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รายงานวิจัยฉบับสมบูรณ์

ศักยภาพของข้าวไร่ในการลดการแข่งขันของวัชพืช

โดย

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30 มิถุนายน 2543

FINAL REPORT

ALLELOPATHIC POTENTIAL OF UPLAND RICE TO REDUCE WEED COMPETITION

BY

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30 JNUE 2000

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ชุดโครงการทุนวิจัยหลังปริญญาเอก

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ผู้วิจัยขอขอบคุณ สำนักงานกองทุนสนับสนุนการวิจัยเป็นอย่างสูง ที่สนับสนุนด้านการเงินสำหรับงานวิจัยหลังปริญญาเอกในครั้งนี้

ขอบคุณ กองพฤกษศาสตร์และวัชพืช กรมวิชาการเกษตร ที่ให้ความอนุเคราะห์สถานที่ห้องปฏิบัติการ เรือนทดลอง และเครื่องมือวิทยาศาสตร์

ขอบคุณ คุณฉวีวรรณ วุฒิญาโณ ธนาคารเชื้อพันธุ์ข้าว ศูนย์วิจัยข้าวปทุมธานี ที่เอื้อเฟื้อเมล็ดพันธุ์ข้าวไร่สำหรับงานวิจัย

ขอบคุณ ดร. พูนพิภพ เกษมทรัพย์ มหาวิทยาลัยเกษตรศาสตร์ที่แนะนำเทคนิคการใช้เครื่องมือวัดการสังเคราะห์แสง

ท้ายที่สุด ขอขอบคุณ ศ. ดร. รังสิต สุวรรณเขตนิคม และ ศ. ดร.เบญจวรรณ ฤกษ์เกษม ที่ให้คำปรึกษาและคำแนะนำในการวิจัยมาโดยตลอด

บทคัดย่อ

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วัตถุประสงค์:
เพื่อศึกษาแนวทางการควบคุมวัชพืชในข้าวไร่โดยชีววิธี (allelopathy)

ขอบเขตการวิจัย:
คัดเลือกสายพันธุ์ข้าวไร่ จำนวน 569 สายพันธุ์ จากธนาคารเชื้อพันธุ์ข้าว กรมวิชาการเกษตร เพื่อทดสอบศักยภาพในการลดการเจริญเติบโตของวัชพืชเมื่อปลูกร่วมกัน นำสายพันธุ์ที่มีศักยภาพในการลดการเจริญเติบโตของวัชพืชในระดับต่างกัน มาทดสอบด้วยวัชพืชสำคัญที่พบทั่วไปในระบบการปลูกข้าวไร่ ทดสอบศักยภาพในการลดการเจริญเติบโตของวัชพืชเมื่อปลูกร่วมกับข้าวที่มีอายุต่าง ๆกัน และศึกษาความแตกต่างทางด้านการสังเคราะห์แสงของสายพันธุ์ข้าวไร่ที่คัดเลือก

ผลที่ได้รับ:
พบว่าสายพันธุ์ข้าวไร่ 23 สายพันธุ์ มีศักยภาพในการลดการเจริญเติบโตของพืชทดสอบได้ และสายพันธุ์ที่คัดเลือกไว้ 2 สายพันธุ์ (BWSD 16 และ BWSD 19) สามารถลดการเจริญเติบโตของวัชพืชใบแคบและใบกว้างได้ในสภาพเรือนทดลอง

สรุปสาระสำคัญของผลที่ได้จากการวิจัย:
การควบคุมวัชพืชในข้าวไร่โดยชีววิธี (allelopathy) สามารถกระทำได้โดยใช้สายพันธุ์ข้าวที่มีศักยภาพ ในการลดการเจริญเติบโตของวัชพืช แต่จำเป็นต้องศึกษาต่อไปในระบบการปลูกข้าวไร่ ซึ่งมีปัจจัยของสภาพแวดล้อมเข้ามาเกี่ยวข้องด้วย

ข้อเสนอแนะสำหรับงานวิจัยในอนาคต:
นำสายพันธุ์ข้าวไร่ที่มีศักยภาพในการลดการเจริญเติบโตของวัชพืชไปทดสอบในสภาพไร่ ซึ่งมีความหลากหลายของชนิดวัชพืช และมีสภาพแวดล้อมที่แตกต่างจากการทดลองในห้องปฏิบัติการหรือเรือนทดลอง หากพบว่าสายพันธุ์ดังกล่าวยังคงมีศักยภาพในการลดการแข่งขันของวัชพืชในสภาพไร่ได้ จะได้นำสายพันธุ์นั้นไปใช้ในการปรับปรุงพันธุ์ข้าวไร่ เพื่อนำไปสู่เป้าหมายลดการใช้สารกำจัดวัชพืชในการปลูกข้าวไร่ต่อไป

คำหลัก: ข้าวไร่ การควบคุมวัชพืชโดยชีววิธี การแข่งขันของวัชพืช

Abstract

Project Code: PDF/ 47/ 2541

Project Title: Allelopathic potential of upland rice to reduce weed competition

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Project Period: 1 JULY 1998- 30 JUNE 2000

Objectives: To use allelopathy as a potential strategy for biological rice weed control.

Methodology: Allelopathic potential was investigated in 569 rice accessions under laboratory condition. Four selected accessions were tested for allelopathic potential at different growth stages of rice. Selectivity of allelopathic rice on weed species was also determined. Photosynthesis of allopathic and non-allopathic accessions was investigated.

Results: Twenty three rice accessions decreased total dry weight of *Echinochloa crusgalli and Lactuca sativa* by>50% when grown together under laboratory condition. Two selected accessions (BWSD 16 and BWSD 19) exhibited the strongest allopathic effect on two monocots and four dicots weed species under glasshouse condition.

Discussion & Conclusion: It is plausible to utilize allopathic rice accessions to reduce weed competition in the field. However, the allopathic activity of those accessions should be further determined in the upland rice system with various environmental factors.

Suggestion/ Further Implication/ Implementation: The further investigation of allopathic potential in selected accessions (BWSD 16, BWSD 19, BWSD 22 and BWSD 25) should be established in upland rice system. These rice accessions then can be used as genetic resources to improve the allopathic potential in upland rice resulting in the reduction of herbicide application.

Key words: allelopathy, upland rice, weed competition

Executive Summary

Weeds are the greatest yield-limiting constraint in upland rice. Allelopathy is a potential strategy for biological weed control in rice. Allopathic potential in upland rice (*Oryza sativa* L.) was investigated in 569 accessions under laboratory condition. Results indicated that genotypic variation for allopathic potential exists in Thai upland rice germplasm. Twenty three rice accessions decreased total dry weight of *Echinochloa crusgalli* and *Lactuca sativa* by more than 50% when grown together. Most accessions with allelopathic potential were collected from the Northern Thailand. Four selected accessions (BWSD 16, BWSD 19, BWSD 22 and BWSD 25) were selected and tested in glasshouse with two monocots (*E. colona* and *E. crusgalli* and four dicots (*Euphorbia geniculata*, *Mimosa invisa*, *M. pudica* and *L. sativa)* weed species. Variation in allelopathic effect on the test species was measured. BWSD 16 and BWSD 19 exhibited the strongest allelopathic effect. These two accessions suppressed the growth of two monocots by 49-63% and four dicots weeds by 30-73%. In contrast, BWSD 22 had a slight allopathic effect only on some of test species. BWSD 16 and BWSD 19 clearly exhibited the allelopathic activity when weed species *M. invisa* was sown at 0 and 5 days after rice germination. In addition, photosynthesis rates and chlorophyll content in both allelopathic and non-allelopathic accessions were similar. Hence, allelopathic activity does exist in selected accessions, BWSD 16 and BWSD 19.

These findings indicate that allelopathy in upland rice might be used as an alternative method for controlling weeds in upland rice system to avoid harmful effects caused by herbicides on human health and the environment.

1. INTRODUCTION

1.1 Allelopathy

The term 'allelopathy' means inhibitory or stimulatory effects by root exudates, leaf leachates, crop residues and volatile chemical emitted from plants. It can be used as a weed management tool in three different ways: by planting an allelopathic crop or cultivar; planting an allelopathic non crop species associated with the crop; or through allelopathic residues left in the soil from a previous crop (Gliessman, 1982). Weston (1996) proposed that allelopathy may offer potential for biorational weed control through the production and release of allelochemicals from leaves, flowers, seeds, stems and roots of living or decomposing plant materials. In addition, under appropriate conditions, allelochemicals may be released in quantities suppressive to developing weed seedlings. Among these methods, allelochemical exudates which is naturally produced by plant can be merely potential herbicides (Duke, 1985; Worsham, 1989).

1.2 Allelopathy in plants

The phenomena of allelopathy have been found in numerous crops. For instances, allelopathic lines of the following crops have shown inhibition of weed growth: beets (*Beta vulgaris*), lupin (*Lupinus spp.*), maize (*Zea mays*), wheat (*Triticum aestivum*), oats (*Avena spp.*), peas (*Pisum sativum*), barley (*Hordeum vulgarae*), rye (*Secale cereale)* and cucumber (*Cucumis sativus*) (Rice, 1984). Putnam and Duke (1974) found some of 526 accessions of cucumber, originating from 41 countries, exhibiting powerful growth inhibition of *Panicum miliaceum* and *Brassica hirta*. Interestingly, one of these accessions showed 87% growth inhibition of the tested species and 25 other accessions had a 50% growth inhibitory effect. Later, a field study indicated that allelopathic activity could only be obtained under certain conditions. Total weed population was reduced by 54% in one accession but inhibition did not occur consistently and rainfall could suppressed this allelopathic effect

(Lockerman and Putnam, 1979).

In *Avena* spp., 3,000 accessions were tested for their ability to exude scopoletin, a compound known to inhibit root growth (Fay and Duke, 1977). It was found that four accessions exuded three times of scopoletin and inhibited the growth of wild mustard in the sand culture. The phytotoxic symptoms of tester plants were chlorotic, stunted and/or twisted, indicating that inhibition was caused by chemical rather than by competition.

Barley (*Hordeum vulgarae*) has been known as a "smother" crop because of its ability to suppress weeds. Overland (1966) reported that barley produced and released phytotoxic substances in concentartions that inhibited the growth of several common weeds. To date, none of allelopathic cultivar has been commercialized for any of the crops mentioned, however, these results indicated that the transfer of allelopathic genes is relevant to weed control research (Burke, 1987).

1.3 Allelopathy in rice

Allelopathy in rice was firstly observed in seed production plots which were naturally infested with ducksalad (*Hetheranthera limosa*) at Arkansas Rice research Institute, USA (Dilday *et. al.*, 1989a and 1991). During 1988-1989, 10,000 accessions of rice were evaluated for allelopathic potential in ducksalad. Of these, 3.5% were categorized as allelopathic when they had a weed free radius at the base of rice plant >10 cm. The screening experiment was also conducted for allelopathic activity in 5,000 rice accessions against some weed species such as *Ammania coccinea*, *Echinochloa crusgalli*, *Brachiaria platyphylla* and *Heteranthera limosa*. Two hundred (3.9%) of these accessions from 27 countries demonstrated allelopathic potential against one or more of these weed species (Dilday *et. al.*, 1989b). A follow-up study using a strongly allelopathic accession planted in a weed mixture showed 72-95% control of *H. limosa, A. coccinea* and *Bacopa rodundifolia* (Lin *et. al.*, 1992a,b). Later, 12,000 rice accessions were evaluated for allelopathic potential against ducksalad and

5,000 accessions against redstem (Purple ammania). The results showed that 412 rice accessions were allelopathic to redstem, 145 accessions to ducksalad and 16 accessions to both species (Dilday *et. al.*, 1997 and 1998).

In Japan, 189 rice strains were tested for allelopathic potential in the laboratory using the 'Plant Box Method' (Fujii, 1993). Diversity of rice strains were Japonica type (72 accessions), Indica type (18), Tropical Japonica type (32), Chinese type (29), African type (4) and 34 unidentified strains. Each strain was planted together with lettuce (*Lactuca sativa*). The result showed that twenty four strains had more than 75% inhibition on radicle growth of lettuce. It was noted that Tropical Japonica types had stronger allelopathic potential than the improved cultivars.

In Egypt, field screening for allelopathic potential of 1,000 rice accessions was conducted. A natural infestation of target weed species, *E. crusgalli* and *Cyperus difformis* occurred in the field. Thirty accessions of those showed promising allelopathic activity (50-90% weed reduction) against *E. crusgalli* and 15 were allelopathic (30-75% weed reduction) against *C. difformis*. Five accessions showed strong allelopathic potential for both weed species (Hassan *et. al.*, 1997 and 1998).

At International Rice Research Institute, IRRI, a laboratory screening procedure for allelopathic rice had been established (Navarez and Olofsdotter, 1996). Seeds of *E. crusgalli* were placed in the petri-dish with 7-day-old rice seedlings. The plants were grown together for 10 days before measuring the root length of tester plant. Allelopathic rice caused strong inhibition of root growth of weed. The result was confirmed in the field in 1995 and 1996. It was found that 19 of 111 rice accessions was capable to reduce growth of *E. crusgalli* by >40% and 7 accessions suppressed *E. crusgalli* dry weight by>50%. In addition, two rice accessions had a strong inhibition of both grass weed *E. crusgalli* and broadleaved weed *Trianthema portulacastrum* (Olofsdotter *et. al.*, 1997).

It is likely that allelopathy is widespread in rice germplasm since those allelopathic rice accessions were originated in 37 countries around the world. In Thailand, preliminary laboratory study among 50 upland rice genotypes confirmed that allelopathic rice genotypes exist (Maneechote and Krasaesindhu, 1996). As more than 1,000 accessions of upland rice in Rice Germplasm Bank of Thailand are still needed to be screened for the stronger allelophatic effects.

1.4 Allelopathic chemical in root exudates

With a few exceptions, the allelopathic chemicals reported from higher plants are secondary compounds that arise from either the acetate or shikimate pathway (Einhellig, 1995). Higher plants regularly release organic compounds by volatilization from their surfaces, and through leaf leachates and root exudates. Root exudates comprise both high and low-molecular weight solutes released or secreted by roots. The most important components of the high molecular weight (HMW) solutes are mucilage and ectoenzyme and those of the low-molecular weight (LMW) fractions are organic acids, sugars, phenolic acids and amino acids (Marschner, 1995). So far, no breakthroughs have been achieved in trying to characterize chemicals involved in rice allelopathy (Olofsdotter *et. al.*, 1997). Recently, some allelopathic compounds were identified in water from allelopathic rice cultivars as 3-hydroxybenzoic acid (3HBA), 4-hydroxybenzoic acid (4HBA), 4-hydroxyhydrocinnamic acid (4HHCA), 3,4-dihydroxyhydrocinnamic acid (3,4DHHCA) and tentatively identified 4-hydroxyphenylacetic acid (4HPAA) when compared with water from non-allelopathic rice cultivars (Mattice *et. al.*, 1997 and 1998).

Unfortunately, chemical approaches in allelopathy were often performed under arbitrary condition. Rather than collecting the responsible extracellular inhibitors from the intact, living donor plants, tissue extracts from either fresh or dried plant materials were commonly used (Rice, 1984). Compounds identified in this manner, however, were not necessarily responsible for the observed allelopathic interactions. Collection of allelopathic chemicals from undisturbed plant root system is difficult because of their low concentrations and the high level of contaminants in growth media such as soil

(Tang and Young, 1982).

1.5 Plant growth stages and allelopathic potential

Plants produce different allelochemicals at different development stages. Dekker and Meggit (1983) found that most allelochemicals were released during germination and early growth. In barley, the highest amount of allelopathic alkaloids were released at 36 days after germination at the rate of less than 2g plant-1day-1 when grown in hydroponic culture (Liu and Lovett, 1993). In rice, the different stages of donors plants were used in various experiments. For examples, rice plants at 1-2 months-old (Fujii, 1993), rice seedlings at 7 days-old (Olofsdotter *et. al.*, 1997) and pregerminated rice at day 0 (Maneechote and Krasaesindhu, 1996). Nevertheless, weed control research should focus on allelopathic activity during early development stages. During this period, weeds which germinate and establish faster than crops will lead to the severe weed problems (Zimdahl, 1980). In upland rice cultivation where rice and weeds germinate at the same time, the identification of allelopathic activity in rice at the early stage is required.

1.6 Mechanisms of action of alellochemicals

Mechanisms of inhibitory effects of allelochemicals have not been adequately researched since the allelopathic compounds are secondary compounds. Allelochemicals active against higher plants are typically characterized as suppressing seed germination, causing injury to root growth and other meristems or inhibiting seedling growth (Einhellig, 1995). They can also affect mineral uptake by altering membrane function in plant roots, as when phenolic acids depolarise electrical membrane potential and thereby inhibit the absorption of mineral ions into plants (Balke, 1985).

1.7 Factors affecting quantities of allelochemicals produced by plants

The amount of allelochemicals in plants are influenced by many factors. The factors which affect the photosynthesis play an important role on allelochemical production. The light intensity, daylength, mineral deficiencies, water stress and temperature may affect the quantity of those chemicals in plants (Rice, 1974).

1.8 Screening procedures for allelopathy

In allelopathy research, it is essential for all studies to test compounds released by the living donor plant on growth and development of another living receiver plant. To prove that the effects were allelopathic, careful experimental design was used to differentiate them from the influences of competition for light, water and nutrients. Bioassays are helpful techniques to screen the large number of plant species in order to search for the allelopathic plants. Many procedues were proposed to be used for screening steps. For examples, filter papers can be used as a never ending resource of water so that two species can be germinated in the same petridish without competing for water (Liu and Lovett, 1993). Agar can also be used as a germination medium as it allows the use of very small amounts of allelochemicals (Fujii, 1993; Maneechote and Krasaesindhu, 1996) and therefore it is very useful in the fractional and extrating phase of allelopathy research (Pederson, 1986).

1.9 Tester plants

As weed seeds germinate unevenly resulting in high variation of germination rates and radicle elongation measurements. Research on allelopathic activity in rice has used different tester species. Barnyardgrass (*Echinochloa crusgalli*) is a common grass weed found in rice field and is widely used as tester plant in numerous experiments (Dilday *et. al.*, 1989a,1989b; Hassan *et. al.*, 1994; Maneechote and Krasaesindhu, 1996; Olofsdotter *et. al.*, 1997). Lettuce (*Lactuca sativa*) is quite versatile to be represent the dicot weed species because germination rate is high and uniform (Fujii, 1993; Maneechote and Krasaesindhu, 1996). The other dicots weeds, *Ammania coccinea*, *Heteranthera limosa*, and sedge, *Cyperus difformis*, were also tested for allelopathic activity in rice (Dilday *et. al.*, 1989a and 1989b). In Thailand, the major weeds found in upland rice are *Ageratum conyzoides*, *Biden pilosa*, *Mimosa invisa*, *Digitaria* spp., *Dactyloctenium aegyptium* and *Eleusine indica* (Vongsaroj, 1997).

1.10 Objectives of this project

The ultimate goal of this project was to utilize allelopathy to reduce herbicide uses and increase yield in upland rice. To reach this goal, the following objectives were addressed in the project.

1. To identify the upland rice genotypes with strong allelopathic potential.

2. To study allelopathic potential at different growth stages of rice.

3. To determine the selectivity of allelopathic rice on weed species.

2. MATERIALS AND METHODS

2.1 Plant materials

Upland rice germplasm

A total of 569 accessions of upland rice (*Oryza sativa* L.) from Rice Germplasm Bank of Rice Research Institute, Department of Agriculture, Thailand were evaluated for allelopathic activity. The origin of upland rice accession is shown in Table 2.1 and local name of accessions are in Annex 1.

Table 2.1 Number of upland rice accessions in different regions of Thailand.

Region	No. of accessions
North	270
Northeast	12
East	8
South	56
Central	29
Unknown	194
Total	**569**

Tester species

Barnyardgrass (*Echnichloa crusgalli* L. Beauv.)

Jungle rice (*Echnichloa colona* L. Link),

Painted spurge (*Euphorbia geniculata* Ort.)

Sensitive plant (*Mimosa invisa* Mart.)

Sensitive plant (*M. pudica* L.)

Lettuce cv. Grand Rapids (*Lactuca sativa* L.)

2.2 Laboratory procedure

Agar (0.5% w/v) was placed in 250-ml glass bottles with 50 mm in diameter (25 ml per bottle) and allowed to solidify. Rice and tester species were sown together in each bottle. Treatments consisted of five seeds of rice and ten seeds of a tester species. Rice seeds were placed as a single row on the agar surface and tester species sown in two rows parallel to rice row. Then the lid was closed to prevent the moisture loss. The bottles were placed in a growth room illuminated with fluorescent lights (photoperiod,12h: light intensity, approximately 50-60 μmol m^{-2} s^{-1}; temperature 27°C dark/light). Four replicates of each accession were made for each tester species using randomized block design. Experiments were carried out separately for each tester species and fifty rice accessions were assayed at a time. The tester species sown without rice was retained as controls.

Ten days after sowing, growth of tester plants were determined. Shoot length was measured as length of the longest leaf for monocots and as the combined length of hypocotyl for dicots. The dry weight of shoot and roots were taken after oven drying at 70°C for 48 h.

2.3 Glasshouse procedure

Ten-days old seedlings of rice germinated on agar were transplanted into 10 cm-diam plastic pot, containing 500 g Bangkhen clay soil (60% clay, 31% silt and 9% sand, pH 5.6, CEC 25.7 meq/100g soil). One day after transplanting, ten germinated seeds of each tester species were sown in the same manner as in the bottle. Plants were grown in the glasshouse with soil maintained at or near field capacity by daily watering. Rice accessions were arranged in four replicates using Completely Block Design. Growth of tester plants (plant height and number of leaves) was determined. Sixty days after sowing, tester plants were harvested and measured for leaf number, length and dry weight of shoot/root.

2.4 Identification of upland rice genotypes with strong allelopathic activity

Five hundred sixty nine accessions of upland rice from Rice Germplasm Bank in Thailand were tested for allelopathic activity. The experiments were conducted in the laboratory by using the agar method (Maneechote and Krasaesindhu, 1996). Fifty accessions of rice were tested at a time. Barnyardgrass (*Echinochloa crusgalli*) and lettuce (*Lactuca sativa* cv. Grand Rapids) represent the monocots and dicots tester species, respectively. The shoot and root length of tester plants were measured 10 days after planting. Dry weight of shoot and root of tester species were measured separately. Control check (without rice and with non-allelopathic rice) will be included in each bioassay.

Response of each tester species was calculated as relative growth as followed.

$$\textit{Relative Dry Weight} = \frac{\text{total dry weight of tester species grown with rice}}{\text{total dry weight of tester species grown without rice}} \times 100\%$$

Based on the relative dry weight of each tester species, the rice accessions were classified into four groups:

0-25% = highly allelopathic

26-50% = moderately allelopathic

51-75% = slightly allelopathic

76-100% = no allelopathic

This classification is useful for characterizing allelopathic potential present in upland rice accessions and the representative from each group will be used as plant materials in the second experiment.

2.5 Allelopathic activity in rice to major weed species

To evaluate rice genotypic differences in allelopathic potential against some common weed species in upland rice plantation, four accessions (BWSD 16 and BWSD 19, BWSD 22 and BWSD 25) were selected. Two accessions (BWSD 16 and BWSD 19) are moderately allelopathic giving the relative growth of *L. sativa* by 26-50%. BWSD 22 is slightly allelopathic with <25% inhibition on tester species. BWSD 25, which had no inhibitory effects on both species, was used as non-allelopathic check. Those selected four accessions were repeatedly bioassayed with *L. sativa*

Ten days later, rice seedlings were transplanted to the soil for seed multiplication. Rice seeds harvested from selected accessions were separately tested for allelopathic potential with six tester species in the laboratory. Consequently, five seedlings in each bottle were transplanted into 10 cm-diam plastic pot, containing 500g Bangkhen clay soil. One day after transplanting, ten germinated seeds of each tester species were sown in the same manner as in the bottle. Plants were grown in the glasshouse with soil maintained at or near field capacity by daily watering. Rice accessions were arranged in four replicates using Complete Block Design. Growth of tester plants (plant height and number of leaves) was weekly determined. Thirty days after sowing, tester plants were harvested. Leaf area, length and dry weight of shoot/root of tester plants were measured.

2.6 Allelopathic potential at different growth stages of rice.

To verify whether there were differences between allelopathic and non-allelopathic rice, in allelopathy at the different growth stages of rice. Four selected accessions of rice (BWSD 16, BWSD 19, BWSD 22 and BWSD 25) were planted in soil. Five germinated seeds of each accession were placed in 30 cm-diam plastic pot, containing 5 kg Bangkhen clay soil. At various growth stages of rice (at 0, 5, 10, 15, 20, 25, 30 and 35 days after rice germination), tester species was planted in the same manner as in the bottle. Plants were kept in the glasshouse with soil moisture maintained at or near field capacity by daily watering. Pots were arranged in four replicates using Complete Block Design. Growth of tester plants (plant height and number of leaves) was weekly determined. Sixty days after sowing rice seeds, rice and tester plants were harvested. Leaf area, length and dry weight of shoot/root of tester plants were measured. The growth parameters of both donors and receiver plants were evaluated.

2.7 Physiological characteristics of allelopathic upland rice

To evaluate the physiological differences between the allelopathic and non-allelopathic rice accessions, plants were grown in the 30 cm-diam plastic pots in the glasshouse. Three plants of each accession were grown in a pot. At the tillering stages, single leaf net photosynthesis in the 1^{st} and 2^{nd} leaf of each plant were collected using a portable photosynthesis system model LI-6400 (Li-Cor, Lincoln, NE) at 1,500 $\mu mol.m^{-2}.s^{-1}$ light intensity. Air flow to the chamber was adjusted to give approximately 50% humidity. Leaf temperature was kept at $28 \pm 1\,^{\circ}C$. Data was taken when photosynthesis was steady. Chlorophyll content of each accession was also determined by chlorophyll meter (Minolta, Japan).

For each accession, photosynthesis of flag leaf was measured at various light intensity (100, 200, 500, 1000, 1500, 2000 $\mu mol.m^{-2}.s^{-1}$) at the booting stage. Each plant was used as one replicate. Four plants were measured for each accession.

3. GENOTYPIC VARIATION OF ALLELOPATHIC ACTIVITY IN UPLAND RICE

3.1 Allelopathic activity on *Echinochloa crusgalli*

The responses of *E. crusgalli* to 569 accessions of upland rice were determined under laboratory condition. Shoot and root length of test species was inhibited when grown with allelopathic accessions (data not shown). Most of rice accessions (87.7%) tested did not contain allelopathic potential. None of the rice accessions showed 0-25% relative growth of tester species. Only one accession (0.2%) was grouped in the 26-50%. About 12% of 569 accessions could reduce relative growth of *E. crusgalli* by 25-50% (Table 3.1). It is obvious that allelopathic rice originated in the north where the hilltribes population are greater than any other part of Thailand.

In the north, upland rice accessions are mostly widespread in Chiangmai with 16 accessions were slightly allelopathic to *E. crusgalli* (Table 3.2). In northeast, only one accession from Nakonratchasima gave 51-75% relative growth of test species. Most of the slightly allelopathic rice (35 accessions) was from unknown origin (Table 3.2).

Table 3.1 Distribution of upland rice accessions based on relative growth of two test species *E. crusgalli*.

Region	Number of accessions (%)				Total
	Relative growth				
	0-25	26-50	51-75	76-100	
E. crusgalli					
North	0	0	4.6	26.9	31.5
Northeast	0	0	0.2	1.9	2.1
East	0	0	0	4.0	4.0
South	0	0	0.4	9.5	9.8
Central	0	0	0.9	17.6	18.5
Unknown	0	0.2	6.2	27.8	34.1
Total	**0**	**0.2**	**12.1**	**87.7**	**100.0**

Table 3.2 Responses of *Echinochloa crusgalli* to 569 accessions of upland rice from different regions of Thailand. Data are four replicates of relative growth of tester species germinated with rice compared to that of tester species germinated alone.

Region	Number of accessions				Total
	Relative growth (%)				
	0-25	26-50	51-75	76-100	
NORTH					
Chiangrai	0	0	0	1	1
Chiangmai	0	0	16	49	65
Kamphaengphet	0	0	0	37	37
Lumpoon	0	0	0	7	7
Maehongsorn	0	0	0	7	7
Nan	0	0	6	7	13
Pichit	0	0	0	10	10
Pitsanuloke	0	0	2	6	8
Prae	0	0	0	4	4
Sukhothai	0	0	0	7	7
Utaithani	0	0	4	87	91
Uttradit	0	0	2	18	20
Total	0	*0*	*30*	*240*	***270***
NORTHEAST					
Khonkaen	0	0	0	2	2
Loei	0	0	0	5	5
Mookdaharn	0	0	0	1	1
Nakonpanom	0	0	0	1	1
Nakonratchasima	0	0	1	1	2
Nongkhai	0	0	0	1	1
Total	*0*	*0*	*1*	*11*	***12***
EAST					
Chantaburi	0	0	0	2	2
Kanchanaburi	0	0	0	15	15
Rayong	0	0	0	3	3
Trat	0	0	0	3	3
Total	*0*	*0*	*0*	*23*	***23***
SOUTH					
Chumporn	0	0	0	2	2
Naratiwat	0	0	0	3	3
Pattaloong	0	0	2	44	46
Phangha	0	0	0	5	5
Total	*0*	*0*	*2*	*54*	***56***
CENTRAL					
Patumthani	0	0	0	1	1
Nakornpathom	0	0	1	2	3
Ratchaburi	0	0	0	1	1
Saraburi	0	0	0	9	9
Total	0	0	1	13	***14***
UNKNOWN	*0*	*1*	*35*	*158*	***194***
TOTAL	*0*	*1*	*69*	*499*	**569**

3.2 allelopathic activity on *Lactuca sativa*

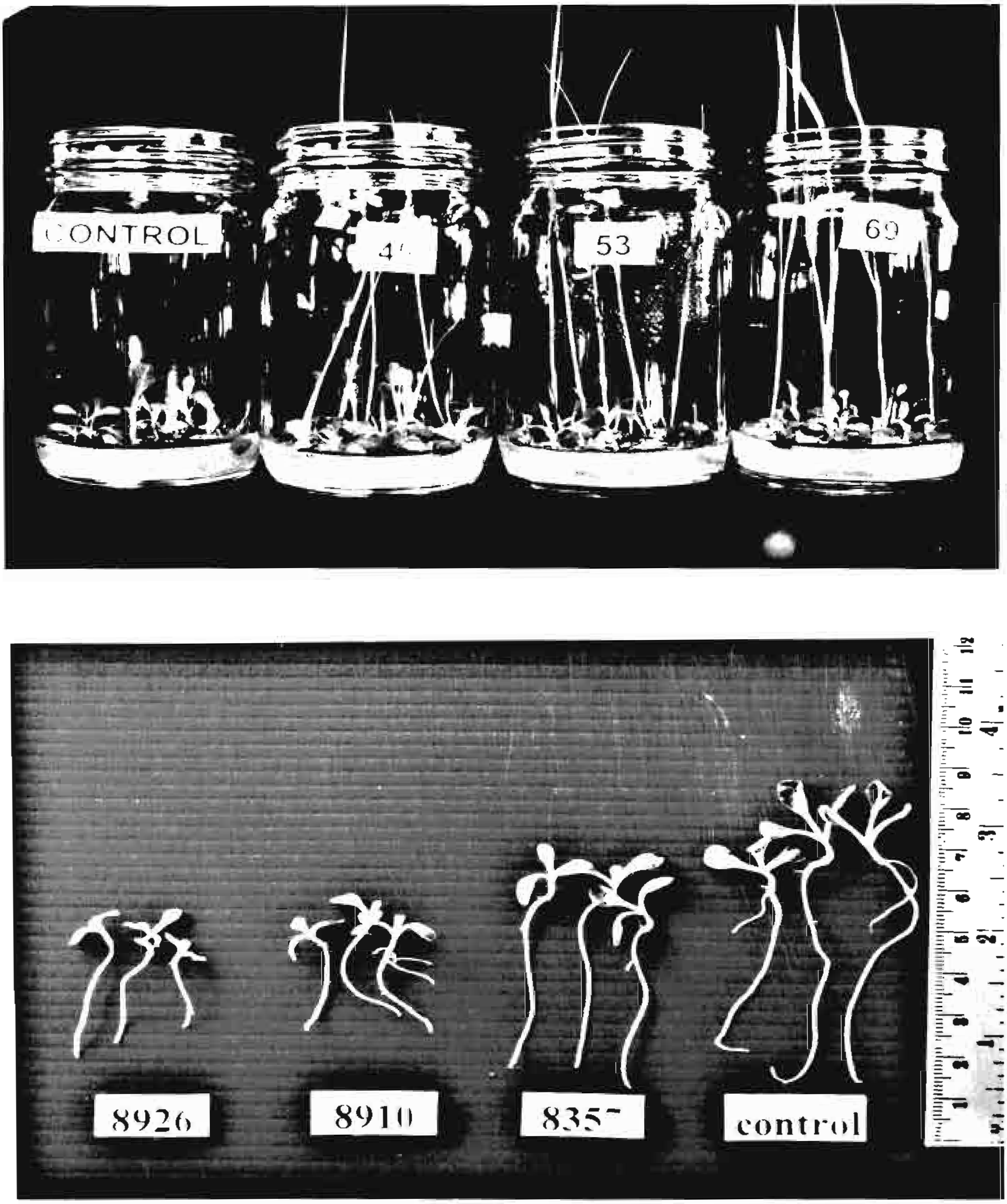
The responses *L. sativa* to 569 accessions of upland rice were determined. Ten days after germination, shoot and root length of test species were inhibited when grown with allelopathic rice accessions (Picture 3.1). None of the rice accessions showed 0-25% relative dry weight of tester species (Table 3.3). The relative growth of tester species, was ranged in 26-100%. When tested with *L. sativa,* 23 accessions were ranked into 26-50%, 82 into 51-75% and 464 into 76-100% relative dry weight of the tester. Only 4% of the 569 accessions were moderately allelopathic to the test species (Table 3.3).

Most of moderately allelopathic rice (16 accessions) originated in the Northern Thailand, particularly in Chiangmai and Utaithani (Table 3.4). It is interesting to note that allelopathic rice was not found in the other regions of Thailand. About 464 accessions of 569 accessions were found to be non-allelopathic.

Total dry weight of test species, *L. sativa* and *E. crusgalli*, was depressed by allelopathic rice accessions. The relative growth of test species was reduced by 50-75% when grown with allelopathic accession (Table 3.2 and 3.3). Shoot and root length of two test species were also inhibited (data not shown). A genotypic variation of allelopathic acitvity in Thai upland rice germplasm is suggested by these results. About 4% of germplasm were allelopathic against L. sativa. Similarly, in USDA-ARS collection, about 3.75% of rice germplasm had allelopathic effects against test species (Dildays *et. al.*, 1998). In addition, The inhibitory effect of allelopathic rice depended upon the plant species. *L. sativa* was more sensitive to allelopathic activity than *E. crusgalli*. It may be due to the differences in species. *L. sativa* is dicots crop plants which is more sensitive than the *E. crusgalli*, moncots grass weed. However, the laboratory and field study in Philippines showed that 17% of rice accessions suppressed the growth of *E. crusgalli* by more than 40% (IRRI, 1998). Differences in inhibitory activity of allelopathic rice may be due to the screening procedure and the stage of rice plant since plants produce different allelochemicals at different development stages. Dekker and Meggit (1983) found that most allelochemicals were released during germination and early growth.

The degree of inhibition was greater with the increasing growth stages of rice. Fujii (1993) used plant box method with 30-60 days-old rice plants. Olofsdotter *et. al.*, (1997) assayed rice seedlings at 7 days-old. In this study, rice and *E. crusgalli* germinated at the same time. Among those procedures, plant box method by Fujii (19993) had greater effects on test species than any other procedures. Nevertheless, weed control research should focus on allelopathic activity during early development stages. During this period, weeds which germinate and establish faster than crops will lead to the severe weed problems (Zimdahl, 1980). In upland rice cultivation where rice and weeds germinate at the same time, the identification of allelopathic activity in rice at the early stage is required.

Although allelopathic rice could suppress the growth of test species when grown on agar, the allelopathic activity of these accessions need to be further investigated when grown in the soil. Selectivity of allelopathic activity on various weed species is also required.



Picture 3.1 Shoot and root length of *L. sativa* were inhibited when grown with allelopathic rice accessions.

Table 3.3 Distribution of upland rice accessions based on relative growth of two test species, *L. sativa*.

Region	Number of accessions (%)				Total
	Relative growth				
	0-25	26-50	51-75	76-100	
L. sativa					
North	0	0.5	3.0	27.9	31.5
Northeast	0	0.2	0.4	1.6	2.1
East	0	0	0.2	3.9	4.0
South	0	0	0	9.8	9.8
Central	0	2.3	7.0	9.1	18.5
Unknown	0	1.1	3.9	29.2	34.1
Total	**0**	**4**	**14.4**	**81.6**	**100.0**

Table 3.3 Responses of *Lactuca sativa* to 569 accessions of upland rice from different regions in Thailand. Data are four replicates of relative growth of tester species.

Region	Number of rice accessions				Total
	Relative growth (%)				
	0-25	26-50	51-75	76-100	
NORTH					
Chiangrai	0	0	0	1	1
Chiangmai	0	3	5	57	65
Kamphaengphet	0	0	3	34	37
Lumpoon	0	0	0	7	7
Maehongsorn	0	0	1	6	7
Nan	0	0	1	12	13
Pichit	0	0	1	9	10
Pitsanuloke	0	0	0	8	8
Prae	0	0	1	3	4
Sukhothai	0	0	0	7	7
Utaithani	0	13	40	38	91
Uttradit	0	0	5	15	20
Total	*0*	*16*	*57*	*197*	***270***
NORTHEAST					
Khonkaen	0	0	0	2	2
Loei	0	0	2	3	5
Mookdaharn	0	1	0	0	1
Nakonpanom	0	0	0	1	1
Nakonratchasima	0	0	0	2	2
Nongkhai	0	0	0	1	1
Total	*0*	*1*	*2*	*9*	***12***
EAST					
Chantaburi	0	0	1	1	2
Kanchanaburi	0	0	0	15	15
Rayong	0	0	0	3	3
Trat	0	0	0	3	3
Total	*0*	*0*	*1*	*22*	***23***
SOUTH					
Chumporn	0	0	0	2	2
Naratiwat	0	0	0	3	3
Pattaloong	0	0	0	46	46
Phangha	0	0	0	5	5
Total	*0*	*0*	*0*	*56*	***56***
CENTRAL					
Patumthani	0	0	0	1	1
Nakornpathom	0	0	0	3	3
Ratchaburi	0	0	0	1	1
Saraburi	0	0	0	9	9
Total	*0*	*0*	*0*	14	***14***
UNKNOWN	0	6	22	166	**194**
TOTAL	**0**	**23**	**82**	**464**	**569**

4. ALLELOPATHIC ACTIVITY OF SELECTED UPLAND RICE ACCESSIONS ON MAJOR WEED SPECIES

4.1 Effects on monocots species

4.1.1 *Echinochloa colona*

Shoot length of test species, *E. colona*, was significantly inhibited at 30 days after emergence compared with the control (data not shown). At harvesting, shoot dry weight per plant of test species was significantly affected by BWSD 16 and was slightly reduced by BWSD 19 (Table 4.1). Total dry weight per plant of test species was highly inhibited by BWSD 16 and BWSD 19 while that of test species was slightly affected by BWSD 22. Leaf area of test species was also minimized when grown with BWSD 16 and BWSD 19. In contrast, leaf area of test species was not affected by neither BWSD 22 nor BWSD 25 (Table 4.1). However, shoot length of test species was more susceptible to BWSD 16, BWSD 19 and BWSD 22 compared with the non-allelopathic check BWSD 25 (Figure 4.1). It is noticeable that allelopathic effects were consistent with leaf area, shoot length and total dry weight of *E. colona*. The color of leaves of test species in the treatment with BWSD 16 and BWSD 19 were yellowish green whereas that with BWSD 25 (check) was green (Picture 4.1).

4.1.2 *Echinochloa crusgalli*

Shoot length of *E. crusgalli* was moderately reduced with tested with BWSD 16 and BWSD 19. However, BWSD 22 and BWSD 25 did not inhibit shoot length of the test species. In addition, shoot and root growth of *E. crusgalli* was markedly reduced when grown together with BWSD 16 and BWSD 19 (Table 4.2). Leaf area of each test plant was reduced by 75, 60 and 45% when tested with BWSD 16, BWSD 19 and BWSD 22, respectively (Figure 4.2).

Table 4.1 Effects of four selected rice accessions on shoot length and dry weight of shoot and root of *Echinochloa colona L.* Link. Data are the mean of four replicates. Ten seedlings of test species were used as one replicate.

Rice accession	Shoot length (cm)	Shoot DW (mg)	Root DW (mg)	Total DW (mg)
BWSD 16	33.5 a[1]	628 a	215 a	843 a
BWSD 19	33.6 a	1017 ab	284 a	1301 ab
BWSD 22	37.5 a	1566 b	399 a	1965 bc
BWSD 25	46.3 b	1759 b	607 b	2366 c

[1] Means in column followed by the same letter are not significantly different by Duncan Multiple Range Test at $p < 0.05$

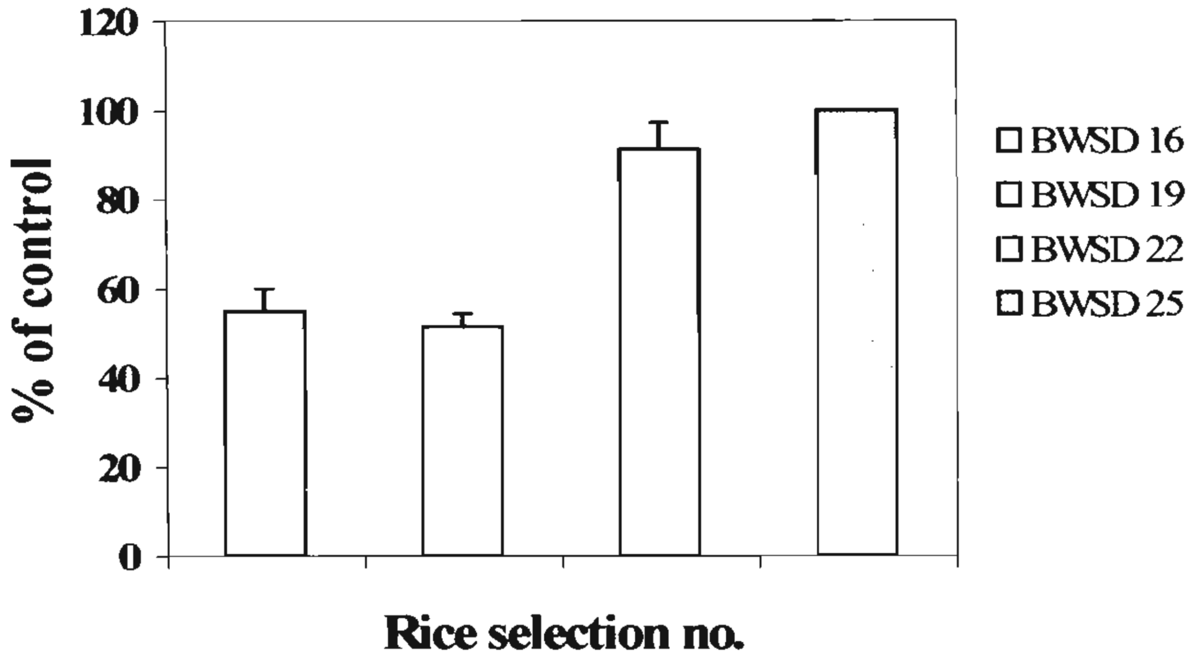
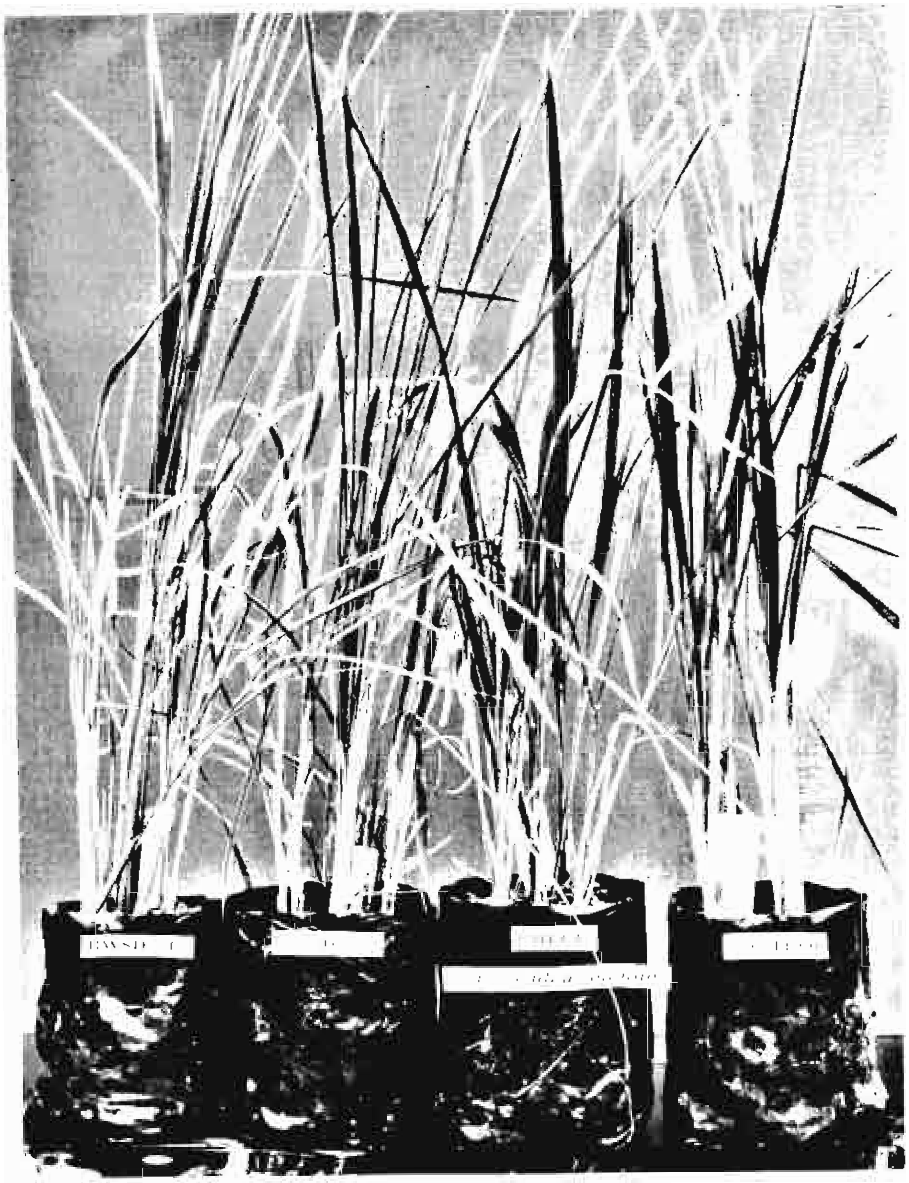


Figure 4.1 Leaf area of *Echinochloa colona* when grown with four selected rice accessions. Data are the mean of four replicates in percentage of non-allelopathic check (BWSD 25). Vertical bars represent the standard errors of the means.



Picture 4.1 Growth of test species *Echinochloa colona* was inhibited when grown with allelopathic rice accession, BWSD 16 or BWSD 19, in the soil.

Table 4.2 Effects of four selected rice accessions on shoot length and dry weight of shoot and root of *Echinochloa crusgalli* L. Beauv. Data are the mean of four replicates and ten seedlings were used in each replicate.

Rice accession	**Shoot length (cm)**	**Shoot DW (mg)**	**Root DW (mg)**	**Total DW (mg)**
BWSD 16	30.0 a[1]	931 a	198 a	1129 a
BWSD 19	33.5 a	923 a	239 a	1162 a
BWSD 22	36.8 ab	1311 b	278 a	1589 b
BWSD 25	40.1 b	1832 b	513 b	2345 c

[1] Means in column followed by the same letter are not significantly different by Duncan Multiple Range Test at $p< 0.05$

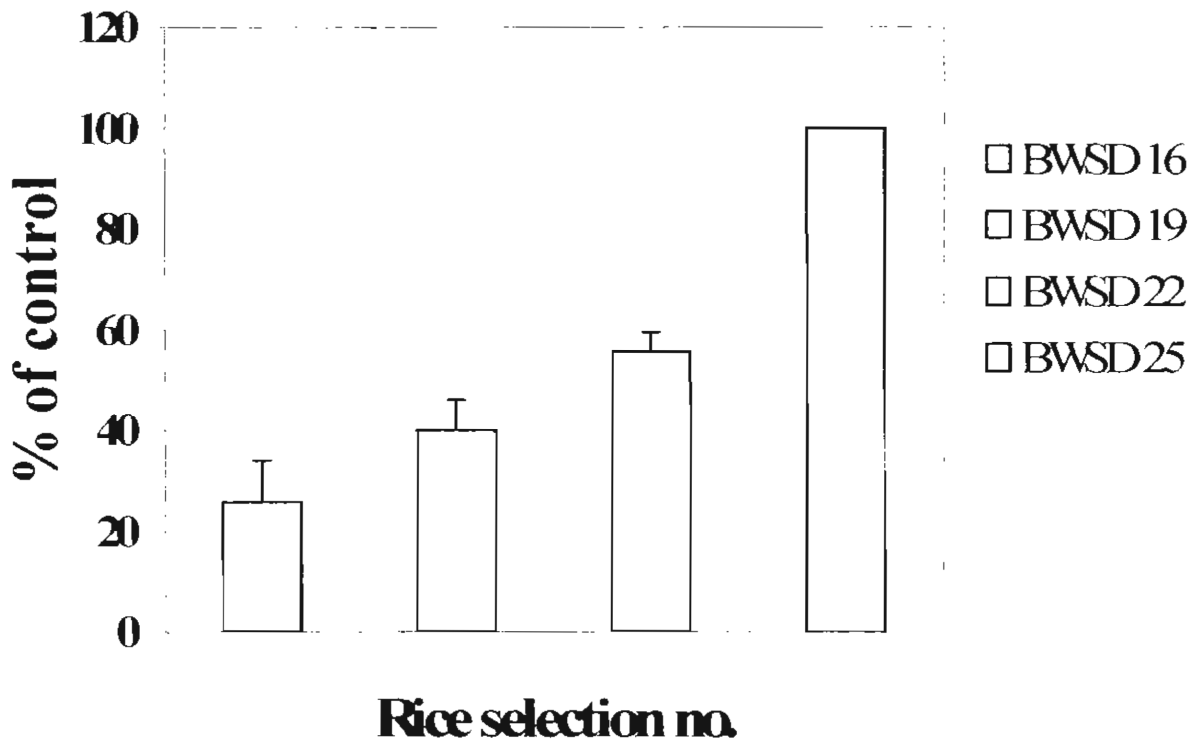


Figure 4.2 Leaf area of *Echinochloa crusgalli* when grown with four selected rice accessions. Data are the mean of four replicates in percentage of non-allelopathic check (BWSD 25). Vertical bars represent the standard errors of the means.

4.2 Effects on dicots species

4.2.1 *Euphorbia geniculata*

Shoot length of *E. geniculata* was moderately reduced when tested with BWSD 16 and was slightly reduced by BWSD 19 and BWSD 22. Similarly, shoot and root growth of *E. geniculata* was markedly reduced when grown together with BWSD 16 and BWSD 19 (Table 4.3). Leaf area of each test plant was reduced when tested with BWSD 16, BWSD 19 and BWSD 22 by 62, 50 and 39%, respectively (Figure 4.3).

4.2.2 *Mimosa pudica*

Shoot length of *M. pudica* was moderately reduced when tested with BWSD 16, BWSD 19 and BWSD 22. Shoot and root growth of *M. pudica* was markedly reduced when grown together with BWSD 16 and BWSD 19. However, BWSD 22 had a little effect on total dry weight of *M. pudica* (Table 4.4). Leaf area of each test plant was reduced when tested with BWSD 16, BWSD 19 and BWSD 22 by 65, 45 and 44%, respectively (Figure 4.4).

4.2.3 *Mimosa invisa*

Shoot length of *M. invisa* was inhibited when tested with BWSD 16 and BWSD 19 and was slightly reduced by BWSD 22. BWSD 19 had a strong allelopathic effect on shoot and root growth of *M. invisa.* In contrast, BWSD 16 and BWSD 22 were slightly allelopthic to test species (Table 4.5). Leaf area of each test plant was reduced more than 60% when tested with BWSD 16, BWSD 19 and BWSD 22 (Figure 4.5). When grown with BWSD 16, *M. pudica* plants became smaller and had less number of leaves with yellowish green (Picture 4.3A). At harvest, root length of test species was observed. When grown with BWSD 25, root length was longer than that with BWSD 19 (Picture 4.3B).

4.2.4 *Lactuca sativa*

For *L. sativa*, the growth was more sensitive to allelopathic rice accessions, BWSD 16, BWSD 19 and BWSD 22 (Table 4.6 and Figure 4.6). BWSD 16 and BWSD 19 depressed the total dry weight of *L. sativa* by three times compared with that in non-allelopathic check BWSD 25 (Table 4.6). Likewise, shoot and root dry weight was inhibited by those accessions. Leaf area of L. sativa was badly affected after grown with allelopathic rice for 30 days. BWSD 16, BWSD 19 and BWSD 22 reduced the leaf area per plant by 75, 83 and 60%, respectively (Figure 4.6).

The current result showed that the inhibitory activity of allelopathic rice depended on weed species (Figure 4.1-4.6). BWSD 16 and BWSD 19 gave the same pattern of test species inhibition as in the laboratory experiment. In contrast, BWSD 22 which was slightly allelopathic to two test species, *E. crusgalli* and *L. sativa*, in the laboratory exhibited the variation of allelopathic potential on different test species. For instances, It was moderately allelopathic to *E. crusgalli*, *Mimosa pudica*, *M. invisa* and *L. sativa* at different levels. In general, the growth of test species was markedly inhibited when grown with allelopathic accessions. This indicates that allelopathic accessions released allelochemicals into the soil resulting in inhibition of growth. However, the released allelochemicals in each accession might be different in both quantity and types of allelochemicals since trend of inhibition was not the same in all test species. Much of evidence indicates that several chemicals are released together and may exert toxicity in an additive or synergistic manner (Putnam and Tang, 1986). Thongma *et al.*, (1998) investigated the allelopathic activity of Mexican sunflower extract in soil and found that the degree of inhibitory activity was dependent on the test plant species.

To date, some allelopathic compounds were identified in water from allelopathic rice cultivars as 3-hydroxybenzoic acid (3HBA), 4-hydroxybenzoic acid (4HBA), 4-hydroxyhydrocinnamic acid (4HHCA), 3,4-dihydroxyhydrocinnamic acid (3,4DHHCA) and tentatively identified 4-hydroxyphenylacetic acid (4HPAA) (Mattice *et. al.*, 1997 and 1998).

Table 4.3 Effects of four selected rice accessions on shoot length and dry weight of shoot and root of *Euphorbia geniculata*. Data are the mean of four replicates and ten seedlings were used in each replicate.

Rice accession	Shoot length (cm)	Shoot DW (mg)	Root DW (mg)	Total DW (mg)
BWSD 16	10.3 a[1]	273.7 ab	53.1 ab	326.8 a
BWSD 19	12.8 b	245.0 a	43.8 a	288.8 a
BWSD 22	13.6 b	341.8 b	63.4 bc	405.2 ab
BWSD 25	16.1 c	415.8 ab	70.9 c	486.7 b

[1] Means in column followed by the same letter are not significantly different by Duncan Multiple Range Test at $p < 0.05$

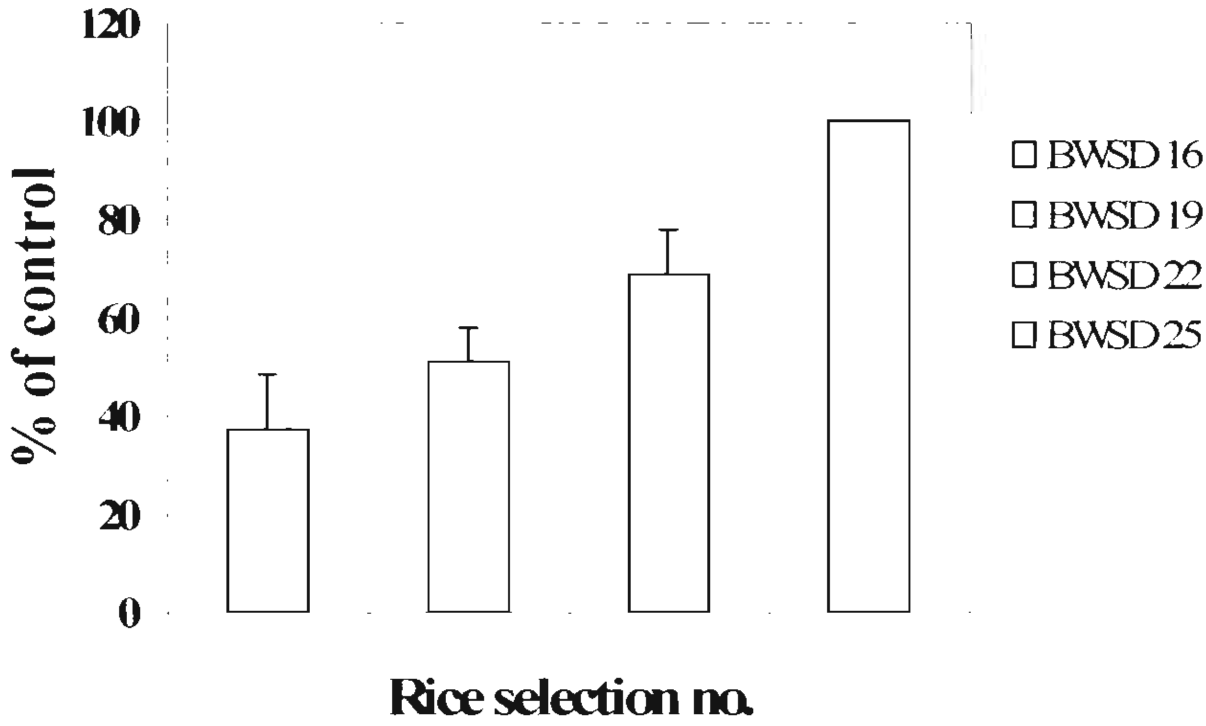


Figure 4.3 Leaf area of *Euphorbia geniculata* when grown with four selected rice accessions. Data are the mean of four replicates in percentage of non-allelopathic check (BWSD 25). Vertical bars represent the standard errors of the means.

Table 4.4 Effects of four selected rice accessions on shoot length and dry weight of shoot and root of *Mimosa pudica* L. Data are the mean of four replicates and ten seedlings were used in each replicate.

Rice accession	Shoot length (cm)	Shoot DW (mg)	Root DW (mg)	Total DW (mg)
BWSD 16	11.0 a[1]	577 a	189 a	766 a
BWSD 19	10.7 a	804 b	190 a	994 ab
BWSD 22	11.1 a	807 b	244 b	1051 b
BWSD 25	13.6 b	823 b	259 b	1082 b

[1] Means in column followed by the same letter are not significantly different by Duncan Multiple Range Test at $p < 0.05$

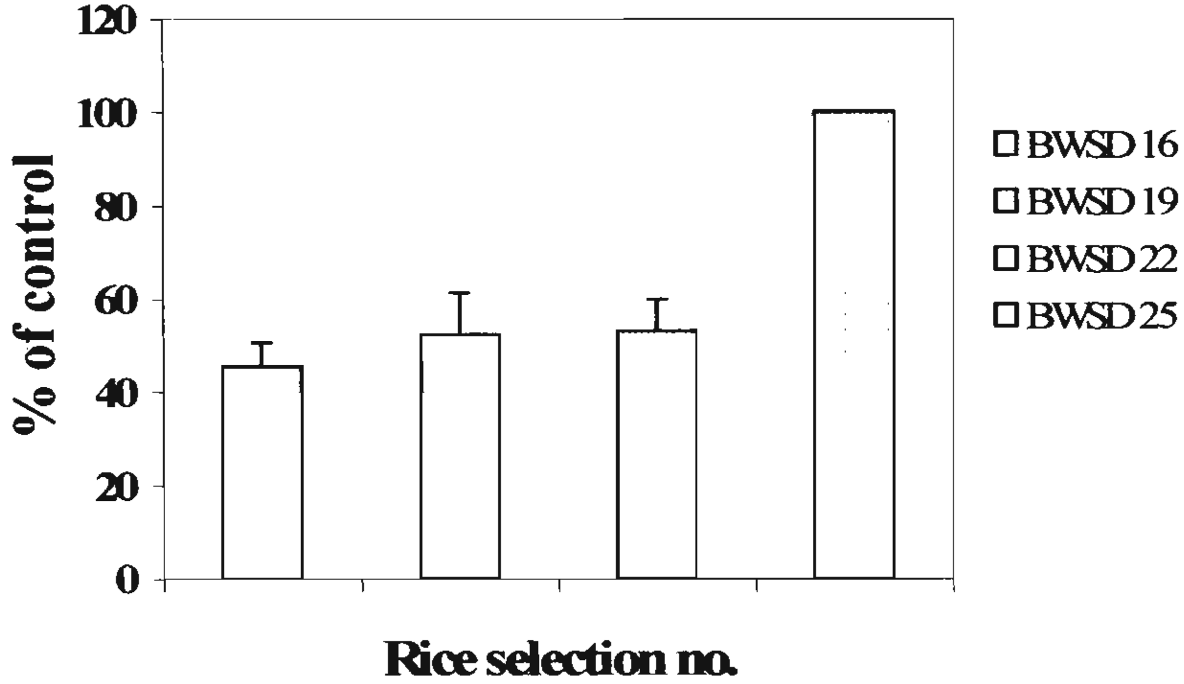


Figure 4.4 Shoot length of *Mimosa pudica* when grown with four selected rice accessions. Data are the mean of four replicates in percentage of non-allelopathic check (BWSD 25). Vertical bars represent the standard errors of the means.

Table 4.5 Effects of four selected rice accessions on shoot length and dry weight of shoot and root of *Mimosa invisa*. Data are the mean of four replicates and ten seedlings were used in each replicate.

Rice accession	**Shoot length (cm)**	**Shoot DW (mg)**	**Root DW (mg)**	**Total DW (mg)**
BWSD 16	7.8 a[1]	29.3 bc	11.3 b	40.6 bc
BWSD 19	7.9 a	18.5 a	7.1 a	25.6 a
BWSD 22	9.5 ab	27.1 b	11.1 b	38.2 ab
BWSD 25	10.5 b	36.0 c	11.4 b	47.4 c

[1] Means in column followed by the same letter are not significantly different by Duncan Multiple Range Test at $p< 0.05$

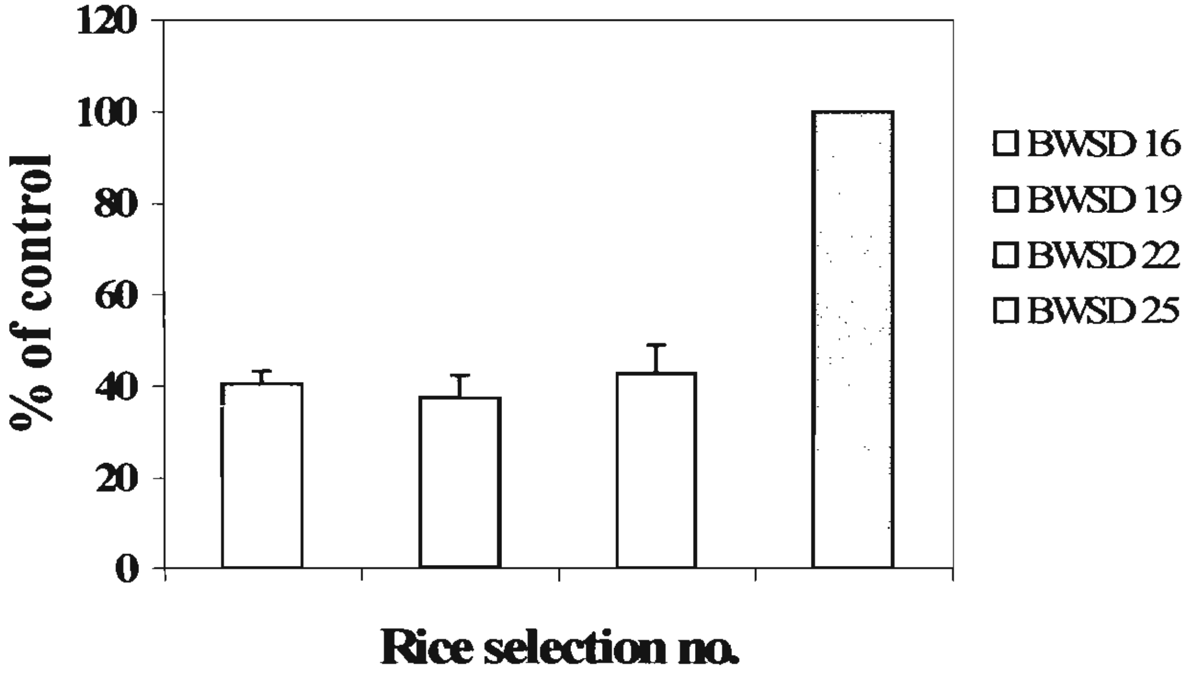
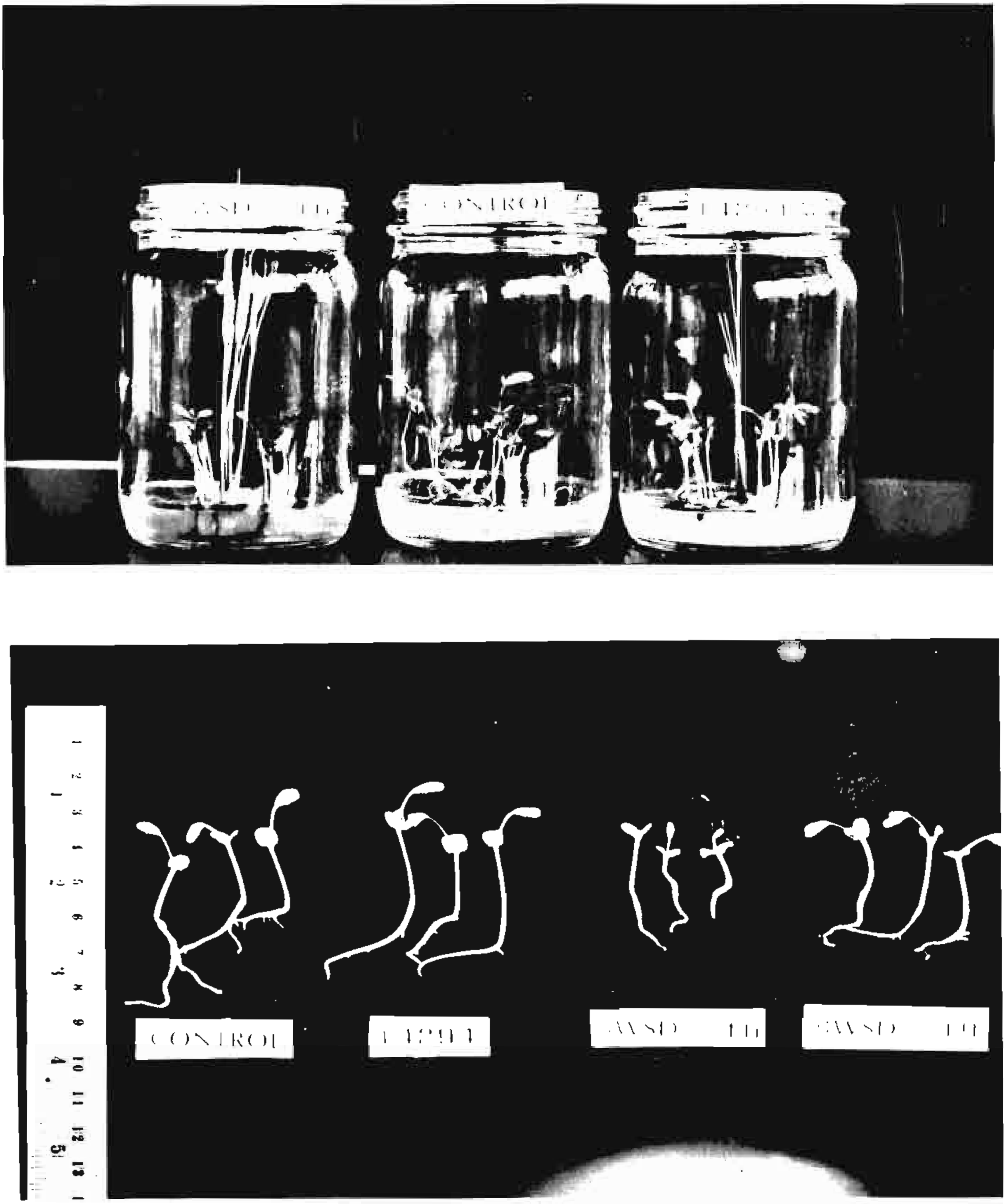


Figure 4.5 Leaf area of *Mimosa invisa* when grown with four selected rice accessions. Data are the mean of four replicates in percentage of non-allelopathic check (BWSD 25). Vertical bars represent the standard errors of the means.



Picture 4.2 Shoot length (A) and root length (B) of *Mimosa invisa* was inhibited when grown with allelopathic rice accession, BWSD 16 or BWSD 19, on 0.5% agar.

Picture 4.3 Growth of test species, *Mimosa invisa*, was suppressed when grown with allelopathic rice BWSD 16 and BWSD 19 (two on the right) in the soil under glasshouse condition.

Table 4.6 Effects of four selected rice accessions on shoot length and dry weight of shoot and root of *Lactuca sativa* L. Data are the mean of four replicates and ten seedlings were used in each replicate.

Rice accession	**Shoot length (cm)**	**Shoot DW (mg)**	**Root DW (mg)**	**Total DW (mg)**
BWSD 16	3.7 a[1]	11.5 a	7.9 ab	19.4 a
BWSD 19	2.8 a	13.3 a	3.3 a	16.6 a
BWSD 22	4.7 b	27.5 b	8.1 ab	35.6 ab
BWSD 25	5.9 c	42.8 c	13.6 b	56.4 b

[1] Means in column followed by the same letter are not significantly different by Duncan Multiple Range Test at $p < 0.05$

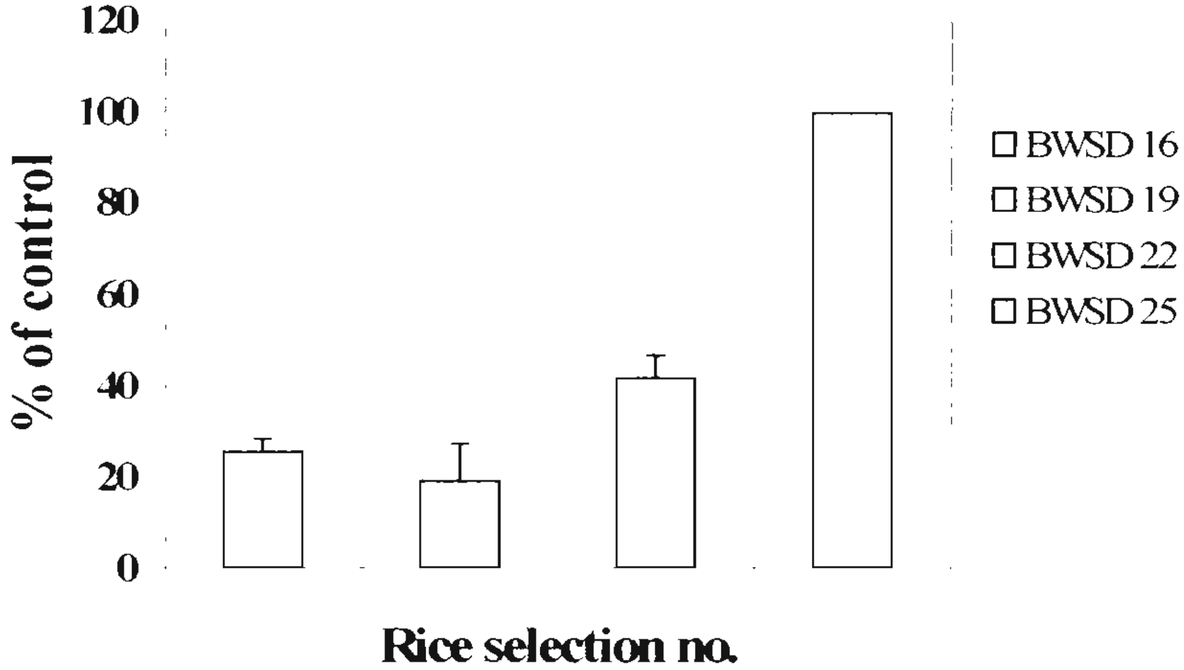


Figure 4.6 Shoot length of *Lactuca sativa* when grown with four selected rice accessions. Data are the mean of four replicates in percentage of non-allelopathic check (BWSD 25). Vertical bars represent the standard errors of the means.

5. ALLELOPATHIC POTENTIAL OF SELECTED UPLAND RICE ACCESSIONS AT DIFFERENT GROWTH STAGES

5.1 At 30 days after sowing

To evaluate whether allelopathic activity depends upon the growth stage of rice, *Mimosa invisa* was used as test species. At various growth stages of rice (0, 5, 10, 15, 20, 25, and 30 days), test plants were sown in the soil. At thirty days after sowing, shoot length of test species was measured. The results showed that at 0 day, no difference in shoot length was found in all four accessions. However, at 5-day, allelopathic accessions significantly reduced shoot length when compared with BWSD 25. After 10-day, the inhibitory effects were similar in all accessions (Table 5.1). Number of leaves was not significantly different among those accessions at all stages of rice. However, at 0-, 5- and 10-day, BWSD 16 and BWSD 19 were likely to reduce the number of *M. invisa* leaves when compared with BWSD 22 and BWSD 25 (Table 5.2).

5.2 At 60 days after sowing

When grown with BWSD 16, BWSD 19 and BWSD 22 at 0 and 5 days after rice germination, shoot length of *M. invisa* was markedly decreased compared with the non-allelopathic check BWSD 25. In contrast, all four accessions (BWSD 16, BWSD 19, BWSD 22 and BWSD 25) equally suppressed shoot length of test species when grown with rice at 10, 15, 20, 25 and 30-day old (Figure 5.1). The results indicate that allelopathic activity was interfered with competition effect when rice plants had larger canopy. Smaller plants perform less efficiently in the shade of the higher (Picture 5.1). Hence shading effects and competition for light and nutrient can obscure the allopathic activity at the beginning stage.

Similarly, total dry weight and number of leaves were inhibited by allopathic rice BWSD 16 and BWSD 19 when grown with 0-day and 5-days old rice (Figures 5.2 and 5.3). When *M. invisa* germinated at 10, 15, 20, 25 and 30 days later than rice, it would be very difficult to separate the allelopathy from competition effects. This may be due to the additive or synergistic effects between allelopathy and competition (Putnam and Tang, 1986). The results of this experiment indicated that BWSD 16, BWSD 19 and BWSD 22 were allelopathic to test species *M. inivisa* at the early stages (0 and 5 days)(Figures 5.2 and 5.3). It would be possible to use these allelopathic accessions as a biological tool to control weeds in upland rice system. However, field experiments have to be conducted to investigate the inhibitory effects of those allelopathic accessions prior to making use of them.

Table 5.1 Shoot length of test species *Mimosa invisa* grown with rice at various growth stages (0, 5, 10, 15, 20, 25 and 30 days). Data are the average of four replicates (first check).

Rice Accession	Shoot length (cm)						
	0*	5	10	15	20	25	30
BWSD 16	4.3a[1/]	4.4a	2.7a	1.5a	3.3a	1.9a	1.2a
BWSD 19	5.1a	5.6a	4.2b	2.7a	3.3a	2.3a	1.9a
BWSD 22	4.3a	5.9a	3.8b	2.5a	3.6a	2.6a	1.9a
BWSD 25	4.1a	7.8b	4.5b	5.3b	5.2b	2.8a	2.2a

* days after rice germination

[1/] Mean in column followed by the same letter are not significantly different by Duncan Multiple Range Test at $p<0.05$

Table 5.2 Number of leaves of test species *Mimosa invisa* grown with rice at various growth stages (0, 5, 10, 15, 20, 25 and 30 days). Data are the average of four replicates at 30 days (first check).

Rice Accession	Number of leaves						
	0*	5	10	15	20	25	30
BWSD 16	5	5	4	4	4	3	3
BWSD 19	6	6	5	5	5	3	3
BWSD 22	5	7	6	4	5	4	3
BWSD 25	6	7	6	5	5	4	3
	NS	NS	NS	NS	NS	NS	NS

* days after rice germination NS = not significantly different

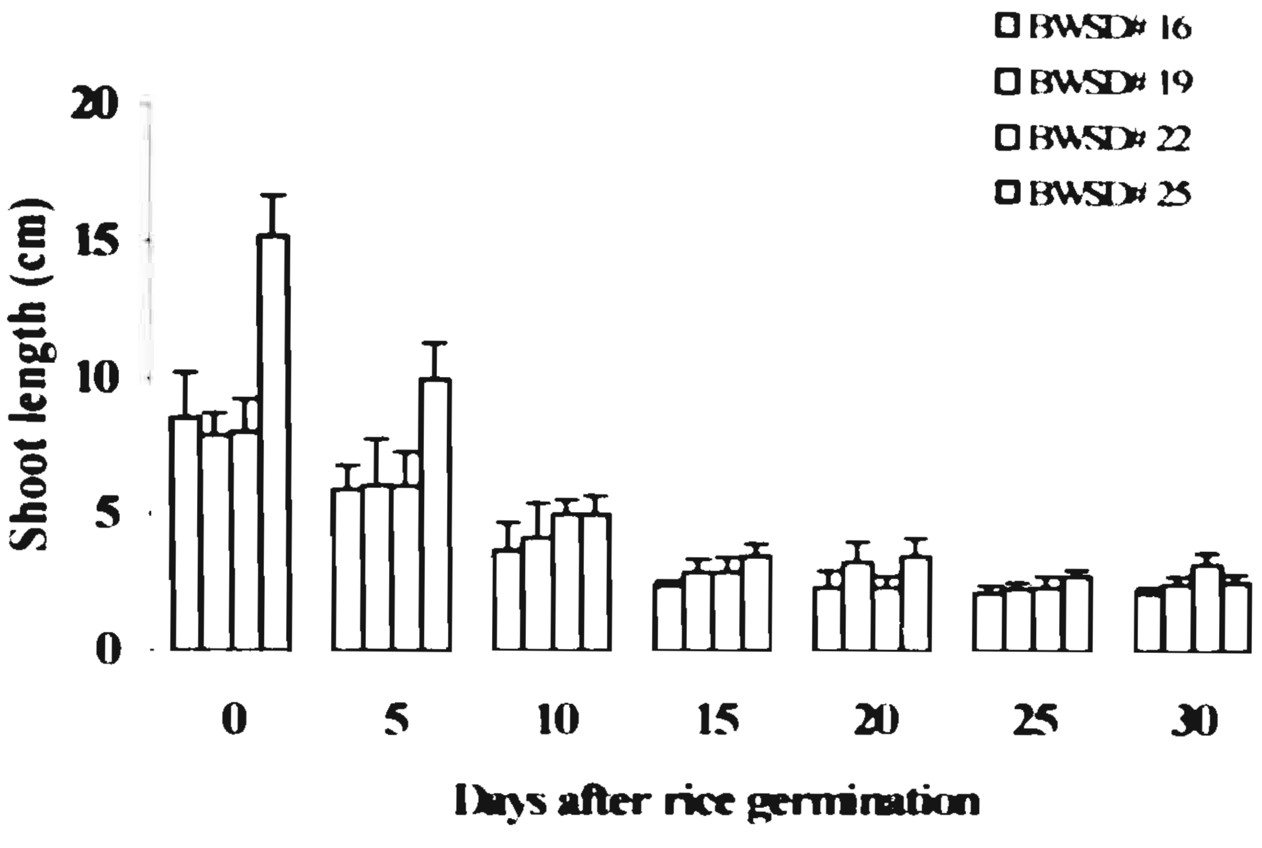


Figure 5.1 Shoot length of *Mimosa invisa* when grown with rice accessions at different stages of rice. Data are the mean with standard errors of four replicates

Picture 5.1 Additive effects between allelopathy and competition in *Mimosa invisa* plants when grown with 30-day non-allelopathic rice accession (BWSD 25).

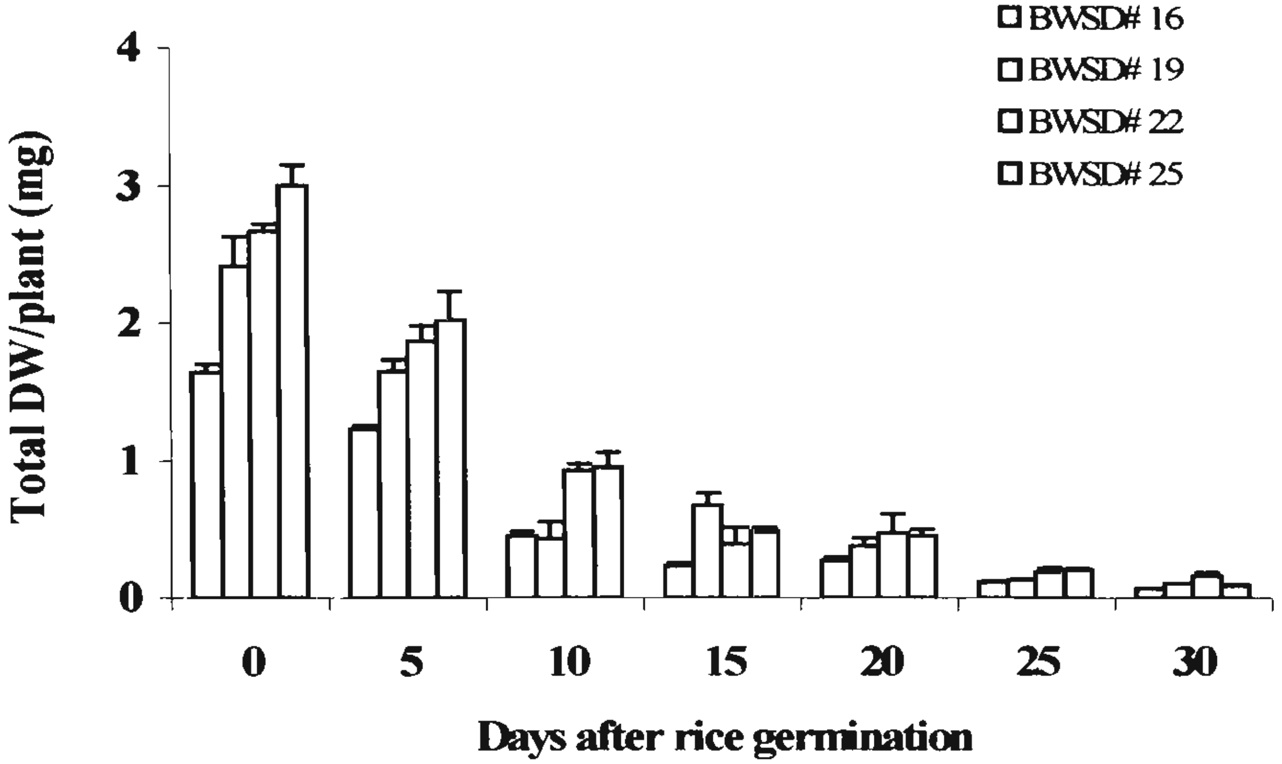


Figure 5.2 Total dry weight per plant of *Mimosa invisa* when grown with rice accessions at different stages of rice. Data are the mean with standard errors of four replicates.

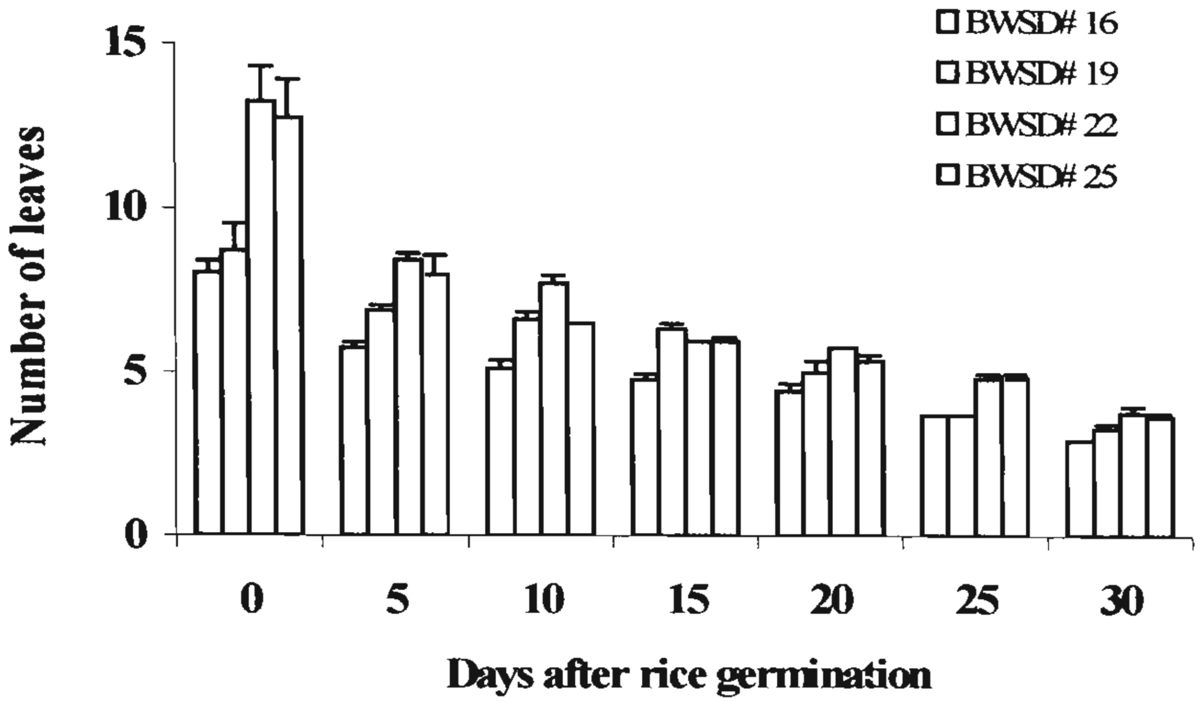


Figure 5.3 Number of leaves of *Mimosa invisa* when grown with rice accessions at different stages of growth. Data are the mean with standard errors of four replicates.

6. PHYSIOLOGICAL CHARACTERISTICS OF FOUR ALLELOPATHIC UPLAND RICE ACCESSIONS

At tillering stage, photosynthetic assimilationin the first and second leaf of four selected accessions were not significantly different. The photosynthetic carbon assimilation in the first leaf of BWSD 16, BWSD 19, BWSD 22 and BWSD 25 were 9.05, 10.56, 9.09, and 12.63 (μmole CO_2 m^{-2} s^{-1}), respectively (Table 6.1). Likewise, chlorophyll contents of those four accessions were similar. However, photosynthesis and chlorophyll content in non-allelopathic accession, BWSD 25, were slightly higher than all three allelopathic accessions BWSD 16, BWSD 19 and BWSD 22.

Photosynthetic assimilation in flag leaf of all four accessions were increased with a range of light intensity (100, 200, 500, 1000, 1500 and 2,000 μ mole photon m^{-2} s^{-1}) (Figure 6.1). The maximum photosynthetic rates were shown at 1,000 μmole photon m^{-2} s^{-1} of light intensity. Although BWSD 19 and BWSD 25 had a slightly greater photosynthetic rate than BWSD 16 and BWSD 22, it was unlikely to state that photosynthesis was responsible for allelopathic activity.

Table 6.1 Photosynthetic rate ($\mu moleCO_2\ m^{-2}\ s^{-1}$) and chlorophyll content (spad unit) four selected rice accessions at light intensity of 1500 $\mu mole\ m^{-2}\ s^{-1}$. Data are the mean of four measurements.

Accession No.	**Photosynthesis ($\mu moleCO_2\ m^{-2}\ s^{-1}$)**		**Chlorophyll content**	
	1st leaf	2nd leaf	1st leaf	2nd leaf
BWSD 16	9.05	10.04	34.1	34.4
BWSD 19	10.56	15.07	22.8	27.3
BWSD 22	9.09	12.08	28.4	31.1
BWSD 25	12.63	15.93	35.9	30.8
	NS*	NS	NS	NS

*NS = No significant difference at $p < 0.05$

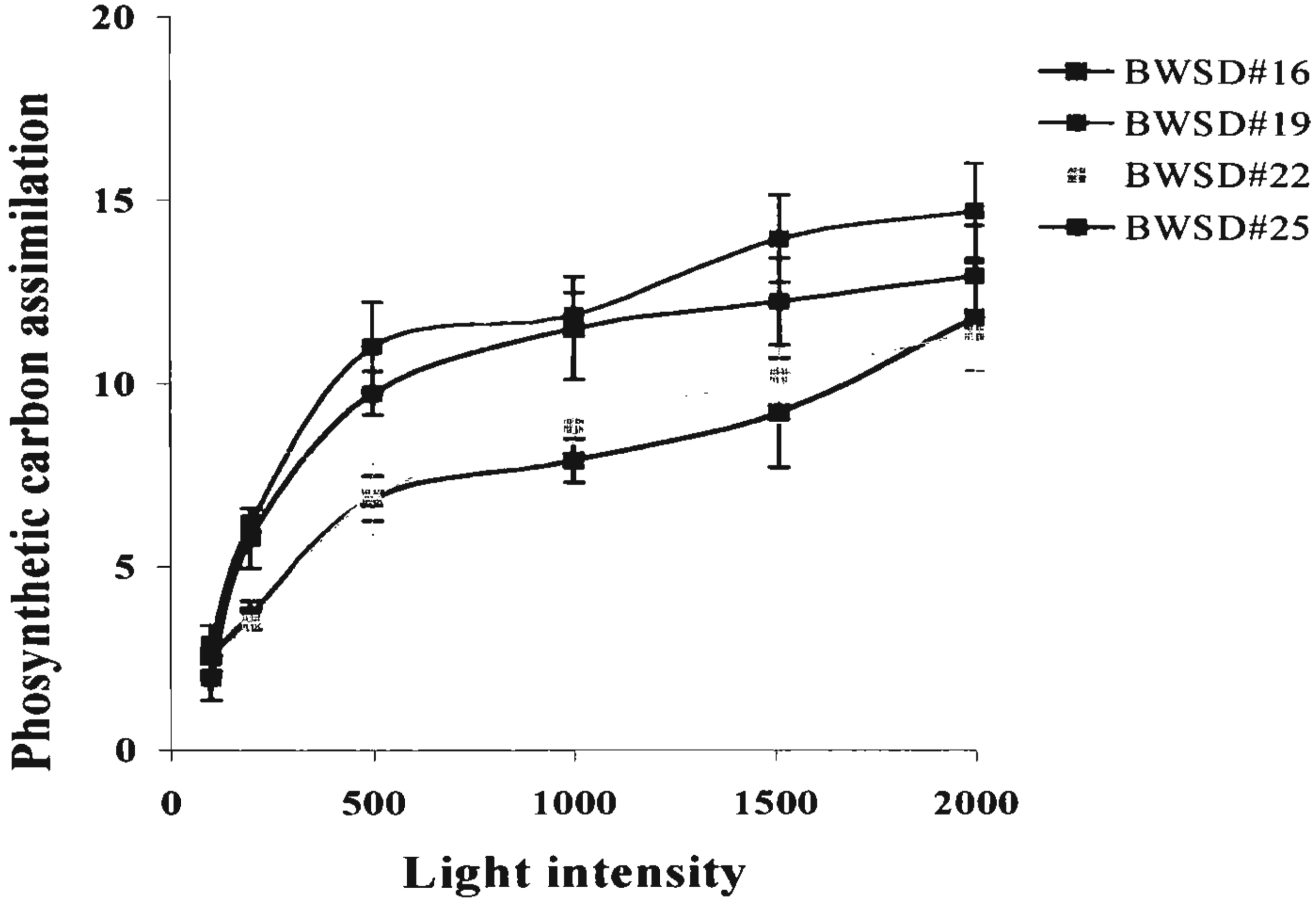


Figure 6.1 Change in photosynthetic carbon assimilation (μmole $CO_2m^{-2}.s^{-1}$) with a range of light intensity (100, 200, 500, 1000, 1500, 2000 μmole $m^{-2}.s^{-1}$).

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8. Publication arising from TRF Project PDF/47/2541

8.1 Conference paper

Maneechote, C., P. Krasaesindhu and R. Suwanketnikom. 1999. Allelopathic activity of upland rice in Thailand. Proceedings of the 17th Asian-Pacific Weed Science Society Conference, Central Plaza Hotel, Bangkok, 22-26 November 1999, volume 2, *In press.*

8.2 Working papers- In progress papers

Maneechote, C. and R. Suwanketnikom. 2000. Identification of allelopathic activity in Thai upland rice germplasm. Weed Science.

Maneechote, C. and R. Suwanketnikom. 2000. Weed suppression- allelopathy or competition. Weed Research.

Annex 1 List of upland rice accessions from Rice Germplasm Bank of Thailand.

No.	GS No.	Name	Type*	District	Province
1	1115	JAO HAWM	NG	_	_
2	1376	MAHK HUA	G	_	_
3	1376	MAHK HUA	G	_	_
4	1380	PONG LUE	G	_	_
5	1382	PRAE GAM	G	_	_
6	1397	LEUM WANG	G	_	_
7	1399	HUA HAWK	G	_	_
8	1400	DAW MAHNAM	G	_	_
9	1402	DAW KHAO	G	_	_
10	1402	DAW KHAO	G	_	_
11	1404	PAE	G	_	_
12	1404	PAE	G	_	_
13	1405	HAO	G	_	_
14	1406	HAO	G	_	_
15	1406	HAO	G	_	_
16	1407	HAO	G	_	_
17	1407	HAO	G	_	_
18	1412	GAHB ZAHNG	_	_	_
19	1419	LONG	_	_	_
20	1452	DAWK PUD	G	_	_

21	1452	DAWK PUD	G	_	_
22	1463	DAW YAHNG	G	_	_
23	1469	GAHB ZAHNG	G	_	_
24	1476	DAW DAENG	G	_	_
25	1480	DAW KHAO	G	_	_
26	1499	PAE	G	_	_
27	1500	LAI LUANG	G	_	_
28	1776	GLUM DAM	NG	_	_
29	1778	HAO	G	_	_
30	1779	SEW	NG	_	_
31	1780	DAW DAM	G	_	_
32	1790	DAW MAKHEUA	G	_	_
33	1794	DAW GAI KHAO	NG	_	_
34	1802	GAI TERNG	NG	_	_
35	1805	SIM	NG	_	_
36	1807	PAE	G	_	_
37	1812	DAM	G	_	_
38	1817	SEW	G	_	_
39	1819	PRAE DAENG	G	_	_
40	1820	DAENG	NG	_	_
41	1850	HOK LAI	G	_	_
42	1905	DAM MALED LEK	NG	_	_
43	1911	DAWK DAWM	NG	_	_

44	1917	DAENG	NG	_	_
45	1934	GRAI KHAO	NG	_	_
46	1941	DAWK MAHK	NG	_	_
47	1942	BAO HAWM	NG	_	_
48	1944	DAWK MUD	NG	_	_
49	1947	DAWK PA-YAWM	NG	_	_
50	2328	MALAGKIT SUNGSONG (HB 434)	G	_	_
51	2497	DAWK DAWM	NG	_	_
52	2581	MA NAM 1	G	_	_
53	2690	DAWK MAI	NG	_	_
54	2904	KING LAW	NG	_	_
55	3116	SEA MAEJAN	G	_	_
56	3123	DAENG	G	_	_
57	3124	KHAO	G	_	_
58	3144	HAO	G	_	_
59	3154	DAW HAI	G	_	_
60	3175	KHAO' LAW	G	_	_
61	3188	IT KHAO	G	_	_
62	3192	DAW TAWNG	G	_	_
63	3197	KHAO PAE	G	_	_
64	3216	CHANG SAEN	G	_	_
65	3218	KHAO' PRAE MALED YAI	G	_	_

66	3219	HAO	G	_	_
67	3234	STAINLESS	G	_	_
68	3277	HAO GAEN KHAO	G	_	_
69	3283	E-NAWN DAM	G	_	_
70	3291	PAN PAE	G	_	_
71	3310	NO NAME	G	_	_
72	3311	NO NAME	G	_	_
73	3315	GAEN DAENG	G	_	_
74	3400	KHAO LAM PUENG	NG	_	_
75	3459	KHAO RAI	NG	_	_
76	3605	HAO	G	_	_
77	3606	PAE	G	_	_
78	3656	LEUANG YAI RAI	NG	_	_
79	3663	KHAO' TAI	NG	_	_
80	3669	LEUANG YAI	NG	_	_
81	3706	GAM DAD RAI	NG	_	_
82	3709	LEUANG TAWNG RAI	NG	_	_
83	3715	KHI MEUANG NAWK RAI	NG	_	_
84	3717	KHAO' SI NUAN	NG	_	_
85	3762	SETTI	NG	_	_
86	3765	LEUANG	NG	_	_
87	3778	NIAW LAI	G	_	_
88	3781	NO NAME	NG	_	_

89	3782	KHAO' KHAO	NG	_	_
90	3784	GON JUD	NG	_	_
91	3809	KHAO LON YUNG	NG	_	_
92	3883	DAW SAHM DEUAN	G	_	_
93	3884	DAW PLAH MAW	G	_	_
94	3885	DAW PLAH SEW	G	_	_
95	3887	DAW PON	G	_	_
96	3888	DAW NAM MAN WUA	G	_	_
97	3890	E- DAM	G	_	_
98	3891	DAW PUD	G	_	_
99	3892	SAHM DEUAN	_	_	_
100	3893	PAWNG AEW I	_	_	_
101	3894	PAWNG AEW II	_	_	_
102	3895	PAWNG AEW	_	_	_
103	4015	KHAO SAI	_	_	_
104	4019	NAHN DAM	_	_	_
105	4020	KHAO MALI	_	_	_
106	4021	KHAO TAH HONG	_	_	_
107	4022	KHAO YA LA	_	_	_
108	4033	GAN TANG	_	_	_
109	4374	E-NAWN DAENG	G	_	_
110	4410	HAWM OM	G	_	_
111	4414	WANG DIN	NG	_	_

112	4415	KHAMU	G	_	_
113	4416	LEUANG FUN	NG	_	_
114	4417	HAO	G	_	_
115	4418	HAO DAENG	G	_	_
116	4420	HAO	G	_	_
117	4421	HAO DAW	G	_	_
118	4422	HAWM PAI	G	_	_
119	4423	HAWM	G	_	_
120	4425	E-NAWN	G	_	_
121	4426	E-NAWN	G	_	_
122	4427	SEW 13	G	_	_
123	4428	SEW 273-8-4	NG	_	_
124	4429	SEW DAENG	G	_	_
125	4430	SEW 273-8-8	G	_	_
126	4431	SEW DAM	G	_	_
127	4432	SEW DAM	G	_	_
128	4433	SEW DAM	G	_	_
129	4434	GLUAY	NG	_	_
130	4435	GLUM DAM	G	_	_
131	4436	DAWK MAI HAWM	G	_	_
132	4437	SIM DAM	G	_	_
133	4438	NIAW DAM	G	_	_
134	4439	MAGAWK PI	G	_	_

135	4441	MA NAM	G	_	_
136	4442	MA NAM 1	G	_	_
137	4444	SI TRANG	NG	_	_
138	4445	SI TRANG (B)	G	_	_
139	4446	HAWM MAEJO	G	_	_
140	4448	DAW LEUANG NAM PUENG	NG	_	_
141	4449	MA TAHN LAI	NG	_	_
142	4450	LEUANG NOI	NG	_	_
143	4451	MA HING 269-7-22-1	G	_	_
144	4453	JAN	G	_	_
145	4454	BPI 76	G	_	_
146	4458	IR 944-102-2-3-2	NG	_	_
147	4459	IR 1480-147-3-2-1	NG	_	_
148	4460	IR 1480-147-3-2-2	NG	_	_
149	4461	IR 1407-141-6-3-4	_	_	_
150	4462	IR 1747-F5B-13	NG	_	_
151	4464	IR 1746-226-1-1-3	NG	_	_
152	4465	IR 1746-226-1-2-2	G	_	_
153	4466	NO NAME (144 B/2/6)	NG	_	_
154	4467	ADNY 8	NG	_	_
155	4474	E-NAWN NAH	G	_	_
156	4475	E-MEUD	G	_	_

157	4476	E-NERNG	G	_	_
158	4538	NIAW NGAH	G	_	_
159	4551	JAO YAM SAHN DAENG	NG	_	_
160	4557	POO KAO TAWNG	NG	_	_
161	4560	KHAO' KHAO	NG	_	_
162	4564	LEUANG TAWNG	NG	_	_
163	4568	SAITON	NG	_	_
164	4571	KHAO GAEN	NG	_	_
165	4572	GAI RIANG	NG	_	_
166	4574	JAO JE WAH	NG	_	_
167	4621	SAWAHNG AHROM	NG	_	_
168	4626	NAHNG MUD	NG	_	_
169	4649	WUA PAN LAK	NG	_	_
170	4983	KHAO KAD	NG	_	_
171	5037	KHAO RAI	NG	ศรีสำโรง	สุโขทัย
172	5244	DAW KHAO	G	แม่ริม	เชียงใหม่
173	5245	DAW HAWM NAM PUENG	G	ดอยสะเก็ด	เชียงใหม่
174	5246	LEB MUE NAGAE	G	ดอยสะเก็ด	เชียงใหม่
175	5247	DAW DAWK NGAE	G	ดอยสะเก็ด	เชียงใหม่
176	5249	DAW HAWN	G	ดอยสะเก็ด	เชียงใหม่
177	5250	DAW LAI	G	สันกำแพง	เชียงใหม่
178	5251	KHAO	G	สันกำแพง	เชียงใหม่
179	5252	SAHMDEUAN	G	สันกำแพง	เชียงใหม่

180	5253	GAEW DAW	G	สันกำแพง	เชียงใหม่
181	5254	GAEW PUK	G	สันกำแพง	เชียงใหม่
182	5255	FEUANG KAM	G	สันกำแพง	เชียงใหม่
183	5256	KHAO PAH	G	สันกำแพง	เชียงใหม่
184	5257	KHAO	G	สันกำแพง	เชียงใหม่
185	5258	DAW LAI	G	สันกำแพง	เชียงใหม่
186	5263	DAW LAI	G	แม่ริม	เชียงใหม่
187	5264	PAH PUENG	G	เชียงใหม่	เชียงใหม่
188	5265	NAHNG GOW	G	เชียงใหม่	เชียงใหม่
189	5266	LEUANG LUANG	G	เชียงใหม่	เชียงใหม่
190	5267	DAWK NGAE	G	เมือง	ลำพูน
191	5268	DAW NOI	G	เมือง	ลำพูน
192	5269	KHAO LAI	G	เมือง	ลำพูน
193	5270	DAW TAMADAH	G	ป่าซาง	ลำพูน
194	5271	DAW KHAO	G	ป่าซาง	ลำพูน
195	5272	NOK KHAO	NG	ป่าซาง	ลำพูน
196	5273	DAW WAENG HAK	G	บ้านโฮ่ง	ลำพูน
197	5274	LAI MAEJO	G	สันป่าตอง	เชียงใหม่
198	5275	GAEW JO	G	สันป่าตอง	เชียงใหม่
199	5277	GLUAY	G	สันป่าตอง	เชียงใหม่
200	5278	GAEW LAI	G	หางดง	เชียงใหม่
201	5279	MAEJO	G	หางดง	เชียงใหม่
202	5281	GLUAY	G	หางดง	เชียงใหม่

203	5283	NAHNG GAI	G	สันป่าตอง	เชียงใหม่
204	5286	GAEW	G	สันป่าตอง	เชียงใหม่
205	5289	PAH DAENG	G	หางดง	เชียงใหม่
206	5290	SINGAPORE	G	หางดง	เชียงใหม่
207	5291	DAWK PUD	G	สารภี	เชียงใหม่
208	5292	PUANG HAHNG GLAHNG	G	ปาย	แม่ฮ่องสอน
209	5293	KHAO LEB	NG	แม่สะเรียง	แม่ฮ่องสอน
210	5294	MAWNG NO	NG	แม่สะเรียง	แม่ฮ่องสอน
211	5295	KHAO RANG	NG	แม่สะเรียง	แม่ฮ่องสอน
212	5459	HAWM BAI	NG	สามง่าม	พิจิตร
213	5787	HAWM DONG	NG	บัวใหญ่	นครราชสีมา
214	6251	GUE	G	นครไทย	พิษณุโลก
215	6308	SEW DAENG	G	ชาติตระการ	พิษณุโลก
216	6312	DAWK PONG	NG	นครไทย	พิษณุโลก
217	6350	KHAO' PRAE	G	นครไทย	พิษณุโลก
218	6355	MAN SONG	NG	นครไทย	พิษณุโลก
219	6421	HAO	G	นครไทย	พิษณุโลก
220	6871	KHAO' DAENG	NG	ด่านช้าง	นครปฐม
221	6924	PAN KHAMEN	NG	ด่านช้าง	นครปฐม
221	6925	KHAO' KHAMEN	NG	ด่านช้าง	นครปฐม
222	6950	LEUANG NOI	G	สันป่าตอง	เชียงใหม่
223	6959	BEW PUI	NG	สันป่าตอง	เชียงใหม่
224	6961	LOCAL 4	NG	สันป่าตอง	เชียงใหม่

225	6970	KHAO 5	NG	สันป่าตอง	เชียงใหม่
226	6977	BAN JAYO	NG	สันป่าตอง	เชียงใหม่
227	6981	JAO HAWM	NG	สันป่าตอง	เชียงใหม่
228	6982	KHAW KHA	NG	สันป่าตอง	เชียงใหม่
229	6985	MOTOZA	NG	สะเมิง	เชียงใหม่
230	6990	VE CHAI	NG	สะเมิง	เชียงใหม่
231	6995	MTO 7417 D-B-50-1-2	NG	สะเมิง	เชียงใหม่
232	8342	เหลืองหอม	NG	ท่าปลา	อุตรดิตถ์
233	8343	ดอกอ้อ	NG	ท่าปลา	อุตรดิตถ์
234	8345	น้ำราด	NG	ท่าปลา	อุตรดิตถ์
235	8346	เหลืองนางนวล	NG	ท่าปลา	อุตรดิตถ์
236	8347	หอมทอง	NG	ท่าปลา	อุตรดิตถ์
237	8348	เหลืองทองย้อย	NG	ท่าปลา	อุตรดิตถ์
238	8349	กล้วยง้าว	NG	ฟากท่า	อุตรดิตถ์
239	8353	หมากผัว	G	ฟากท่า	อุตรดิตถ์
240	8354	กล้วยง้าวกลาง	G	ฟากท่า	อุตรดิตถ์
241	8355	กล้วยง้าวดอ	G	ฟากท่า	อุตรดิตถ์
242	8356	มะผัว	G	ฟากท่า	อุตรดิตถ์
243	8357	ขี้ตมแร่	G	ฟากท่า	อุตรดิตถ์
244	8358	ขี้ตมขาว	G	ฟากท่า	อุตรดิตถ์
245	8360	ช้างแดง	G	ฟากท่า	อุตรดิตถ์
246	8361	ปลาซิว	G	ฟากท่า	อุตรดิตถ์
247	8362	วังดอ	G	ฟากท่า	อุตรดิตถ์

248	8363	อะฮิ	G	ฟากท่า	อุตรดิตถ์
249	8364	ม้าฮ้อ	G	ฟากท่า	อุตรดิตถ์
250	8365	ม้าน้ำ	G	ฟากท่า	อุตรดิตถ์
251	8366	เล็บช้าง	G	ฟากท่า	อุตรดิตถ์
252	8875	KHOA SAMER	NG	เมือง	อุทัยธานี
253	8876	LEUANG	NG	เมือง	อุทัยธานี
254	8881	LEUANG TA KLONG	NG	เมือง	อุทัยธานี
255	8883	SAHM RUANG	NG	เมือง	อุทัยธานี
256	8887	SA GRUAD	G	ทัพทัน	อุทัยธานี
257	8889	SAI YUD	NG	ทัพทัน	อุทัยธานี
258	8890	GAN PLOO	G	ทัพทัน	อุทัยธานี
259	8891	PUANG PET	NG	ทัพทัน	อุทัยธานี
260	8892	PAWN SAWAN	NG	ทัพทัน	อุทัยธานี
261	8893	LEUANG TAWNG	NG	ทัพทัน	อุทัยธานี
262	8896	TAWNG RAHK SAI	NG	ทัพทัน	อุทัยธานี
263	8898	MIN SAWN	NG	ทัพทัน	อุทัยธานี
264	8899	TAWNG MAH ENG	NG	ทัพทัน	อุทัยธานี
265	8902	AWN	G	บ้านไร่	อุทัยธานี
266	8903	ME	NG	บ้านไร่	อุทัยธานี
267	8904	TIA	NG	บ้านไร่	อุทัยธานี
268	8905	LEUANG TAWNG	NG	บ้านไร่	อุทัยธานี
269	8907	DAENG	NG	บ้านไร่	อุทัยธานี
270	8909	LEUANG GLIANG	NG	บ้านไร่	อุทัยธานี

271	8910	ME LAI DAENG	NG	บ้านไร่	อุทัยธานี
272	8912	PRAE DAENG	G	บ้านไร่	อุทัยธานี
273	8913	KHAO	NG	บ้านไร่	อุทัยธานี
274	8914	PRAE	G	บ้านไร่	อุทัยธานี
275	8916	KHAO PRAJUAB	NG	บ้านไร่	อุทัยธานี
276	8917	LEUANG PRATAHN KAW YAO	NG	บ้านไร่	อุทัยธานี
277	8918	E - JAE	NG	บ้านไร่	อุทัยธานี
278	8919	MED LEK	G	บ้านไร่	อุทัยธานี
279	8920	LOOK PUENG	NG	บ้านไร่	อุทัยธานี
280	8923	LEUANG AWN	NG	บ้านไร่	อุทัยธานี
281	8924	KHAO WIANG	NG	บ้านไร่	อุทัยธานี
282	8925	DON MEUANG	NG	บ้านไร่	อุทัยธานี
283	8926	LEB MUE NAHNG	NG	บ้านไร่	อุทัยธานี
284	8928	E - NAWN	G	บ้านไร่	อุทัยธานี
285	8931	NONG KHON	NG	บ้านไร่	อุทัยธานี
286	8932	FUND NGOO	G	บ้านไร่	อุทัยธานี
287	8933	LEUANG NGERN	NG	บ้านไร่	อุทัยธานี
288	8935	LAI	NG	บ้านไร่	อุทัยธานี
289	8936	NIAW LAI	G	บ้านไร่	อุทัยธานี
290	8937	LEUANG YAI	NG	บ้านไร่	อุทัยธานี
291	8938	DAENG	NG	บ้านไร่	อุทัยธานี
293	8939	LEUANG RAI	NG	บ้านไร่	อุทัยธานี

294	8940	JED RUANG	NG	บ้านไร่	อุทัยธานี
295	8943	TA POW LOM	NG	หนองฉาง	อุทัยธานี
296	8944	KHAO AH-GAHD	NG	หนองฉาง	อุทัยธานี
297	8945	NAHNG MON	NG	หนองฉาง	อุทัยธานี
298	8946	LEUANG PRATAHN YAI WAI	NG	หนองฉาง	อุทัยธานี
299	8947	KHAO TAH LEUAM	NG	หนองฉาง	อุทัยธานี
300	8949	KHAO TAH DEEH	NG	หนองฉาง	อุทัยธานี
301	8950	LEUANG PRATAHN GAEW	NG	สว่างอารมณ์	อุทัยธานี
302	8951	KHIAW LA - AW	NG	สว่างอารมณ์	อุทัยธานี
303	8952	HAH RUANG	NG	สว่างอารมณ์	อุทัยธานี
304	8954	MEA LAHD	NG	สว่างอารมณ์	อุทัยธานี
305	8956	MALI 3	NG	สว่างอารมณ์	อุทัยธานี
306	8957	SAI YUD	NG	สว่างอารมณ์	อุทัยธานี
307	8958	DI SI	NG	หนองขาหย่าง	อุทัยธานี
308	8959	KHAO ROM PO	NG	หนองขาหย่าง	อุทัยธานี
309	8960	ROI RUANG	NG	หนองขาหย่าง	อุทัยธานี
310	8961	KHAO CHLERN	NG	หนองขาหย่าง	อุทัยธานี
311	8962	SAO CHIANG MAI	NG	หนองขาหย่าง	อุทัยธานี
312	8963	AWN GLIN	NG	หนองขาหย่าง	อุทัยธานี
313	8964	SI NUAN KHANG LAI	NG	หนองขาหย่าง	อุทัยธานี
314	8965	KHAO U-TAI	NG	หนองขาหย่าง	อุทัยธานี
315	8967	KHAO MED YAO	NG	หนองขาหย่าง	อุทัยธานี

316	8968	KHAO SA KET	NG	หนองขาหย่าง	อุทัยธานี
317	8969	LEUANG TAWNG	G	ลานสัก	อุทัยธานี
318	8970	KHAO HAWM	G	ลานสัก	อุทัยธานี
319	8971	KHAO TA LIAM	NG	ลานสัก	อุทัยธานี
320	8972	PAWN SAWAN	NG	ลานสัก	อุทัยธานี
321	8973	PONG	NG	พรานกระต่าย	กำแพงเพชร
322	8974	KHAIW NGOO	G	พรานกระต่าย	กำแพงเพชร
323	8976	GON JUD	NG	พรานกระต่าย	กำแพงเพชร
324	8977	NAH KHAWAN	NG	พรานกระต่าย	กำแพงเพชร
325	8979	LEUANG PRATEW	NG	พรานกระต่าย	กำแพงเพชร
326	8981	PUANG GRA KAW	NG	พรานกระต่าย	กำแพงเพชร
327	8982	HAWM JAN	_	พรานกระต่าย	กำแพงเพชร
328	8983	GRA BAWK	NG	พรานกระต่าย	กำแพงเพชร
329	8984	A NGAWY	NG	พรานกระต่าย	กำแพงเพชร
330	8985	MALI LEUAY	NG	พรานกระต่าย	กำแพงเพชร
331	8987	TAH GUI	NG	ขาณุวรลักษบุรี	กำแพงเพชร
332	8988	DAENG	G	ขาณุวรลักษบุรี	กำแพงเพชร
333	8989	LEUANG PRATAHN GAEW	NG	ขาณุวรลักษบุรี	กำแพงเพชร
334	8990	LEUANG RAI	NG	ขาณุวรลักษบุรี	กำแพงเพชร
335	8991	BUA KHAO	NG	ขาณุวรลักษบุรี	กำแพงเพชร
336	8992	HAWM SUAN	NG	ขาณุวรลักษบุรี	กำแพงเพชร
337	8993	MEDMAKHAM	NG	ไม่ปรากฏสถานที่	ไม่ปรากฏ สถานที่

338	8994	MAEW	NG	ขาณุวรลักษบุรี	กำแพงเพชร
339	8995	HAWM MALI	NG	ขาณุวรลักษบุรี	กำแพงเพชร
340	8996	DI SI	NG	ไทรงาม	กำแพงเพชร
341	8997	LOI	NG	ไทรงาม	กำแพงเพชร
342	8998	HAH RUANG	NG	คลองขลุง	กำแพงเพชร
343	8999	KHAO TAH NON	NG	คลองขลุง	กำแพงเพชร
344	9001	PAHK LAD	NG	ลานกระบือ	กำแพงเพชร
345	9002	LEUANG TAWNG KUM	NG	ไม่ปรากฏสถานที่	ไม่ปรากฏ สถานที่
346	9003	LI SAW	NG	คลองลาน	กำแพงเพชร
347	9004	PAHNG	NG	คลองลาน	กำแพงเพชร
348	9005	LEUANG NGAO	G	คลองลาน	กำแพงเพชร
349	9006	KHAO LUA	G	คลองลาน	กำแพงเพชร
350	9008	NIAW DAENG	G	คลองลาน	กำแพงเพชร
351	9009	NIAW DAM	G	คลองลาน	กำแพงเพชร
352	9010	NIAW DAENG	NG	คลองลาน	กำแพงเพชร
353	9011	KHAO	G	คลองลาน	กำแพงเพชร
354	9012	LAGUFOO	NG	คลองลาน	กำแพงเพชร
355	9013	TAYI-AE (LAI)	NG	คลองลาน	กำแพงเพชร
356	9015	JAO DAM	NG	คลองลาน	กำแพงเพชร
357	9016	KHAO' DAENG	NG	คลองลาน	กำแพงเพชร
358	9017	LI SAW	NG	คลองลาน	กำแพงเพชร
359	9018	HAH RUANG	NG	คีรีมาศ	สุโขทัย

360	9020	MED MA KHEUA	NG	คีรีมาศ	สุโขทัย
361	9022	MEUANG GRUANG	NG	คีรีมาศ	สุโขทัย
362	9023	NAH SUAN	NG	_	_
363	9024	IRAT 104	NG	_	_
364	9026	SILIWAH	NG	_	_
365	9027	IR 3646-9-1-1	NG	_	_
366	9029	KICHANG	NG	แม่แจ่ม	เชียงใหม่
367	9030	ข้าวน้อย		_	_
368	9049	คอสามเดือน		_	_
369	9057	คอเล็ก		_	_
370	9058	ข้าวขาว		_	_
371	9063	ดอกมะเขือ		_	_
372	9064	เกวียนหัก		_	_
373	9065	DAW TAO BOM	G	ฝาง	เชียงใหม่
374	9067	คอดอกแง้		_	_
375	9075	งัวราง		_	_
376	9080	เจ้าหลวย		_	_
377	9085	ขาวประพันธุ์		_	_
378	9089	RANG PAW SAW	NG	แม่ลาน้อย	แม่ฮ่องสอน
379	9091	มะหล่าง		_	_
380	9092	SAENG	G	อ. เมือง	แม่ฮ่องสอน
381	9093	ดอกขาวน้อย		_	_
382	9094	NIAW GAI TEUANG	G	แม่แจ่ม	เชียงใหม่

383	9095	อีขาวน้อย		_	_
384	9105	MA WAI HAWM	G	แม่แจ่ม	เชียงใหม่
385	9110	JAO DAM	NG	แม่แจ่ม	เชียงใหม่
386	9111	SEW MAE JAN	G	แม่แจ่ม	เชียงใหม่
387	9114	EW DAENG	G	แม่แจ่ม	เชียงใหม่
388	9123	KHAO' SIM	NG	แม่แจ่ม	เชียงใหม่
389	9401	LEUANG TAWNG	NG	เมือง	ระยอง
390	9920	LOOK JIN	NG	_	นราธิวาส
391	9937	NGAH CHAHNG	NG	_	นราธิวาส
392	9940	HAHNG CHAMOD	NG	_	นราธิวาส
393	10143	JAO MAENG ME	NG	ด่านซ้าย	เลย
394	10438	PLE ZHAI GLANG	NG	_	เชียงใหม่
395	10451	MAEJO	G	_	เชียงใหม่
396	10461	GAEW LAI	G	_	เชียงใหม่
397	10473	HAWM MAE JAN	NG	_	เชียงใหม่
398	10479	NAIW SAN-PAH-TAWNG	_	_	_
399	10487	JAO NOK	NG	_	เชียงใหม่
400	10488	DAW NAW PRAO	G	_	เชียงใหม่
401	10517	BER GWA	G	_	เชียงใหม่
402	10616	SMGC 83011	NG	สะเมิง	เชียงใหม่
403	10618	SMG 80016	G	สะเมิง	เชียงใหม่
404	10622	LEUANG TAWNG	NG	ธัญบุรี	ปทุมธานี
405	10864	PAN NOK KHAO NAK	NG	ตะพานหิน	พิจิตร

406	11120	LEUANG RAI	NG	ทองผาภูมิ	กาญจนบุรี
407	11131	LEB NOK	NG	เมือง	พังงา
408	11133	YAH YAW	NG	เมือง	พังงา
409	11134	KHAO' LEUANG	NG	เมือง	พังงา
410	11149	YAH YEW	NG	เมือง	พังงา
411	11190	KHAO RAI	_	_	_
412	11230	NAM TOW	G	ศรีสัชนาลัย	สุโขทัย
413	11286	BIAW PAE	NG	คลองลาน	กำแพงเพชร
414	11338	TON TIA	NG	กิ่ง อ.ห้วยคต	อุทัยธานี
415	11372	LEUANG NGERN	NG	กิ่ง อ.ห้วยคต	อุทัยธานี
416	11384	NIAW HAWM	NG	บ้านไร่	อุทัยธานี
417	11395	TON TIA	NG	บ้านไร่	อุทัยธานี
418	11407	KHAENG RAI	NG	บ้านไร่	อุทัยธานี
419	11414	NIAW PAE	G	บ้านไร่	อุทัยธานี
420	11415	KHAO' TIA	NG	บ้านไร่	อุทัยธานี
421	11459	BEU AUA POO	NG	สังขละบุรี	กาญจนบุรี
422	11481	TOW TIA AUA	NG	ศรีสวัสดิ์	กาญจนบุรี
423	11487	AI SER	G	ท่ามะกา	กาญจนบุรี
424	11497	KHAO' LEUANG	NG	ศรีสวัสดิ์	กาญจนบุรี
425	11498	LEUANG TAWNG	NG	ศรีสวัสดิ์	กาญจนบุรี
426	11500	NIAW PAE	G	ศรีสวัสดิ์	กาญจนบุรี
427	11503	IAW DAENG	G	ศรีสวัสดิ์	กาญจนบุรี
428	11505	LEUANG TAWNG	NG	ศรีสวัสดิ์	กาญจนบุรี

429	11506	TON TIA	NG	ศรีสวัสดิ์	กาญจนบุรี
430	11516	BEU WAH WO	NG	ทองผาภูมิ	กาญจนบุรี
431	11521	BEU NER PER	NG	ทองผาภูมิ	กาญจนบุรี
432	11527	BEU WAH WO NER PER	NG	ทองผาภูมิ	กาญจนบุรี
433	11565	LEUANG HAI	NG	ศรีสวัสดิ์	กาญจนบุรี
434	11567	LEUANG TAWNG	NG	ศรีสวัสดิ์	กาญจนบุรี
435	11629	DAWK PAW	G	ท่าวังผา	น่าน
436	11702	SE SA	G	สอง	แพร่
437	11713	KHAO' HAO	G	ลอง	แพร่
438	11890	DAW TAI	G	เมือง	น่าน
439	12231	HAWM MALI	NG	บ้านฉาง	ระยอง
440	12232	KHAO" LEUANG	NG	บ้านฉาง	ระยอง
441	12329	KHAO GLING	NG	บ่อไร่	ตราด
442	12333	TAWNG MAH RO	G	บ่อไร่	ตราด
443	12353	KHAO GLING	NG	เขาสมิง	ตราด
444	13585	KHAO' KHAO	G	ชุมแพ	ขอนแก่น
445	13595	DAWK PUD	G	ชุมแพ	ขอนแก่น
446	13785	DAW	G	กิ่ง อ.สันติสุข	น่าน
447	13787	KHAO" PRAE	G	เมือง	แพร่
448	13788	KHAO" PRAE	G	เมือง	แพร่
449	13934	PAE PA LO	G	ท่าอุเทน	นครพนม
450	13966	GA SAEN	G	ดงหลวง	มุกดาหาร

451	14023	PA SEW	G	นาแห้ว	เลย
452	14025	KHAO" PERNG	G	ปากชม	เลย
453	14037	KHAO" LAI	G	ด่านซ้าย	เลย
454	14101	KHAO' PAE	G	ปากชม	เลย
455	14112	HAWM MALED YAO	NG	แม่ริม	เชียงใหม่
456	14113	NO NAME	NG	แม่ริม	เชียงใหม่
457	14114	KHAO' DAM	NG	หางดง	เชียงใหม่
458	14117	KHAO' HAO	G	หางดง	เชียงใหม่
459	14138	HAO DAENG	G	สะเมิง	เชียงใหม่
460	14139	KHAO' PAE	G	แม่ลาน้อย	แม่ฮ่องสอน
461	14140	NO NAME	NG	สะเมิง	เชียงใหม่
462	14141	KHAO' SEW	G	หางดง	เชียงใหม่
463	14142	HUAY MUANG	NG	เมือง	ราชบุรี
464	14232	LEB MOO	NG	โป่งน้ำร้อน	จันทบุรี
465	14233	LA AWNG TANONG	NG	โป่งน้ำร้อน	จันทบุรี
466	14294	PO BAI SI	NG	บางมูลนาก	พิจิตร
467	14295	KHAO GRU	NG	โพนทะเล	พิจิตร
468	14296	HIN GAWNG	NG	โพนทะเล	พิจิตร
469	14297	TA POW LOM	NG	โพนทะเล	พิจิตร
470	14298	DAWK DOO	NG	บางมูลนาก	พิจิตร
471	14300	PUANG HAHNG CHAHNG	NG	โพธิ์ประทับช้าง	พิจิตร
472	14301	GON JUD	NG	ตะพานหิน	พิจิตร

473	14306	KHAO KAD	NG	เมือง	พิจิตร
474	14313	HAWM MALI	NG	เมือง	พัทลุง
475	14314	GOO MEUANG LEUANG	NG	เมือง	พัทลุง
476	14318	LEUAD NOK	NG	เมือง	พัทลุง
477	14319	KHAO RUANG YAO	NG	เมือง	พัทลุง
478	14320	JUK TIAM LEUANG	NG	เมือง	พัทลุง
479	14321	GOO MEUANG KHAO	NG	เมือง	พัทลุง
480	14322	NAHNG GLAI	NG	เมือง	พัทลุง
481	14328	BOW U-DEN	_	_	_
482	14329	KHAO'KHAO	NG	เมือง	พัทลุง
483	14331	SAI RAI	NG	เมือง	พัทลุง
484	14336	KHAO'SAI	NG	เมือง	พัทลุง
485	14337	BUK ROK	NG	เมือง	พัทลุง
486	14341	CHAW KHAO	NG	เมือง	พัทลุง
487	14345	MAI TAHK	NG	เมือง	พัทลุง
488	14346	KHAO' DAM	NG	เมือง	พัทลุง
489	14347	NAHNG GAWNG	NG	เมือง	พัทลุง
490	14350	BOW SAI LIANG	NG	เมือง	พัทลุง
491	14355	LI TI	NG	เมือง	พัทลุง
492	14356	LOOK JIN	NG	เมือง	พัทลุง
493	14357	KHAO SA MAE	NG	เมือง	พัทลุง
494	14358	KHAO GAM NAN	NG	เมือง	พัทลุง
495	14359	KHAO MAE MA	NG	เมือง	พัทลุง

496	14360	KHAO JIN	NG	เมือง	พัทลุง
497	14365	NO NAME	NG	เมือง	พัทลุง
498	14366	NIAW CHAMOD	G	เมือง	พัทลุง
499	14367	NIAW PLEUAK DAM	NG	เมือง	พัทลุง
500	14368	NIAW LOOK PUENG	NG	เมือง	พัทลุง
501	14371	NIAW KHAMIN	NG	เมือง	พัทลุง
502	14372	NIAW KHAO	NG	เมือง	พัทลุง
503	14374	NIAW SEW	NG	เมือง	พัทลุง
504	14376	NIAW DAM RAI	NG	เมือง	พัทลุง
505	14383	LEB NOK	NG	เมือง	พัทลุง
506	14385	KHAO' KHEM	NG	เมือง	พัทลุง
507	14386	NAHNG KHAHK	NG	เมือง	พัทลุง
508	14387	NAHNG GLIN	NG	เมือง	พัทลุง
509	14389	KHAO' RUANG SAN	NG	เมือง	พัทลุง
510	14391	LEUANG TAWNG	NG	เมือง	พัทลุง
511	14392	KHAO' DAM	NG	เมือง	พัทลุง
512	14394	KHAO'LEUANG	NG	เมือง	พัทลุง
513	14397	YAH YAW	NG	เมือง	พัทลุง
514	14398	AI WAHNG	NG	เมือง	พัทลุง
515	14399	SI DOWN	NG	เมือง	พัทลุง
516	14402	JAO YAM SAHN KHAO	NG	เมือง	พัทลุง
517	14403	NOK KAO BIN LON	NG	เมือง	พัทลุง
518	14404	KHAO' AEK	NG	เมือง	พัทลุง

519	14405	GRA RIANG	NG	เมือง	พัทลุง
520	14406	HAW LUANG RAHM	NG	เมือง	พัทลุง
521	14417	NIAW CHAW	NG	กิ่ง อ.เกาะยาว	พังงา
522	14432	NOK BIN LONG	NG	กิ่ง อ.พะโต๊ะ	ชุมพร
523	14434	MALAENG DAH LAI	NG	กิ่ง อ.พะโต๊ะ	ชุมพร
524	14452	SAI BUA	NG	กิ่ง อ.ดอนพุด	สระบุรี
525	14453	KHAO' PUANG	NG	กิ่ง อ.ดอนพุด	สระบุรี
526	14461	NAHNG NGAHM	NG	กิ่ง อ.ดอนพุด	สระบุรี
527	14462	KHAO PRAGUAD	NG	กิ่ง อ.ดอนพุด	สระบุรี
528	14463	KHAO TA POW	NG	กิ่ง อ.ดอนพุด	สระบุรี
529	14464	KHAO TAH PRAE	NG	กิ่ง อ.ดอนพุด	สระบุรี
530	14465	KHAO TAH PRAE	NG	กิ่ง อ.ดอนพุด	สระบุรี
531	14468	SAI BUA	NG	กิ่ง อ.ดอนพุด	สระบุรี
532	14469	KHAO' PUANG	NG	กิ่ง อ.ดอนพุด	สระบุรี
533	14780	BIAW PAE	NG	เมือง	น่าน
534	14783	BIAW JI HUD	NG	เมือง	น่าน
535	14792	KHAO' GAI	NG	ปัว	น่าน
536	14819	KHAO' GAM	G	สา	น่าน
537	14834	HAO DAW	G	สา	น่าน
538	14846	KHAO' YUAK	G	ท่าวังผา	น่าน
539	14856	KHAO' DAENG	G	ท่าวังผา	น่าน
540	14865	KHAO' KHAO	NG	ท่าวังผา	น่าน
541	14867	KHAO' KHAO	NG	ท่าวังผา	น่าน

542	14878	KHAO' NAWN	NG	ทุ่งช้าง	น่าน
543	14947	KHAO' GAM	G	ชาติตระการ	พิษณุโลก
544	14949	KHAO LEK	G	ชาติตระการ	พิษณุโลก
545	14956	PAN KHAO' KHAO	NG	ศรีสัชนาลัย	สุโขทัย
546	14981	PRAE NGAW	NG	ศรีสัชนาลัย	สุโขทัย
547	14990	BEU DAWNG KI	G	บ้านไร่	อุทัยธานี
548	14994	KHAO' MEE	NG	บ้านไร่	อุทัยธานี
549	14995	NIAW DAENG	NG	บ้านไร่	อุทัยธานี
550	14996	LEUANG KHAO	G	บ้านไร่	อุทัยธานี
551	15001	KHAO LEK	NG	บ้านไร่	อุทัยธานี
552	15002	NIAW DAENG	NG	บ้านไร่	อุทัยธานี
553	15007	LAI YAI	G	บ้านไร่	อุทัยธานี
554	15009	DAENG LEK	NG	บ้านไร่	อุทัยธานี
555	15011	LEUANG YAI	NG	บ้านไร่	อุทัยธานี
556	15016	NIAW LAI	G	บ้านไร่	อุทัยธานี
557	15042	TON TAI	NG	บ้านไร่	อุทัยธานี
558	15053	KHAO' KHAO	NG	บ้านไร่	อุทัยธานี
559	15054	LEUANG TAWNG	NG	บ้านไร่	อุทัยธานี
560	15062	LEUANG YAI	NG	บ้านไร่	อุทัยธานี
561	15064	LEUANG NGERN	NG	บ้านไร่	อุทัยธานี
562	15065	NO NAME	NG	บ้านไร่	อุทัยธานี
563	15190	SEW KHAO	G	_	เชียงราย
564	15891	RAHK HAENG	_	_	_

565	15903	JAO SAWUEY	NG	จักราช	นครราชสีมา
566	15932	KHAO' MAEW	_	_	_
567	16046	KHAO YAI	G	สังคม	หนองคาย
568	16237	JAO HAW	NG	สะเมิง	เชียงใหม่
569	16238	NAM ROO	NG	สะเมิง	เชียงใหม่

*N = glutinous rice

NG = non-glutinous rice

Annex 2 Conference Paper

ALLELOPATHIC ACTIVITY OF UPLAND RICE IN THAILAND

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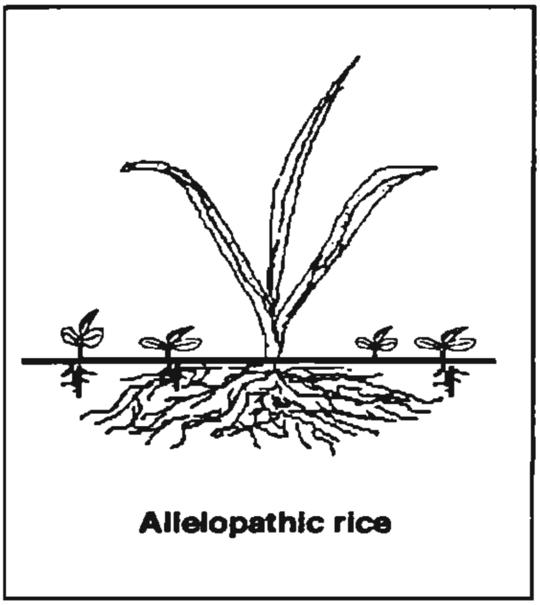
Abstract: Five hundreds and sixty nine accessions of upland rice was screened in agar for allelopathic activity by tested with *Echinochloa crusgalli* and *Lactuca sativa*. The results show that genetic variation for allelopathic potential does exist in Thai upland rice. About 0.2% of germplasm was allelopathic to *E. crusgalli* whereas about 4% had a strong allelopathic effect on *L. sativa*. Four selected accessions (BWSD 16 and 19 exhibited 50-75% inhibition, BWSD 22 had 25-50% inhibition and BWSD 25 had no inhibitory effects on both test species) were further tested with two monocots (*E. colona* and *E. crusgalli*) and five dicots (*Bidens pilosa*, *Euphorbia geniculata*, *Mimosa invisa*, *M. pudica* and *L. sativa*) in the soil. BWSD 16 and BWSD 19 had a strong allelopathic effect on seven test species. In addition, variation of allelopathic effects between test species was found.

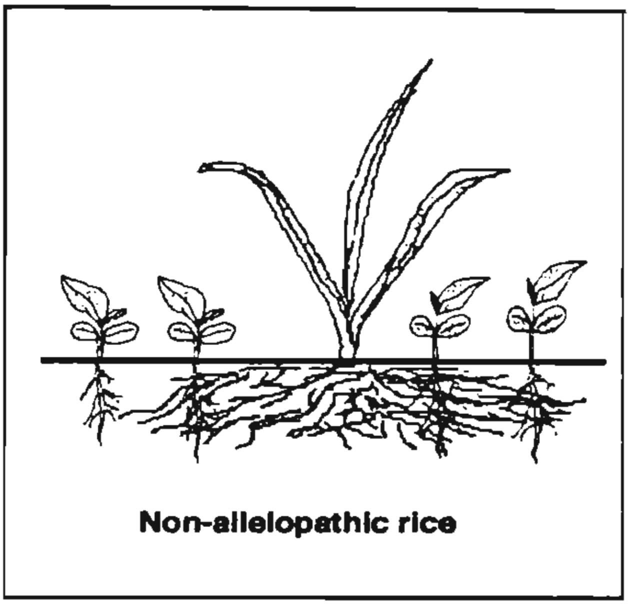
Keywords: allelopathic activity, genetic variation, upland rice

Introduction

Allelopathy can be defined as a phenomenon which one plant species can inhibit or promote the growth of another plant species throughout the leachates, crop residue, chemical emitted from leaves and/or root exudate (Rice, 1974). In this study, allelopathy is focused on the activity of one living rice plant can inhibit the growth of test species (Pic. 1)

Allelopathy in rice was firstly observed in the seed production plots which were naturally infested with ducksalad (*Hetheranthera limosa*) at Arkansas Rice research Institute, USA (Dilday *et al.*, 1991). Later, allelopathic potential in rice has been reported in many countries e.g.), Japan (Fujii, 1992), Philippines (Olofsdotter and Navarez, 1996), Korea (Kim and Shin, 1998), and Egypt (Hassan *et al.*, 1998). Although some accessions of rice (*Oryza sativa*) are more likely to have allelopathatic activity to suppress both monocots and dicots weeds, more works need to separate the effects between allelopathy and competition.





Upland rice is grown more than 17 million hectares worldwide with annual production about 20 million tonnes (IRRI 1998). Although it contributes only 4% to the total world rice production, it is staple food for more than 100 million poor people (IRRI 1996). Weeds are perceived by upland rice researchers to be the greatest yield-limiting constraint (Arraudeau and Harahap, 1988). At present, herbicides seem to be the cheapest and most efficient methods to control weeds resulting in the increase chemical usage. To date, residual effects of herbicides in rice produces and environment are more highly concerned by the public. Hence, allelopathy may be an alternative way to control weeds in upland rice with no adverse effects.

This study aims to determine whether allelopathic rice exists in Thai rice germplasm and to evaluate the genotypic differences in allelopathic potential against some common weeds in rice cultivation.

Materials and Methods

Laboratory screening

A total of 569 accessions of upland rice (from Rice Germplasm Bank, Rice Resaerch Institute, Department of Agriculture, Thailand) were evaluated for allelopathic activity. Two test species were barnyardgrass (*Echinochloa crusgalli* L. Beauv.) and lettuce (*Lactuca sativa* L.). Five seeds of rice and ten seeds of test species were sown together in the 250ml-glass bottle containing 0.5% agar. Ten days after germination, the total dry weight of test species were determined. Response of each tester species was calculated as relative growth as followed:

$$\text{Relative growth (\%)} = \frac{\text{Total dry weight of test species grown with rice}}{\text{Total dry weight of test species grown without rice}} \times 100$$

Glasshouse study

To evaluate rice genotypic differences in allelopathic potential against some common weeds, four selected accessions (BWSD 16, BWSD 19, BWSD 22 and BWSD 25) were selected. BWSD 16 and 19 exhibited 50-75% inhibition, BWSD 22 had 25-50% inhibition and BWSD 25 had no inhibitory effects on both test species. Seven test species were two monocots (*E. colona* and *E. crusgalli*) and five dicots (*Bidens pilosa*, *Euphorbia geniculata*, *Mimosa invisa*, *M. pudica* and *L. sativa*). Five seedlings of each genotype were grown in a plastic pot and ten germinated seeds of a test species were placed. At 30 days after test species germination, shoot dry weight was measured. Response of each tester species was shown in % of control as followed:

$$\%\text{ of control} = \frac{\text{Shoot dry weight of test species grown with rice}}{\text{Shoot dry weight of test species grown with BWSD 25}} \times 100$$

Results and Discussions

Laboratory screening

Five hundreds and sixty nine accessions of upland rice tested with *E. crusgalli* and *L. sativa* in agar assay exhibited various level of inhibition (Table 1 and 2). The relative growth of both test species were ranged in 26-100%. For *E. crusgalli*, one accession inhibited the relative growth by 50-75% whereas 69 accessions decreased the relative growth by 25-50% (Table 1). For *L. sativa*, 23 accessions could inhibit the relative growth of test species by 50-75% while that was reduced by 25-50% when grown with 82 accessions (Table 2). It is more likely that dicot test species is more sensitive to rice accessions than the monocots. Mostly, allelopathic rice has been found about 3-4% of the screening accessions (Dilday *et al.*, 1991; Hassan *et al.*, 1998; Kim and Shin, 1998). Similar to this study, about 0.2% of germplasm was allelopathic to *E. crusgalli* whereas about 4% had a strong allelopathic effect on *L. sativa*. Obviously, rice accessions from the north showed the greater level of inhibition than those from the other region of Thailand.

Glasshouse study

BWSD 16, BWSD 19 and BWSD 22 inhibited the growth of all test species with different level of inhibition (Fig. 1A-F) when compared to that of BWSD 25. BWSD 16 and BWSD 19 reduced the shoot dry weight of all test species by 50-60% (Fig. 1 A-F). BWSD 22 exhibited the variations of allelopathic activity among the test species. The results were similar to the inhibition level in the laboratory.

In conclusion, genotypic variation for allelopathic potential does exist in Thai upland rice germplasm. Two selected accessions, BWSD 16 and BWSD 19, exhibited strong allelopathic activity on both monocots and dicots test species. The variation of allelopathic effect between test species was found. However, these four accessions will be further tested to check whether their allelopathic effects are maintained under the field condition.

Table 1 Responses of *E. crusgalli* to 569 accessions of upland rice from different regions of Thailand.

Region	Number of genotypes				Total
	Relative growth (%)				
	0-25	26-50	51-75	76-100	
North	0	0	26	153	179
Northeast	0	0	1	11	12
East	0	0	0	23	23
South	0	0	2	54	56
Central	0	0	5	100	105
Unknown	0	1	35	158	194
Total	0	1	69	499	569

Table 2 Responses of *L. sativa* to 569 accessions of upland rice from different regions of Thailand.

Region	Number of genotypes				Total
	Relative growth (%)				
	0-25	26-50	51-75	76-100	
North	0	3	17	159	179
Northeast	0	1	2	9	12
East	0	0	1	22	23
South	0	0	0	56	56
Central	0	13	40	52	105
Unknown	0	6	22	166	194
Total	0	23	82	464	569

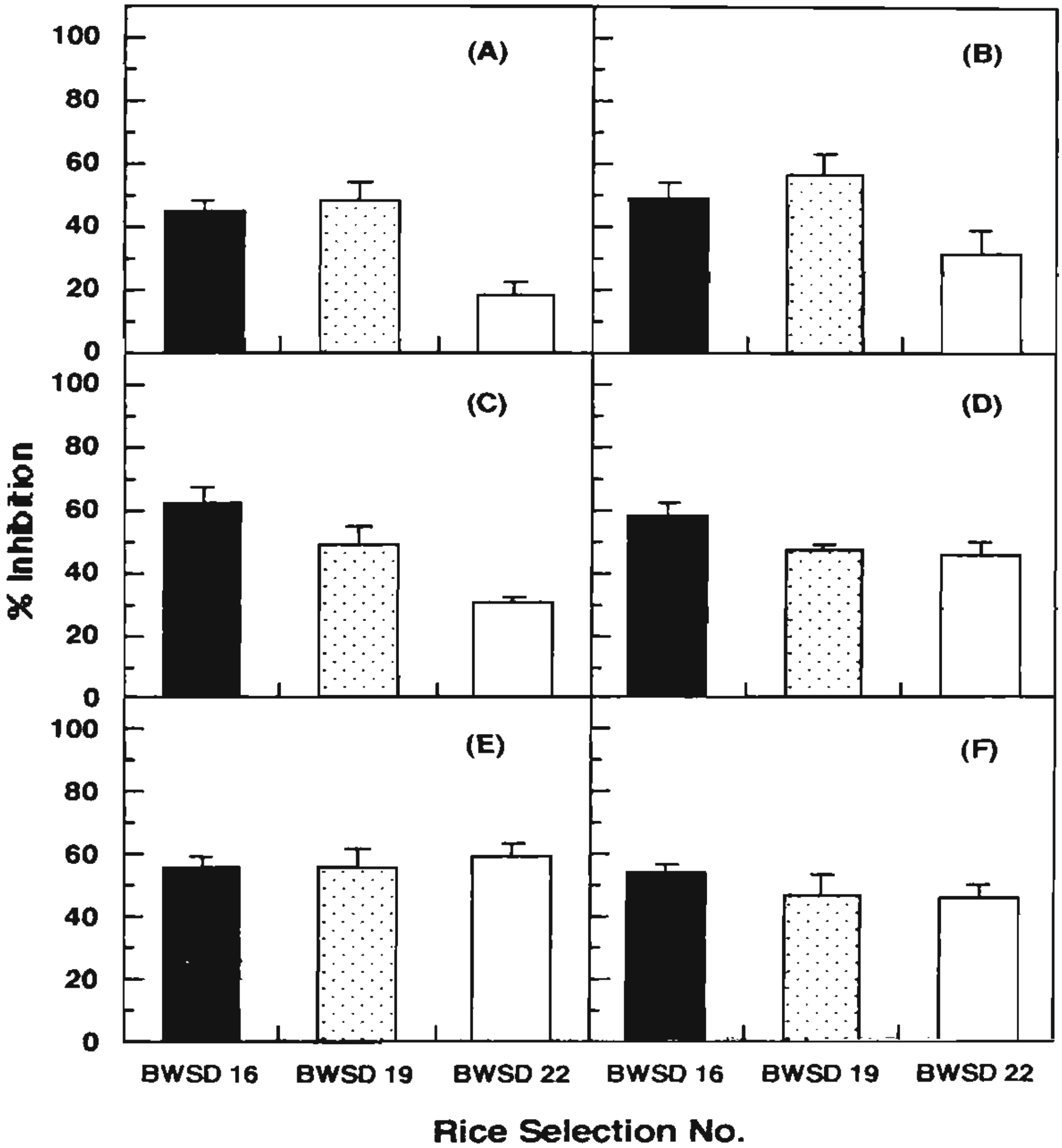


Fig. 1 Inhibition of total dry weight of *Echinochloa colona* (A), *E. crusgalli* (B), *Euphorbia geniculata* (C), *Lactuca sativa* (D), *Mimosa invisa* (E), and *M. pudica* (F) when grown with rice selection BWSD 16, BWSD 19 and BWSD 22. Vertical bars represent standard errors of four replicates.

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