In vitro Effect of Caesalpinia sappan and Crateva magna Extracts in Enhancing Seed Germination and Seedling Growth of KDML105 Rice Variety

Arom Jantasorn, Ponpawit Pongsupap, Thanaprasong Oiuphisittraiwat

ABSTRACT

Background: Rice (Oryza sativa L.) is a major cereal crop planted in Thailand for both local consumption and export. The objective of this study was to investigate the allelopathic effect of Caesalpinia sappan L. and Crateva magna (Lour.) DC. extracts in promoting rice cultivar, Khao Dawk Mali 105 (KDML105) seed germination and seedling growth, at 7 and 14 days after sowing (DAS).

Methods: The C. sappan and C. magna plants were cleaned with tap water and air dried in room temperature then cut into small pieces and ground into fine powder. Plant crude extracts was prepared using ethanol as solvent.

Result: The results showed that rice seed treatment with C. sappan and C. magna extracts was significant (all p<0.05), increasing root length, shoot fresh and dry weight and root fresh and dry weight of rice seedlings at 14 DAS. Seed treatment with these two plant extracts led to a significantly greater vigor index of the KDML105 rice seedling cultivar, when compared with the control. Interestingly, the seed treatment with C. magna extract at a 100 ppm concentration was found to produce the highest enhancement in the overall rice seedling growth parameters, including the vigor index of seedlings. The results showed that a low concentration of C. magna extracts can be potentially used in promoting seedling growth of rice since they improved the overall growth parameters.

Key words: C. magna, C. sappan, KDML105 rice cultivar, Seed germination, Seedling growth.

INTRODUCTION

Rice (Oryza sativa L.) is one of the most economically important crops and planted in all regions of Thailand for both local consumption and export. It is a major cereal crops planted in Thailand, which was the world’s number one exporter of milled rice in 2014 (Charoenrak and Chamswang, 2014). The farmers in Thailand have been using increasingly larger chemical fertilizer applications as to improve both qualitative and quantitative rice yields in paddy fields. However, the continuous use of excess chemical fertilizers has a harmful effect on soil structure, causing soil degradation.

Allelopathy is an ecological system in which chemicals may affect the growth of other crops or in the same crop that produced by one plant species (Batish et al., 2004; Cheng and Cheng, 2015; Trezzi et al., 2016). However, the effect of allelochemicals on growth parameters of plants may occur through several plant mechanisms, i.e., photosynthesis (Swain et al., 2012; Baziar et al., 2014). Rice seedlings treated with allelopathic phenolics had improved seedling growth and some allelochemical substances from plant extracts caused a reduction in root growth (Yang et al., 2002; El-khatib et al., 2004).

Caesalpinia sappan L. is a woody plant which belongs to the Leguminosae family and is widely distributed and cultivated in Southeast Asia, America and Africa (Wu et al., 2017). C. sappan contains several bioactive compounds, including brazillin and brazelein (Ye et al., 2006; Nirmal et al., 2015). Many kinds of bioactive compound activity have been reported from different parts of C. sappan, including the heartwood, leaves and bark (Nirmal and Panichayupakaranant, 2015; Harjit et al., 2016; Lu et al., 2017). Crateva magna (Lour.) DC. is a plant which belongs to the Capparidaceae family. Bioactive compounds from C. magna have been reported for medicinal activity. Previously, the application of C. sappan and C. magna extracts which improved the germination and seedling growth of cereal crop plants has not been reported but Jantasorn et al. (2016) reported that C. sappan extract was more efficient in inhibiting the growth of the plant pathogens, Phytophthora palmivora and Sclerotium rolfsii in vitro. Improvement in the efficacies of plant extracts regarding the growth parameters of crop plants has been reported by various researchers; these crops include soybean and haricot bean (Netser and Mendes, 2011); papaya (Chumpookam et al., 2012) and wheat (Akram et al., 2017). On the other hand, the effect of barnyard grass extracts reduce the growth of...
wheat, corn, soybean and sugar beet (Dawson, 1977; Bhowmik and Doll, 1983; Singh et al., 1988). Sithinon et al. (2017) also reported that weed extract, i.e., jungle rice could reduce the germination and seedling growth of rice cultivar KDML105. Therefore, the objective of this study was to evaluate the effect of C. sappan and C. magna extracts by using different concentrations to enhance the growth parameters of rice cultivar KDML 105 in *in vitro* condition.

**MATERIALS AND METHODS**

**Plant materials**

*Caesalpinia sappan* L. and *Crateva magna* (Lour.) DC. were collected from riparian forest at Bodhivijjalaya College, Sakaeo campus, Thailand in July 2018. Rice cultivar KDML105 seeds were obtained from Surin Rice Research Center, Surin province, Thailand. Plant samples were cleaned with tap water and air dried at 28 ± 3°C. The samples cut into small pieces and ground into fine powder. Each fine powder of plant sample was stored at 4°C.

**Plant extractions**

The extraction procedure was performed as previously (Jantasorn et al., 2017). Each dried plant sample was macerated with 95% ethanol and incubated for seven days at 28 ± 3°C. Then, the ethanol extracts of *C. sappan* and *C. magna* were filtered through two layers of sterile cheesecloth and the solutions were evaporated under reduced pressure. Crude extract of each plant were kept at room temperature until use.

**Bioassay to assess seed germination and seedling growth of rice cultivar KDML105**

All rice seeds in experiment were surface sterilized for 30 min in 0.1% sodium hypochlorite solution, then seeds washed three times with sterile distilled water prior to the experimental procedure to prevent contamination. A total of one hundred seeds per treatments were soaked separately in *C. sappan* and *C. magna* extracts at different concentrations as follows: 1) *C. sappan* extract at each of 10, 100 and 1,000 ppm; 2) *C. magna* extract at each of 10, 100 and 1,000 ppm; and 3) also one hundred rice seeds were soaked in distilled water as a control treatment. All experiments were carried out by soaking intact seeds in either plant extract or distilled water as a control for 24 hours at room temperature and then air dried. A total of one hundred seed treatments were sown in between blotter paper method and then spray with distilled water and rolled. The blotter paper rolls of each treatment was placed upright in a plastic bag to maintain moisture and prevent drying during incubation at room temperature (28 ± 3°C) and subjected to a light exposure of 12 h light and 12 h darkness. Data were taken at 7 and 14 days after sowing (DAS) only to determine the germinated percentage (GP) of the seeds by using the following formula (Raun et al. 2002): GP = total number of germinated seeds/total number of seeds tested x 100. The root length, shoot height, root and shoot dry weight of rice produced by soaking seeds in the plant extracts were measured. The experiment was arranged in a completely randomized design (CRD) and each treatment consisted of four replicates and the experiment was repeated twice.

**Seed vigor test**

Growth parameters data in each experiment were taken at 7 DAS and 14 DAS to determine the rate of seedling vigor. A total of 25 seeds of each treatment were sampled and used in four replications. The seedling vigor index (SVI) was calculated according to formula (Abdul-baki and Anderson, 1973).

\[
SVI = (RL + SL) \times GP
\]

Where

- \( RL \) = seedling root length
- \( SL \) = seedling shoot length
- \( GP \) = germination percentage.

**Statistical analyses**

The data recorded on various characters were subjected to Fisher’s method of analysis of variance and interpretation of data was done as given by Gomez and Gomez (1984). Means were compared by least significant difference (LSD) (p<0.05) using the Statistix 8 statistical program (analytical software, SXW, Tallahassee, FL, USA).

**RESULTS AND DISCUSSION**

The results showed that the seed treatment with *C. sappan* and *C. magna* extracts was not significant (p<0.05) to promoted the seed germination of rice at 7 DAS and 14 DAS when compared with the control. The average germination percentages of rice seeds at 7 DAS and 14 DAS were 97.9% (Table 1) and 96.0% (Table 2), respectively. The overall effect of the two plant extracts at 7 DAS was significant increased the rice seedling especially to shoot dry weight at each concentration when compared to the water treatment. Furthermore, the *C. magna* crude extract (1,000 ppm) was effective in increasing fresh weight of root (Table 1). The results at 14 DAS showed that the effect of *C. sappan* and *C. magna* extracts was significant (all p<0.05) increased root length, fresh weight of root and shoot and root dry weight of rice seedlings over control. Root fresh weight and root length were affected by both plant extracts at each concentration but only *C. magna* at a concentration of 1,000 ppm did not significantly increase the root fresh weight of rice seedlings. Specifically, *C. magna* extract at a concentration of 100 ppm resulted in the highest shoot fresh and dry weight of all rice seedlings, which were 4.453 g and 0.488 g, respectively (Table 2). Accordingly, *C. magna* extract at a concentration of 10 ppm was effective in increasing the root dry weight to 0.118 g. The overall effect of *C. sappan* extract at each concentration was significant and led to an increase in almost all growth indicators of rice seedlings when compared to the control. Treatment with *C. sappan* and *C. magna* extracts led to significantly greater

---

*In vitro Effect of Caesalpinia sappan and Crateva magna Extracts in Enhancing Seed Germination and Seedling...*
In vitro Effect of *Caesalpinia sappan* and *Crateva magna* Extracts in Enhancing Seed Germination and Seedling Growth

**Table 1:** Effect of rice seeds treatment with *Caesalpinia sappan* and *Crateva magna* extracts promoting seed germination and seedling growth at 7 days after sowing.

| Plant extracts/ concentrations (ppm) | Root length (cm) | Shoot length (cm) | Root fresh weight (g) | Shoot fresh weight (g) | Root dry weight (g) | Shoot dry weight (g) | Seed vigor index (%) |
|-------------------------------------|------------------|------------------|----------------------|-----------------------|---------------------|---------------------|---------------------|
| *Caesalpinia sappan*                |                  |                  |                      |                       |                     |                     |                     |
| 10                                  | 8.50             | 8.21             | 0.873 bc             | 2.405                 | 0.073               | 0.205 a             | 1642                | 98.3                |
| 100                                 | 8.26             | 8.36             | 0.753 c              | 2.138                 | 0.078               | 0.143 b             | 1612                | 97.0                |
| 1,000                               | 8.37             | 8.06             | 0.773 c              | 2.095                 | 0.055               | 0.180 a             | 1602                | 97.5                |
| *Crateva magna*                     |                  |                  |                      |                       |                     |                     |                     |
| 10                                  | 8.48             | 8.11             | 0.920 abc            | 2.405                 | 0.098               | 0.215 a             | 1634                | 98.5                |
| 100                                 | 9.24             | 8.72             | 0.975 ab             | 2.390                 | 0.088               | 0.208 a             | 1759                | 98.0                |
| 1,000                               | 8.72             | 8.64             | 1.095 a              | 2.260                 | 0.098               | 0.205 a             | 1710                | 98.5                |
| Control (distilled water)           | 8.16             | 8.59             | 0.865 bc             | 2.345                 | 0.060               | 0.195 a             | 1632                | 97.5                |
| Mean                                | 8.53             | 8.38             | 0.893                | 2.291                 | 0.078               | 0.193               | 1656                | 97.9                |
| CV                                  | 9.00             | 7.14             | 14.59                | 7.210                 | 32.470              | 12.64               | 6                   | 1.4                 |
| F-test\(^f\)                        | ns               | ns               | *                    | ns                    | ns                  | ns                  |                     |
| LSD                                 | 0.194            | 0.0362           |                      |                       |                     |                     |                     |

Means followed by the same letter in each column do not significantly different, when analyses using Least Significant Difference test (LSDs) at P<0.05. \(^f\)ns = not significantly and \(^f\)*, \(^f\)** are significantly at p<0.05 and p<0.01, respectively.

**Table 2:** Effect of rice seeds treatment with *Caesalpinia sappan* and *Crateva magna* extracts promoting seed germination and seedling growth at 14 days after sowing.

| Plant extracts/ concentrations (ppm) | Root length (cm) | Shoot length (cm) | Root fresh weight (g) | Shoot fresh weight (g) | Root dry weight (g) | Shoot dry weight (g) | Seed vigor index (%) |
|-------------------------------------|------------------|------------------|----------------------|-----------------------|---------------------|---------------------|---------------------|
| *Caesalpinia sappan*                |                  |                  |                      |                       |                     |                     |                     |
| 10                                  | 8.99 a           | 11.61            | 0.963 a              | 3.868 bc              | 0.115 ab            | 0.383 b             | 1956 b             | 95.0                |
| 100                                 | 10.12 a          | 11.73            | 0.908 a              | 3.698 c               | 0.090 cd            | 0.335 cd            | 2071 ab            | 94.8                |
| 1,000                               | 9.72 a           | 11.81            | 0.923 a              | 3.765 c               | 0.100 abc           | 0.378 b             | 2101 ab            | 97.5                |
| *Crateva magna*                     |                  |                  |                      |                       |                     |                     |                     |
| 10                                  | 9.49 a           | 12.80            | 1.050 a              | 4.263 ab              | 0.118 a             | 0.403 b             | 2145 ab            | 96.3                |
| 100                                 | 10.23 a          | 13.04            | 1.008 a              | 4.453 a               | 0.110 abc           | 0.488 a             | 2245 a             | 96.5                |
| 1,000                               | 8.81 a           | 12.61            | 0.618 b              | 3.608 c               | 0.068 d             | 0.365 bc            | 2058 ab            | 96.0                |
| Control (distilled water)           | 6.50 b           | 10.53            | 0.710 b              | 3.193 d               | 0.092 bc            | 0.310 d             | 1643 c             | 96.3                |
| Mean                                | 9.12             | 12.02            | 0.883                | 3.835                 | 0.099               | 0.38                | 2031               | 96.0                |
| CV                                  | 10.83            | 9.04             | 12.69                | 7.15                  | 15.44               | 7.21                | 8.31               | 2.68                |
| F-test\(^f\)                        | **               | ns               | **                   | **                    | **                  | **                 | ns                 |                     |
| LSD                                 | 1.4679           | 0.166            | 0.4074               | 0.023                 | 0.041               | 250.7              |                     |

Means followed by the same letter in each column do not significantly different, when analyses using Least Significant Difference test (LSDs) at P<0.05. \(^f\)ns and \(^f\)** are non-significantly and significantly at p<0.01, respectively.

The seedling vigor of the KDML105 rice seedling cultivar. The seedling vigor index was significantly higher when it had been treated with the *C. magna* extract at a 100 ppm concentration, compared to the control. However, the positive effect of both *C. sappan* and *C. magna* extracts in enhancing seedling vigor was significantly demonstrated. Interestingly, the seed treatment with *C. magna* extract at a 100 ppm concentration was found to have resulted in the highest enhancement in overall rice seedling growth, including the vigor index of seedlings (Fig 1).

Hence the study indicated that rice seeds treated with different concentrations of *C. sappan* and *C. magna* extracts at 14 DAS had been improved with regard to the overall seedling growth of the rice. In the rice seeds treated with different concentrations of *C. sappan* and *C. magna* extracts at 7 DAS and 14 DAS, the results of the seed germination rate were not significantly different from the water control. Seed germination is the most important stage for critical stage under conditions of stress and crop yields. Plant leaf and fruit extracts were more composed of allelochemicals than root, stem and seed extracts. However, allelochemicals can reduce seed respiration substrates and metabolic energy, with a decrease in plant seed germination and seedling growth (Yarnia et al., 2009; Verma et al., 2012).
In vitro Effect of Caesalpinia sappan and Crateva magna Extracts in Enhancing Seed Germination and Seedling...

Fig 1: Effect of rice seeds treatment with Crateva magna extract has improved seedling growth at 14 DAS; (A) Control (distilled water); (B); (C) and (D) C. magna extract at concentrations of 10, 100 and 1,000 ppm respectively.

The results revealed that C. sappan and C. magna extracts of different concentrations had an effect on the growth of rice cultivar KDML105 seedlings. Most of the initial growth parameters improved by stimulating the application of plant extract under in vitro conditions. Rice seedlings treated with C. sappan and C. magna extracts at each concentration improved all growth parameters, including seedling vigor index at 14 DAS. C. magna extract at a 100 ppm concentration resulted in significantly higher growth parameter results than the control. After treatment with C. magna extract at 100 ppm concentration, the seedling growth parameters, including root length, root fresh and dry weight, shoot fresh and dry weight and seedling vigor index, were 10.23 cm, 1.008 g, 0.110 g, 4.453 g, 0.488 g and 2245, respectively, at 14 DAS. However, the two plant extracts at each concentration improved the overall growth parameters of rice seedlings. A low concentration of C. sappan (10 ppm) applied to rice seeds resulted in a shoot fresh and dry weight and root fresh and dry weight which were significantly different when compared to the seeds treated with high concentration. Yang et al. (2002) also reported that seedlings treated with allelopathic phenolics had improved seedling growth of rice and some allelochemical substances from plant extracts had caused a reduction in root growth (El-khatib et al., 2004). The results demonstrated that C. sappan and C. magna extracts could potentially have an effect on rice as indicated by its effect on plant growth parameters, i.e., root length, root fresh and dry weight, shoot fresh and dry weight and the seed vigor index of seedlings. Improvement in the efficacies of plant extracts regarding the growth parameters of crop plants has been reported by various researchers; these crops include indigenous rice and rice (Kulkarni et al., 2006; Lu et al., 2017); soybean and haricot bean (Netsere and Mendesil, 2011); wheat (Akram et al., 2017); and papaya (Chumpookam et al., 2012). However, the efficacies of these two plant extracts in inhibiting the growth of plant pathogenic fungi have been reported (Jantasorn et al., 2016). It has been reported that the extract from C. sappan was more efficient in inhibiting the growth of P. palmivora and S. rolfsii but the application of C. sappan and C. magna extracts in improving the seedling growth of cereal crop plants has not been reported. The results of the experiment showed the potential of seed treatment with C. sappan and C. magna extracts at 14 DAS to promote improvement in the seedling growth of rice across the overall growth parameters.

CONCLUSION
Seed treatment with C. sappan and C. magna extracts improved the overall growth parameters of rice seedlings under laboratory conditions. A low concentration of C. magna extract (100 ppm) significantly improved the seedling growth parameters of the KDML105 rice cultivar. Our results indicated that these extracts promoted the growth parameters and seedling vigor index of rice at 14 DAS. Therefore, the extracts be useful in promoting the growth of rice seedlings and improving yields. However, further study is required to test the efficacy of these two plant extracts in promoting growth of rice and other crops in greenhouse and paddie field.

ACKNOWLEDGEMENT
The authors gratefully acknowledge Assistant Professor Dr. Jenjira Mongon for her assistance in statistical analysis.

Conflict of interest
The authors declare no conflict of interest.
REFERENCES

Abdul-baki, A.A. and Anderson, J.D. (1973). Vigour determination in soybean by multiple criteria. Crop Science. 13: 630-633.

Akram, S., Saeed, M., Ziaer, M.S. and Iqbal, R. (2017). Effect of aqueous extracts of eucalyptus (Eucalyptus camaldulensis L.) on germination and seedling growth of wheat (Triticum aestivum L.). International Journal of Bioscience. 11(5): 286-293.

Batish, D.R., Setia, N., Singh, H.B. and Kohli, R.K. (2004). Phytotoxicity of lemon-scented eucalypt oil and its potential use as a bioherbicide. Crop Protection. 23: 1209-1214.

Baziar, M.R., Farahvash, F., Mirshekari, B. and Rashidi, V. (2014). Allelopathic effect of ryegrass (Lolium pernsicum) and wild mustard (Sinapis arvensis) on barley. Pakistan Journal Botany. 46: 2069-2075.

Bhowmik, P.C. and Doll, J.D. (1983). Growth analysis of corn and soybean response to allelopathic effect of weed residue at various temperatures and photosynthetic photon flux densities. Journal of Chemical Ecology. 9: 1263-1280.

Chareonrak, P. and Chansrang, C. (2015). Application of Trichodema asperellum fresh culture bioproduckt as potential biological control agent of fungal disease to increase yields of rice (Oryza sativa L.). Journal of the International Society for Southeast Asian Agricultural Sciences. 21: 67-65.

Cheng, F. and Cheng, Z. (2015). Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy. Frontiers in Plant Science. 6: 1-16.

Chumpookam, J., Lin, H.L. and Shiech, C-C. (2012). Effect of smoke-water on seed germination and seedling growth of papaya (Carica papaya cv. Tainung No. 2). Horticence. 47(6): 741-744.

Dawson, J.H. (1977). Competition of late-emerging weeds with sugar beets. Weed Science. 25: 168-170.

El-khatib, A.A., Hegazy, A.K. and Galal, H.K. (2004). Does allelopathy have a role in the ecology of Chenopodium murale. Annales Botanici Fennici. 41: 37-45.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research 2nd Edition New York Wiley Publication P. 680.

Harjit, K., Amini, M.H. and Suttee, A. (2016). Evaluation of antioxidant and anthelmintic properties of Caesalpinia sappan L. leaves. International of Journal Pharmacognosy and Phytochemical Research. 8: 362-368.

Jantason, A., Moungsimuangdee, B. and Dethoup, T. (2016). In vitro antifulgal activity evaluation of five plant extracts against five plant pathogenic fungi causing rice and economic crop diseases. Journal of Biopesticides. 9(1): 1-7.

Jantason A, Mongon J. and Ouiphisistraiwat T. (2017). In vivo antifulgal activity of five plant extracts against Chinese kale leaf spot caused by Alternaria brassicicola. Journal of Biopesticides. 10(1): 43-49.

Kulkami, M.G., Sparig, S.G., Light, M.E. and Van Staden, J. (2006). Stimulation of rice (Oryza sativa L.) seedling vigour by smoke-water and butenolide. Journal of Agronomy and Crop Science. 192: 395-398.

Lu, H., Liu, J., Kerr, P.G., Shao, H. and Wu, Y. (2017). The effect of periphtyon on seed germination and seedling growth of rice (Oryza sativa) in paddy area. Science of the Total Environment. 578: 74-80.

Mohan, G., Anand, S.P. and Doss, A. (2011). Efficacy of Aqueous and Methanol extracts of Caesalpinia sappan L. and Mimosa pudica L. for their potential antimicrobal activity. South Asia Journal of Biological Sciences. 1: 48-57.

Netsere, A. and Mendesil, E. (2011). Allelopathic effect of Parthenium hysterophorus L. aqueous extracts on soybean (Glycine max L.) and haricot bean (Phaseolus vulgaris L.) seed germination, shoot and root growth and dry matter production. Journal of Applied Botany and Food Quality. 84: 219-222.

Nirmal, N.P., Rajput, M.S., Prasad, R.G.S.V. and Ahmad, M. (2015). Brazilian from Caesalpinia sappan heartwood and its pharmacological activities: A review. Asian Pacific Journal of Tropical Medicine. 8: 421-430.

Nirmal, N.P. and Panichayupakaranant, P. (2015). Antioxidant, antibacterial and anti-inflammatory activities of standardized brazilian-rich Caesalpinia sappan extract. Pharmaceutical Biology. 53: 1339-1343.

Raun, S., Xue, Q. and Thilokwisa, K. (2002). Effect of seed priming on germination and health of rice (Oryza sativa L) seeds. Seed Science and Technology. 30: 451-8.

Singh, C.M., Angrirasand, N.N. and Singh, S.D. (1988). Plant ecophysiology. Indian Journal of Weed Science. 20: 63-66.

Sithinoin, P., Lertmongkol, S., Chanprasert, W. and Vajrodaya, S. (2017). Allelopathic effect of jungle rice [Eichinocola colena (L.) Link] extract on seed germination and seedling growth of rice. Agriculture and Natural Resources. 51: 74-78.

Swain, D., Seema, P., Singh, M. and Subadhi, H.N. (2012). Evaluations of allelopathic effect of Echinocola colena weed on rice (Oryza sativa L. "Vandana"). Journal of Environmental Biology. 33: 881-889.

Trezz, M.M., Vital, R.A., Junior, A.A.B., Bittencourt, H.H. and Filho, A.P.S.S. (2016). Allelopathy: driving mechanisms governing its activity in agriculture. Journal of Plant Interactions. 11: 53-60.

Verma, R.K., Verma, S.K., Kumar, S., Kumar, V. and Patra, D.D. (2012). Phytoxic effects of sweet basil (Ocimum basilicum L.) extracts on germination and seedling growth of commercial crop plants. European Journal of Experimental Biology. 2(6): 2310-2316.

Wu, Z., Bao, H., Zhou, F., Liu, J., Meng, F., Feng, L., Lu, J., Zhang, Q., Ye, Y. and Lin, L. (2017). Cytotoxic cassane diterpenoids from the seeds of Caesalpinia sappan. Chinese Chemical Letters. 28: 1711-1717.

Yang, C.M., Chang, F., Lin, S.J. and Chou, C.H. (2002). Effects of three allelopathic phenolics on chlorophyll accumulation of rice (Oryza sativa L.) seedlings: I inhibition of supply orientation. Botanical bulletin of Academia Sinica. 43: 299-304.

Yarnia, M., Benam, M.B.K. and Tabrizi, E.F.M. (2009). Allelopathic effects of sorghum extracts on Amaranthus retroflexus seed germination and growth. Journal of Food, Agriculture and Environment. 7:770-774.

Ye, M., Xie, W., Lei, F., Meng, Z., Zhao, Y.N., Su, H. and Du, L.J. (2006). Brazilian, an important immunosuppressive component from Caesalpinia sappan L. International Immunopharmacology. 6: 426-432.