

## Hard Seededness and Germination of Small White Flower Morningglory

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### ABSTRACT

Small white flower morningglory (*Ipomoea obscura* (L.) Ker-Gawl) has hard seeds. Scarification in 97.7% sulphuric acid for 40 to 120 minutes allowed germination, and the 80 minute treatment produced the fastest germination rate (recorded as coefficient of velocity). For acid scarified seeds germination did not differ at pHs ranging from 2.2 to 8.5, but the coefficient of velocity was greatest at a pH of 7.0, while germination decreased as osmotic potential increased from -0.19 to -0.76 MPa, and no germination occurred at -0.79 MPa. Cold scarification at 4°C did not allow germination of non-scarified seeds and had no effect on the germination of scarified seeds, which germinated equally well (>90%) at constant temperatures between 15 and 35°C. Germination at alternating temperatures did not differ from that at constant temperatures. Seeds on the soil surface did not germinate, but >85% emergence was recorded at sowing depths of 1 and 2 cm. Seeds sown at 8 and 12 cm did not emerge. Reducing light intensity (from 100 to 25% of full sunlight) did not affect seedling emergence or plant dry weight 12 weeks after sowing, but did delay the time to flowering. As this climbing weed can smother pineapple fields, it is important that effective control is achieved at the seedling stage.

**Key words:** small white flower morningglory, *Ipomoea obscura* (L.) Ker-Gawl, seed germination, seedling development, light intensity

### INTRODUCTION

Small white flower morningglory (*Ipomoea obscura* (L.) Ker-Gawl) is a vine belonging to the subfamily Ipomoea and family Convolvulaceae (Elmore *et al.*, 1990). This weed is found in warm, humid tropical regions such as eastern Africa, Asia, northern Australia and Fiji. It grows in pasture, forest, on roadsides and abandoned lands and in sandy soil near the seashore, and from sea level to 1,300 m above sea level (Elmore *et al.*, 1990). It has been reported that small white flower

morningglory infests pineapple fields in Rayong Province, eastern Thailand (Laosinwattana, 1994). This is one of the major pineapple production areas, supplying fruit to canning factories.

Normally, farmers control weeds in pineapple with two herbicide applications. The first application of bromacil alone or in combination with diuron controls weeds for 3 to 4 months. The same herbicides may also be applied at early or late post-emergence. As pineapple grows and leaf density increases, the crop usually inhibits the growth or development of many weeds, but small

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white flower morningglory can grow in pineapple crops and cause serious problems during fruit harvest. As there is no selective post-emergence herbicide available, farmers have to control this weed by hand which increases the cost of production. In order to develop effective control measures, a more thorough understanding of the factors governing seed germination and development of this species is needed.

Factors affecting the germination of small white flower morningglory or other *Ipomoea* spp. have been studied in other countries where the environmental conditions differ from that in Thailand. Horak and Wax (1991) found that when seeds of bigroot morningglory (*I. pandurata*) were scarified by  $H_2SO_4$  for 80 minutes, the percent and rate of germination increased. Furthermore, they found that seeds could germinate in soil at a pH of 5.5 to 7.5. The seeds of various species in the genus *Ipomoea* can germinate at a similar ranges of temperature; *I. coccinia* and *I. obscura* germinate between 10 to 40°C (Hardcastle, 1978), bigroot morningglory between 15 to 30°C and ivyleaf morningglory between 20 to 35°C (Gomes *et al.*, 1978).

The effects of osmotic potential on seed germination of bigroot morningglory have been previously studied; the seeds could not germinate at an osmotic potential of -0.8 MPa (Horak and Wax, 1991). The greatest emergence of purple moonflower morningglory seed was observed when planted 2.5 to 7.5 cm deep (Chandler *et al.*, 1977), while seeds of tall morningglory and ivyleaf morningglory had more than 50% emergence from 7.5 cm in a sandy loam soil and from 5.0 cm in a silt loam soil, respectively (Wilson and Cole, 1966). However, information on seed germination of *Ipomoea* in Thailand is limited.

The objectives of the study were to determine various factors governing seed germination of small white flower morningglory found in Thailand in order to assist in designing effective management methods in pineapple fields.

## MATERIALS AND METHODS

Seeds of small white flower morningglory were collected from a commercial pineapple field at Rayong province, approximately 120 km east of Bangkok during early April 1997. A few days after collection, the capsules were sun-dried and seeds were separated from the dried capsules. A few seeds were planted at a depth of 2 to 3 cm in pots containing clay loam soil (23% sand, 35% silt, 42% clay and 1.7% organic matter) from a commercial pineapple field. Each pot was 15 cm in diameter and 15 cm tall. The pots were placed outdoor in full sunlight (30 to 38°C), and watered as needed. Twenty days after planting, the seedlings of small white flower morningglory were thinned to one plant/pot. At first bloom, each flower was tagged and labeled with the date of blooming. It had previously been determined that seeds reached their physiological maturity at 21 to 22 days after blooming and became hardseeds after that period (Julakasewee *et al.*, 1999). Therefore, seeds used in the experiments were collected 28 days after blooming when the moisture content was approximately 14% (Julakasewee *et al.*, 1999). The dormant hardseeds were separated from the capsules, put in plastic bags, and refrigerated at 5 to 8°C. These hardseeds were used to study various factors affecting their germination, using methods of adapted from those reported by Horak and Wax (1991) and Hardcastle (1978).

Except for the acid scarification and stratification experiments, hardseeds were acid-scarified with 97.7%  $H_2SO_4$  for 80 minutes and rinsed with tap water for 5 minutes in order to break the hardseed prior to the experiments.

### Acid scarification

The hardseeds from refrigerator storage were scarified in 97.7%  $H_2SO_4$  from 0 to 120 minutes (Table 1). Another group of hardseeds were pricked with a needle. The acid treated or needle-pricked hardseeds were put on two layers

**Table 1** Effect of seed scarification with 97.7% H<sub>2</sub>SO<sub>4</sub> and needle-pricking on the germination of morningglory hardseeds.

| Methods of seed scarification | Germination (%)   | Coefficient of velocity | Non-viable seed (%) |
|-------------------------------|-------------------|-------------------------|---------------------|
| 0 min. in acid                | 7 e <sup>1/</sup> | 11.4 g                  | 0 e                 |
| 10 min. in acid               | 9 e               | 15.4 fg                 | 0 e                 |
| 20 min. in acid               | 54 d              | 16.4 fg                 | 0 e                 |
| 30 min. in acid               | 66 c              | 17.4 fg                 | 0 e                 |
| 40 min. in acid               | 89 ab             | 25.6 f                  | 0 e                 |
| 50 min. in acid               | 90 ab             | 27.9 e                  | 1 de                |
| 60 min. in acid               | 93 ab             | 32.6 de                 | 3 cd                |
| 70 min. in acid               | 94 a              | 40.9 bc                 | 3 cd                |
| 80 min. in acid               | 96 a              | 53.2 a                  | 3 cd                |
| 90 min. in acid               | 94 a              | 35.2 c                  | 5 bc                |
| 120 min. in acid              | 94 a              | 34.5 c                  | 6 b                 |
| Needle-pricking               | 85 b              | 33.5 c                  | 13 a                |
| CV (%)                        | 8.60              | 13.09                   | 64.44               |

<sup>1/</sup> Means within the same column followed by the same letters are not significantly different at P<0.05

of 9 cm germination paper in a 10 cm petri dish wetted with 8 ml of distilled water. All petri dishes were placed in an unlit germination chamber maintained at 27°C. Distilled water was added as needed.

The germinated seeds were counted and recorded every day for 14 consecutive days. If the radicle length was longer than 3 mm, those seeds were considered as germinated seeds. The viability of ungerminated seeds was tested by sodium tetrazolium. The seed germination counts were used to calculate the percent germination and coefficient of velocity. The coefficient of velocity was calculated by the following formula (Horak and Wax, 1991):

$$\text{Coefficient of velocity (CV)} = 100[\Sigma Ni / \Sigma NiTi]$$

When, Ni = The accumulated numbers of germinated seed until day i

Ti = The numbers of day [i] after sowing

In the planting depth and light intensity experiments, emergence data were used in the equation instead of germination data.

### pH

Buffer solutions with different pH values of 2.2 to 8.5 (Table 2) were prepared by mixing 0.1 M HCl or NaOH with distilled water. Other experimental procedures were the same as described for the acid scarification experiment.

### Osmotic potential

Eight different osmotic potential solutions (Table 3) were prepared by mixing distilled water with polyethylene glycol 6000 as reported by Michel (1983). After mixing, the osmotic potential of each solution was measured with a vapor pressure osmometer. The control (without polyethylene glycol 6000) was distilled water with an osmotic potential of -0.08 MPa (Mega Pascal). Other experimental procedures were the same as those

described for the acid scarification experiment.

### Cold stratification

The hardseeds of small white flower morningglory were taken from the refrigerator and uniformly mixed with 160 g of fine sand and

placed in a 10 cm petri dish, 25 seeds per petri dish. Before mixing, the sand was cleaned with distilled water and dried. Two milliliters of distilled water was added to the sand in order to keep the petri dish under low moisture conditions. All petri dishes were placed in a refrigerator at a constant temperature of 4°C. Every two week for up to 12 weeks, 8 petri dishes were brought out from the refrigerator and the sand was removed from the seeds by washing with tap water. The seeds from four petri dishes (4 replications) were subjected to acid scarification with H<sub>2</sub>SO<sub>4</sub> for 80 minutes while seeds from the other four petri dishes (4 replications) were not treated. The scarified and unscarified seeds were placed on two layers of 9 cm germinating paper in 10 cm petri dishes. Eight ml of distilled water was added to each petri dish and the petri dishes were kept in the germinating chamber in the dark at 27°C for 14 days. The germination data were recorded as described in the acid scarification experiment.

**Table 2** Effect of pH of germinating solution on the germination of small white flower morningglory.

| pH     | Germination (%)    | Coefficient of velocity |
|--------|--------------------|-------------------------|
| 8.5    | 96 a <sup>1/</sup> | 40.7 a                  |
| 8.0    | 97 a               | 46.1 a                  |
| 7.0    | 98 a               | 54.7 a                  |
| 6.0    | 96 a               | 41.6 a                  |
| 5.0    | 96 a               | 41.5 a                  |
| 4.0    | 96 a               | 46.2 a                  |
| 3.0    | 97 a               | 40.6 a                  |
| 2.2    | 92 a               | 40.7 a                  |
| CV (%) | 4.53               | 9.01                    |

<sup>1/</sup> Means within the same column followed by the same letters are not significantly different at P<0.05

### Temperature

Acid-scarified seeds were placed on 2 layers of 9 cm germination paper in a 10 cm petri dish wetted with 8 ml of distilled water. The petri

**Table 3** Effect of osmotic potential solution on the germination of small white flower morningglory.

| Osmotic potential (MPa) | Germination (%)    | Coefficient of velocity |
|-------------------------|--------------------|-------------------------|
| -0.08                   | 97 a <sup>1/</sup> | 48.1 a                  |
| -0.19                   | 89 b               | 28.9 b                  |
| -0.22                   | 82 c               | 23.6 c                  |
| -0.34                   | 75 c               | 18.8 d                  |
| -0.39                   | 71 d               | 13.2 e                  |
| -0.58                   | 38 e               | 11.7 e                  |
| -0.61                   | 27 f               | 9.9 e                   |
| -0.76                   | 4 b                | 4.5 f                   |
| -0.79                   | 0 g                | 0.0 g                   |
| CV (%)                  | 5.48               | 12.98                   |

<sup>1/</sup> Means within the same column followed by the same letters are not significantly different at P<0.05

dishes were then placed in the germination chamber at either a constant temperature of between 5 and 40°C (Table 4) or a fluctuating temperature (Table 5) for 14 days. The germination data were collected as described in the acid scarification experiment.

### Seeding depth

Acid-scarified seeds were planted in 40 cm wide, 50 cm long and 40 cm tall pots containing clay loam soil to 5 cm below the top edge of the pot. One hundred seeds were placed in each pot at a specific depth ranging from 0 to 12 cm (Table 6). All pots were placed outdoor (30 to 38°C) and watered as needed. The data were collected in the

same manner as in the acid scarification experiment.

### Light intensity

Acid-scarified seeds were planted in 30 cm and 40 cm tall pots containing clay loam soil as in the soil depth experiment. Twenty-five seeds were planted in each pot at a depth of 1 to 2 cm. Four small shade houses, 3 m wide, 4 m long and 2 m tall, were built without walls, to enable airflow and avoid heat buildup. The temperature of each house was approximately equal to that of the open air (28 to 36°C). The roof of the house for the 100% of sunlight plot was covered with transparent saran while in the other houses additional sarans reduced

**Table 4** Effect of constant temperature for 2 weeks on the germination of small white flower morningglory.

| Temperature (°C) | Germination (%)   | Coefficient of velocity (%) |
|------------------|-------------------|-----------------------------|
| 5                | 1 d <sup>1/</sup> | 8.3 e                       |
| 10               | 68 b              | 20.4 d                      |
| 15               | 93 a              | 28.2 cd                     |
| 20               | 96 a              | 32.6 bc                     |
| 25               | 97 a              | 39.1 ab                     |
| 30               | 97 a              | 42.1 a                      |
| 35               | 94 a              | 38.5 ab                     |
| 40               | 38 c              | 34.8 abc                    |
| CV (%)           | 6.02              | 20.96                       |

<sup>1/</sup> Means within the same column followed by the same letters are not significantly different at P<0.05

**Table 5** Effect of fluctuating temperature for 2 weeks on the germination of small white flower morningglory.

| Temperature (°C)       | Germination (%)    | Coefficient of velocity (%) |
|------------------------|--------------------|-----------------------------|
| 20 (16 hrs)/ 10(8 hrs) | 92 a <sup>1/</sup> | 18.8 b                      |
| 30 (16 hrs)/ 20(8 hrs) | 96 a               | 38.6 a                      |
| 40 (16 hrs)/ 30(8 hrs) | 90 a               | 35.7 a                      |
| CV (%)                 | 4.32               | 7.51                        |

<sup>1/</sup> Means within the same column followed by the same letters are not significantly different at P<0.05

**Table 6** Influence of seedling depth on the emergence of small white flower morningglory seedlings.

| Seeding depth (cm) | Emergence (%) | Coefficient of velocity | Dry weight (mg/plant) |
|--------------------|---------------|-------------------------|-----------------------|
| 0                  | 5 f           | 9.04 e                  | 0.277 d               |
| 1                  | 87 a          | 21.32 a                 | 0.465 a               |
| 2                  | 85 b          | 18.80 b                 | 0.402 b               |
| 4                  | 74 c          | 16.25 c                 | 0.390 b               |
| 6                  | 71 d          | 15.02 d                 | 0.352 c               |
| 8                  | 7 e           | 9.25 e                  | 0.275 d               |
| 12                 | 0 g           | 0.00 f                  | 0.000 e               |
| CV (%)             | 2.46          | 4.83                    | 7.62                  |

sunlight to 75, 50, or 25%. Four pots (replications) were placed in each house. The pots were watered every day or as needed. The emergence data were recorded at 14 days after planting. The plants were allowed to grow for 84 days, and plant height, dry weight and the day of first bloom were recorded, calculated, and tabulated (Table 7).

All experiments used a completely randomized design. The experiments were conducted from April 1998 until April 2000 at the Seed Laboratory, Department of Agronomy, Faculty of Agriculture, Kasetsart University, Chatuchak, Bangkok and the Central Laboratory, Faculty of Agriculture Rachmungkala Institute of

Technology, Bangpra, Sriracha, Chonburi, Thailand.

## RESULTS AND DISCUSSION

### Acid scarification

Julakasewee *et al.* (1999) showed that seeds of small white flower morningglory reached physiological maturity at 21 to 22 days after blooming. The seeds used in the experiments were collected at 28 days after blooming and only 7% germinated when they were soaked in distilled water (Table 1). Soaking the hardseeds in 97.7% H<sub>2</sub>SO<sub>4</sub> for 40 minutes or longer allowed maximum

**Table 7** Effect of light intensity on emergence and plant development of small white flower morningglory.

| Light intensity (%) | Emergence (%)      | Plant height (cm) |         | First flower blooming (day after planting) | Plant dry weight at 12 weeks (g/plant) |
|---------------------|--------------------|-------------------|---------|--------------------------------------------|----------------------------------------|
|                     |                    | 4 weeks           | 8 weeks |                                            |                                        |
| 25                  | 81 a <sup>1/</sup> | 17.3 a            | 43.8 a  | 77.6 a                                     | 12.8 a                                 |
| 50                  | 83 a               | 16.8 a            | 39.8 a  | 71.1 ab                                    | 13.7 a                                 |
| 75                  | 80 a               | 12.5 b            | 29.6 b  | 63.5 bc                                    | 18.6 a                                 |
| 100                 | 84 a               | 11.7 b            | 27.4 b  | 57.3 c                                     | 20.4 a                                 |
| CV (%)              | 8.15               | 18.79             | 16.17   | 11.99                                      | 37.92                                  |

<sup>1/</sup> Means within the same column followed by the same letters are not significantly different at P<0.05

germination. The coefficient of velocity of the seeds also increased when seeds were soaked for 50 minutes or longer (Table 1). The highest percent germination occurred with a 40 to 120 minutes soaking, and soaking for 80 minutes resulted in the greatest coefficient of velocity (Table 1). Needle-pricking the seeds before germination also increased percent germination but also the percent of non-viable seeds. These results indicated that after reaching the physiological maturity period, the seeds of small white flower morningglory can not germinate because of impermeability of the seed coat to water, similar to other reports. Seeds of most weeds in the genus *Ipomoea* become dormant because of impermeability of the seed coat to water and dormancy occurs immediately at physiological maturity or a few days after this period (Elmore *et al.*, 1990). This dormancy is called coat-imposed dormancy in which the seed coat is a mechanical barrier and is different from embryo dormancy (Bradbeer, 1998).

### pH

After breaking the dormancy of seeds by acid scarification, the pH of the germinating solution ranging from pH 2.2 to 8.5 did not affect the germination of small white flower morningglory hardseeds (Table 2). The greatest coefficient of velocity occurred at pH 7.0 while a pH below 7.0 reduced the germination rate (Table 2). Bigroot morningglory also germinated very well in soil at a pH of 5.5 to 7.5 which is the normal pH of soil in agricultural land (Horak and Wax, 1991).

### Osmotic potential

Small white flower morningglory seed germinated best in distilled water which had an osmotic potential of  $-0.08$  MPa (Table 3). As the osmotic potential increased the percentage germination and coefficient of velocity decreased. Seeds did not germinate when the osmotic potential was  $-0.79$  MPa. These results were similar to that reported for bigroot morningglory seeds that did

not germinate at an osmotic potential value of  $-0.8$  MPa (Horak and Wax, 1991). Bigroot morningglory is found only in the eastern and southern parts of the United State, not in the west which is drier (Horak and Wax, 1991). Different species of *Ipomoea* have a different tolerance to osmotic stress. Pitted morningglory is more tolerant to osmotic stress than small flower morningglory (Hoveland and Buchanan, 1973). This study confirms observations in the field that the emergence of small white flower morningglory in eastern Thailand occurs only in the rainy season. Therefore, it is essential that farmers should be aware of the emergence of small white flower morningglory during this season and institute control measures while the seedlings are small.

### Cold stratification

Storage of small white flower morningglory hardseeds at  $4^{\circ}\text{C}$  for 0 to 12 weeks did not affect the percent germination and coefficient of velocity of dormant hardseeds or acid-scarified seeds (data not presented). These results indicated that exposure to low temperatures alone cannot break hardseededness of small white flower morningglory. This agreed with the evidence that this weed was a tropical plant.

### Temperature

Germination was 93% to 97% across a constant temperature range of  $15$  to  $35^{\circ}\text{C}$ , while a temperature above or below this range caused a reduction in germination (Table 4). The coefficient of velocity values were similar at a temperature range of  $25$ – $40^{\circ}\text{C}$ , but decreased as temperature decreased (Table 4). Similarly, the appropriate temperature for *I. coccinea* to germinate was reported to be  $10$  to  $40^{\circ}\text{C}$  (Hardcastle, 1978), bigroot morningglory could germinate at  $15$ – $30^{\circ}\text{C}$  (Horak and Wax, 1991), and tall morningglory (*I. purpurea*) and ivyleaf morningglory could germinate at  $15$ – $30^{\circ}\text{C}$  and  $20$ – $35^{\circ}\text{C}$ , respectively (Cole and Coats, 1973 ; Gomes *et al.*, 1978).

Fluctuating temperatures of 20/10°C, 30/20°C, and 40/30°C resulted in 90 to 96% germination but the coefficient of velocity was reduced at 20/10°C (Table 5). Temperatures of 30/20°C and 40/30°C are similar to the average temperature of pineapple fields. Therefore the fluctuating temperature does not appear to be a limiting factor for small white flower morningglory germination in the field.

### Seeding depth

Only five percent of small white flower morningglory hardseeds could germinate at the soil surface. The coefficient of velocity and seedling dry weight were also low when the seeds were placed on the soil surface (Table 6). The highest percent emergence was 87% observed in the seeds planted 1 cm deep. The greatest coefficient of velocity and seedling dry weight were also observed when seeds were planted 1 cm deep in the soil (Table 6). Emergence percentage decreased as planting depth increased beyond 1 cm. Emergence was only 7% when seeds were planted 8 cm deep and none emerged from 12 cm. (Table 6).

Normally, land is ploughed at a 15 cm depth, which is likely to bring many seeds into the optimum zone for germination and emergence. Therefore, the results from the study indicated that even no-tillage of the land before crop planting could not prevent small white flower morningglory establishment.

These results were similar to that reported for bigroot morningglory seeds which became established when their seeds were placed at a 2 cm depth. They could germinate at a 16 cm depth but the percent emergence decreased (Horak and Wax, 1991). Purple moonflower morningglory had the highest percent emergence at a 2.5 to 7.5 cm depth (Chandler *et al.*, 1977) and tall morningglory and ivyleaf morningglory could emerge from a 7.5 cm depth in sandy loam soil and at a 5.0 cm depth in silt loam soil, respectively (Wilson and Cole, 1966). Therefore, the establishment of seedlings

from different soil depths depends on emergence force of the seeds and soil type.

### Light intensity

Light intensity did not affect the emergence of small white flower morningglory when seeds were planted at 1 to 2 cm depth (Table 7). However, under lower light intensity (25 and 50% of sunlight) conditions, the height of small white flower morningglory plants were greater than those grown under high light intensity (75 and 100% of sunlight) (Table 7). Plant dry weight at 12 weeks after planting was not affected by light intensity (Table 7). Planting to first blooming took 57 days under full sunlight and increased to 78 days with 25% of full sunlight (Table 7). These results indicated that small white flower morningglory plants could grow under the lower light conditions of a pineapple canopy.

## CONCLUSION

Normally, small white flower morningglory is a climber and often observed in pineapple fields after it has climbed up and covered the crop, about 6 months after planting. It is very difficult to control this weed when it grows up onto the pineapple plants since it is a dense crop with spiny leaves. The results from the study emphasize the importance for farmers of watching for weed seedlings growing under the pineapple canopy and controlling them before they climb up and cover the crop.

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### LITERATURE CITED

- Bradbeer, J.W. 1988. **Seed Dormancy and Germination**. Blackie, Glasgow and London, 146 p.
- Chandler, J.M., R.L. Munson and C.E. Vaughan. 1977. Purple moonflower: emergence, growth, and reproduction. **Weed Sci.** 25: 163-167.
- Cole, A.W. and G.E. Coats. 1973. Tall morningglory germination response to herbicides and temperature. **Weed Sci.** 21: 443-446.
- Elmore, C.D., H.R. Hurst and D.F. Austin. 1990. Biology and control of morningglories (*Ipomoea* spp.). **Rev. Weed Sci.** 5: 83-114.
- Gomes, L.F., J.M. Chandler and C.E. Vaughan. 1978. Aspects of germination, emergence and seed production of three *Ipomoea* taxa. **Weed Sci.** 26: 245-248.
- Hardcastle, W.S. 1978. Influence of temperature and acid scarification duration on *Ipomoea obscura* Hassk. seed germination. **Weed Res.** 18: 89-91.
- Horak, H.J. and L.M. Wax. 1991. Germination and seedling development of bigroot morningglory (*Ipomoea pandurata*). **Weed Sci.** 39: 390-396.
- Hoveland, C.S. and G.A. Buchanan. 1973. Weed seed germination under simulated drought. **Weed Sci.** 21: 322-324.
- Julakasewee, A., R. Suwanketnikom and S. Chandakul. 1999. Development, germination, and dormancy of small-white flower morningglory [*Ipomoea obscura* (L.) Ker-Gawl] seeds, pp 583 – 587. In **Proceedings I(B) the 17<sup>th</sup> Asian Pacific Weed Science Society Conference**.
- Loasinwattana, C. 1994. **Study on No-tillage in Pineapple and Its Effect on Weed Status and Strategy of Management**. M.Sc. Thesis, Kasetsart University. Bangkok.
- Michel, B.E. 1983. Evaluation of water potentials of solutions of polyethylene glycol 8000 both in the absence and presence of other solutes. **Plant Physiol.** 72: 66-70.
- Wilson, H.P. and R.H. Cole. 1966. Morningglory competition in soybeans. **Weeds** 14: 49-51.