 1% level of significance in the Duncan test. **: significant difference 1%.*

The time spent soaking in water before soaking the extract also affects the inhibitory effect. When not pre-soaked, the inhibitory effect is 25.00% for both roots and stems. When soaking in water 48 hours before soaking the extract, the inhibitory effect increased, reaching 30.51% for the roots and 31.70% for the stems. When soaked in water 96 hours before soaking the extract, the inhibitory effect reached its highest, with 36.92% for the roots and 38.26% for the stems. The difference in inhibitory efficacy between the concentrations of extract (A) and the time to soak in distilled before

soaking in the extract (B) was statistically significant at 1% ($p<0.01$). This means that the interaction between these two factors has a significant effect on the results of the study. The coefficient of variation (CV) indicates high stability of the result, with CV = 0.25% for roots and 0.35% for stems (Table 2).

Research results show that YCL extract effectively inhibits the growth of WR20 depending on the concentration and soaking time before soaking the extract. Increasing extract concentration increases the inhibitory effect. In particular, at a concentration of 0.30 g fresh sample/mL, YCL extract achieved maximum inhibition effect, reaching 100% for both WR20 roots and stems. Soaking water time before soaking the extract also affects the inhibition effect, with a soaking water time of 96 hours before soaking the extract giving the highest inhibition effect. This can be explained by the fact that the absorption and impact of the active ingredients in the extract on WR20 are optimized when WR20 seeds are soaked in water for longer periods of time.

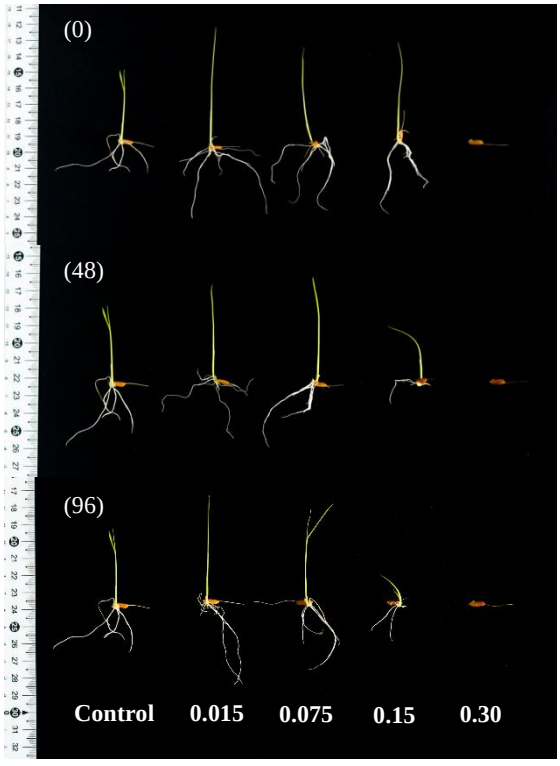

Figure 1. Inhibition of weedy rice by YCL extract at the time of 7 DPT

Note: (0); (48); (96) are the time of soaking water before soaking in the YCL extract, which are 0, 48 and 96 hrs, respectively.

3.2. Effect of RPL extract on the growth and development of WR20

Table 3 and Figure 2 show the inhibitory effect of RPL extract on the growth of WR20 roots and stems at 7 DPT. The results showed that there was a clear difference in the inhibition effect between the extract concentrations and the soaking time before soaking the extract, as well as compared to when treated with YCL extract.

Table 3. Inhibitory effect of RPL extract on roots and stems development of WR20 at 7 DPT

Empirical combination		Inhibition efficacy (%)	
		Roots	Stems
RPL concentration (g of fresh sample/mL) (A)	**0.015**	0.00^{d}	0.00^{d}
	0.075	5.43^{c}	6.09^{c}
	0.15	10.54^{b}	23.23^{b}
	0.30	71.00^{a}	75.00^{a}
Time to soak in distilled before soaking in the extract	**0**	10.25^{c}	6.36^{c}
	48	33.85^{a}	31.75^{b}
	96	25.00^{b}	34.35^{a}
F (A)		**	**
F (B)		**	**
F AxB		**	**
CV (%)		1.47	1.41

*Note: Data are converted to Arcsin($x^{1/2}$) before statistical processing. Means in the same column followed by the same letter are not different at the 1% level of significance in the Duncan test. **: significant difference 1%.*

At a concentration of 0.015 g fresh sample/mL, RPL had no significant inhibitory effect on both WR20 roots and stems (0.00%). Similarly, YCL also had no inhibitory effect at this concentration. However, at a concentration of 0.075 g fresh sample/mL, RPL began to show a slight inhibitory effect, reaching 5.43% for roots and 6.09% for stems, while YCL had no inhibitory effect at similar concentrations. At a concentration of 0.15 g fresh sample/mL, RPL inhibited roots and stems of WR20 by 10.54% and 23.23%, respectively, while YCL achieved a higher inhibition efficiency of 56.57% against roots and 59.95% for stems. In particular, at a concentration of 0.30 g fresh sample/mL, RPL achieved the highest inhibitory effect, with 71.00% for roots and 75.00% for stems, but still lower than the effectiveness of YCL (100%) at the same concentration (Table 3).

The time of soaking water before soaking the extract also affects the inhibitory effect of RPL. Without

pre-soaking water, the inhibition effect was 10.25% for roots and 6.36% for stems. Meanwhile, when using YCL, the inhibition effect was 25.00% for both roots and stems. When soaked in water for 48 hours before soaking the extract, the inhibitory effect of RPL increased significantly, reaching 33.85% for roots and 31.75% for stems, compared to YCL, which was 30.51% for roots and 31.70% for the body. When soaked in water for 96 hours before soaking the extract, the inhibitory effect of RPL reached the highest level, with 25.00% for roots and 34.35% for stems, while YCL showed 36.92% effectiveness for roots and 38.26% for stems.

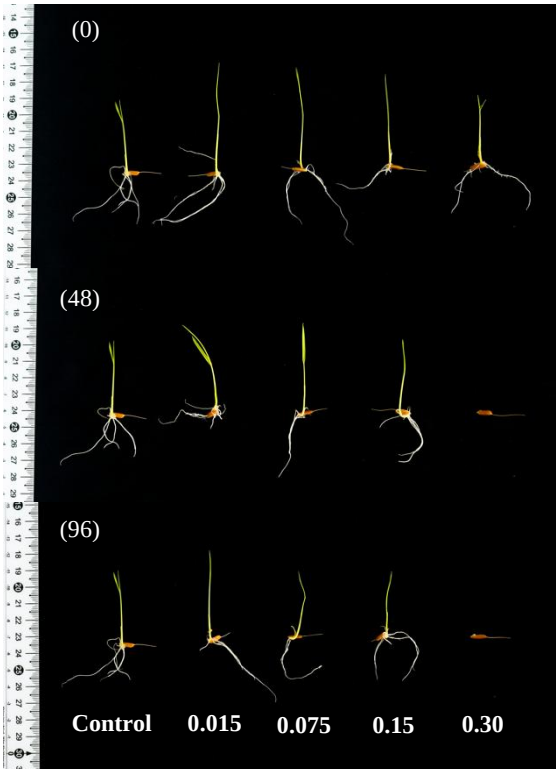

Figure 2. Inhibition of weedy rice by RPL extract at the time of 7 DPT

Note: (0); (48); (96) are the time of soaking water before soaking in the RPL extract, which are 0, 48 and 96 hrs, respectively.

The difference in inhibition efficiency between extract concentrations (A) and soaking time before soaking the extract (B) are both statistically significant at the 1% level ($p<0.01$). This means that the interaction between these two factors has a significant influence on the research results. Specifically, at each different concentration of extract, the soaking time before soaking the extract will also affect the level of inhibition of WR20 roots and stems. For example, at a concentration of 0.30 g fresh sample/mL, when WR20 seeds were soaked in water for 48 hours before soaking the extract, the root and stem inhibition effect reached the highest level. Similarly, at lower concentrations, the soaking time before soaking the extract also has a similar effect, although the inhibition level is not as high. The coefficient of variation (CV) showed high stability of the results, with CV = 1.47% for roots and 1.41% for stems (Table 3).

The research findings indicate that RPL effectively inhibits the growth of WR20, though it is less potent than YCL. This observation aligns with broader literature, which shows that the allelopathic potential of plant extracts varies significantly among different species. Studies by Motmainna et al. (2023) and Khamare et al. (2022) support this notion, highlighting the variability in effectiveness depending on the plant species and extract concentration.

The trend observed in your study, where higher concentrations of RPL extract lead to greater inhibitory effects, is consistent with other research. Sidhu et al. (2023) found that increasing the concentration of plant extracts generally enhances their ability to inhibit weed growth. This is attributed to a higher concentration of active allelopathic compounds that can more effectively affect the target weed.

Furthermore, the finding that longer soaking times improve the inhibition effect of RPL is supported by additional studies. Alam et al. (2018) noted that extended soaking times facilitate better absorption of allelopathic substances, leading to more effective weed control. This insight is consistent with your results showing that soaking WR20 seeds for longer periods enhances the inhibitory effect of the extract.

Overall, the specific results from this research in table 3 showing that at 7DAT, 0.3 g fresh RPL sample/mL caused 71.0% inhibition for roots and 75.0% for stems of WR20, reflect a common pattern where higher concentrations lead to increased inhibition. Sidhu et al. (2023) reported similar trends, where greater extract concentrations resulted in more significant inhibition of weed seed germination and growth. This comparative analysis supports the validity of your findings and underscores the potential of both RPL and YCL extracts in natural weed management strategies.

3.3. Effects of YCL and RPL extracts on stems and roots development of rice OM18

Table 4 and Figure 3 show the effects of YCL extract on OM18 rice. The results showed that, at 2 DPT, the concentration of 0.3 g fresh sample/mL had a positive effect on OM18 rice roots with an inhibition rate of 45.41%. However, at 7 DPT, different concentrations showed a decrease in root length, especially at the concentration of 0.015 g fresh sample/mL, with a decrease of 34.31%. For rice stems, only the concentration of 0.3 g fresh sample/mL showed a slight increase in effectiveness at 2 DPT at 1.72%, while other concentrations showed a decrease, especially was at a concentration of 0.075 g fresh sample/mL with a reduction of 18.10%. However, at 7 DPT, OM18 rice had gradually recovered, and the impact was significantly reduced (Figure 3).

Table 4. Effect (%) of YCL extract on OM18 rice

Concentration	Roots		Stems	
(g fresh sample)	2 DPT	7 DPT	2 DPT	7 DPT
0.015	-18.49d	-34.31d	-3.45b	-4.27a
0.075	-16.98c	-13.23a	-18.10d	-7.66c
0.15	-0.75b	-30.00c	-8.62c	-10.11d
0.30	45.41a	-25.45b	1.72a	-5.37b
F	**	**	**	**
CV (%)	**2.26**	**0.11**	**0.39**	**0.22**

*Note: Means in the same column followed by the same letter are not different at the 1% level of significance in the Duncan test. **: significant difference 1%. Negative value stand for extract stimulation and positive value stand for extract inhibitory.*

Table 5 shows the effects of RPL extract on rice variety OM18. The results showed that, at 2 days of processing, the concentration of 0.3 g of fresh substance/mL had a strong effect on the roots and stems of OM18 rice, with inhibition rates of 96.98% and 35.34%, respectively. In particular, at 7 DPT, RPL still maintained high inhibitory ability with rice root and stem inhibition rates reaching 100% and 80.10%, respectively. This shows that RPL has a more sustainable inhibition ability than YCL (Figures 3 and 4).

Table 5. Effect (%) of RPL extract on OM18 rice

Concentration	Roots		Stems	
(g fresh sample)	2 DPT	7 DPT	2 DPT	7 DPT
0.015	74.97^{d}	33.35^{d}	-6.61^{d}	33.10^{d}
0.075	89.68^{c}	49.76^{c}	8.05^{c}	61.29^{c}
0.15	90.94^{b}	69.34^{b}	14.08^{b}	66.35^{b}
0.30	96.98^{a}	100.00^{a}	35.34^{a}	80.10^{a}
F	**	**	**	**
CV (%)	**0.10**	**0.41**	**1.24**	**0.30**

*Note: Means in the same column followed by the same letter are not different at the 1% level of significance in the Duncan test. **: significant difference 1 Negative value stand for extract stimulation and positive value stand for extract inhibitory.*

This difference can be explained by the chemical nature and inhibitory mechanism of the compounds contained in the two extracts. YCL with main ingredients such as flavonoids and polyphenols, can cause temporary inhibition but does not maintain long-term effects. Meanwhile, RPL contains compounds such as alkaloids and terpenoids, which have stronger and more lasting inhibition, leading to a more sustainable inhibition effect. The inhibitory mechanism of YCL may be related to causing oxidative stress and interfering with plant metabolism, while RPL may directly inhibit important enzymes and cause disruption in the metabolism and plant development (Yoshioka et al., 2004; Shah & Smith (2020); Kostina-Bednarz et al., 2023; Zagoskina et al., 2023).

These results show that the recovery ability of cultivated rice depends on the type of extract and concentration used. As for YCL, OM18 rice was able to recover after inhibition, while RPL caused stronger and more prolonged inhibition. This suggests that the use of these extracts in weedy rice management needs to be carefully considered in terms of dosage and application time to ensure optimal effectiveness and limit negative impacts on cultivated rice. Figures 3 and 4 illustrate the research results on the effects of YCL and RPL extracts on OM18 rice variety, helping to visualize the difference in inhibition efficiency and recovery ability of cultivated rice.

Figure 3. Effect of YCL extract on OM18 rice at 7 DPT

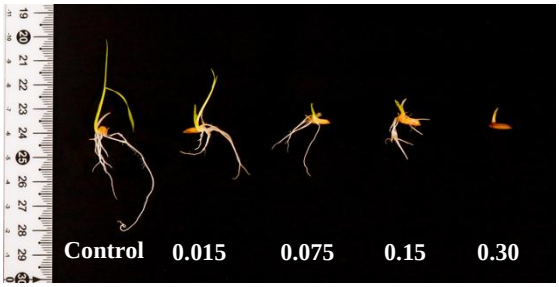

Figure 4. Effect of RPL extract on OM18 rice at 7 DPT

The results of the study showed the effectiveness of extracts from YCL and LPV in inhibiting the growth of WR20 (*Oryza sativa* f. *spontanea*) and affecting OM18 rice. The difference in inhibition efficiency between the two types of extracts has been clearly demonstrated through the statistical results in Tables 2, 3, 4 and 5.

A study by Soltys et al. (2013) showed that allelochemicals, such as flavonoids and polyphenols in a plant species of Asteraceae family, sunflower (*Helianthus annuus* L.) extracts, can induce physiological stress and inhibit weed growth. Anjum and Bajwa (2007) evaluated the bioherbicidal potential of sunflower leaf extracts applied at 100 mL m² post-emergence in three intervals, finding a 70% reduction in lambsquarters (*Chenopodium album*) and enhanced wheat biomass and harvest index compared to untreated controls. Jamil et al. (2009) tested sorghum water extracts, alone and combined with sunflower, Chinese cabbage, eucalyptus, tobacco, and sesame in wheat fields. They observed that sorghum + sunflower at 12 L ha^{-1} was most effective against wild oat and canary grass, with the 6 L ha^{-1} combination being the most cost-effective. In our study, YCL is also expressed the plant inhibitory effect as at a concentration of 0.3 g fresh sample/mL, YCL can inhibit 100% of the growth of WR20 roots and stems. This may be because of the compounds in YCL have the ability to cause strong inhibition but do not maintain long-term effects when applied to OM18 cultivated rice.

Research by Einhellig (1995) has also shown that compounds such as alkaloids and terpenoids in RPL extracts can cause strong and lasting inhibition, corresponding to our results on RPL. At a concentration of 0.3 g fresh sample/mL, RPL showed a high and sustained inhibitory effect on WR20 roots and stems growth, as well as a long-lasting effect on OM18 rice. This shows that RPL has a more sustained inhibition ability than YCL, which may be due to the strong impact of compounds in RPL on plant metabolism and growth.

Compared with previous studies, our results show that the inhibitory effect of plant extracts depends not only on plant extract difference but also on the concentration and soaking water time before soaking the extract solution. Research by Xuan et al. (2004) showed that factors such as concentration and soaking time can greatly influence the inhibitory effect of plant extracts. Our results are consistent with this finding, seeing that a 96-hour soaking time before soaking the YCL extract gave the highest inhibitory effect, while for RPL, 48-hour and 96-hour soaking water times all showed high inhibition efficiency (Xuan, 2004).

These results not only reveal the potential for using extracts of YCL and RPL in weed management, but also suggest that optimization of factors such as extract concentration and time of soaking in water may possibly enhance inhibitory effect. This is important in developing biological alternatives to chemical herbicides, contributing to protecting the environment and human health. While YCL has the ability to cause inhibition on weedy rice and gradually recover on OM18 rice, RPL maintains a more sustainable inhibition effect, but at the same time, also has a lasting effect on OM18 rice. However, careful consideration of dosage and method of use is needed to optimize weedy rice inhibition effectiveness and minimize negative impacts on cultivated rice.

4. CONCLUSION

This study demonstrates that *Cosmos sulphureus* leaf extract (YCL) at 60days after germination is effective in inhibiting weedy rice (WR20). For optimal results, use YCL at a concentration of 0.3 g fresh weight/mL, which achieves complete inhibition of both roots and stems after 7 days.

Additionally, pre-soaking weedy rice seeds in water for 96 hours before applying YCL extract yields the best inhibitory effect.

For *Delonix regia* leaf extract (RPL), a concentration of 0.3 g fresh weight/mL is also recommended. To maximize root inhibition, treat seeds that have been soaked for 48 hours in water. For the best stem inhibition, use RPL on seeds soaked for 96 hours.

These findings suggest significant potential for using YCL and RPL extracts in weedy rice management. However, further field trials are needed to confirm their effectiveness under real cultivation conditions and to develop appropriate application methods.

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