PHYSIOLOGICAL MATURITY AND EFFECT OF SEED PRIMING ON GERMINATION ABILITY OF VEGETABLE SOYBEAN

[*Glycine max* (L.) Merrill]

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Title

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ABSTRACT

Physiological maturity and effect of seed priming on seed quality of two vegetable soybean varieties (AGS 292 and No.75) were conducted in this study that aimed to observe physiological maturity, improvement of germination rate and uniformity of vegetable soybean and, to determine vegetable soybean seed production by means of seed technology. This experiment on physiological maturity was carried out at Maejo University (Sansai, Chiang Mai) for two types of environment: dry season and rainy season, of 2010. Pods and seeds from each variety were sampled at 5-day interval after flowering until harvesting time. Results showed that vegetable soybean seed varieties, AGS 292 and No.75, reached physiological maturity stage at 69 days and 71 days after planting in dry season, and at 68 days and 69 days after planting in rainy season, respectively. The seed priming experiment was conducted in a 4 x 4 factorial in CRD with 3 replications consisting of 4 polyethylene glycol (PEG) concentrations (0, 2.4, 4.7, and 6.5 g per 100 ml of distilled water) and 4 levels of soaking time duration (3, 6, 9 and 12 hours) on vegetable soybean var. AGS 292 and No.75. Results showed that vegetable soybean var. AGS 292 treated with PEG had significantly affected the germination percentage. However, in vegetable soybean var. No.75, there was no significant effect of priming treatments on germination percentage and seedling growth rate. The 12-hour soaking time for seeds in both varieties, proved deleterious. Seeds treated with longer soaking time duration were shown to increase electrical conductivity. However, lowest value of electrical conductivity was observed in seeds treated with PEG. Similar result was found in combined analysis of vegetable soybean var. AGS 292 and No.75.

Keywords: vegetable soybean, physiological maturity, seed priming, PEG

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ABBREVIATIONS

ANOVA	Analysis of variance
cm	Centimeter
Conc:	Concentration
CRD	Completely randomized design
°C	Degree celsius
DAS	Days after seeding
DMRT	Duncan's multiple range test
DNA	Deoxyribonucleic acid
EC	Electrical conductivity
et.al	And another people
g	Gram
Ger %	Germination percentage
hr	Hour
LSD	Least significance difference
m	Meter
mg / seedlings	Milligram per seedlings
ml	Milli liter
mm	Milli meter
MPa	Megapascals
%	Percentage
PEG	Polyethylene glycol
PM	Physiological maturity
RCBD	Randomized complete block design
RNA	Ribonucleic acid
SDM	Seed dry matter
SGR	Seedling growth rate
SMC	Seed moisture content
µS/cm/ seeds	Microsiemens per centimeter per seeds

CHAPTER 1

INTRODUCTION

Soybean is a highly diversified plant, having determinate, indeterminate and semi-determinate types. Photoperiodically, it is highly sensitive and responds differently to changes in environmental conditions. Different planting dates subject soybean plant to different environmental conditions which in turn affect the growth and development of vegetative and reproductive components of yield and physiological processes. Good vegetable soybean seeds ensure a uniform stand of healthy and vigorous plants, which is essential to get the high yield and good quality needed for profitable vegetable soybean production. However, maintaining the quality of vegetable soybean seed is very difficult due to the rapid deterioration of the seed.

Good quality seed is an essential prerequisite for raising a good crop. Producing good quality seed depends on many factors, such as growing season, location, management inputs, diseases and pests, post-harvest handling and storage. Among the environmental factors, high temperature, and high relative humidity are those which exert unfavourable stresses on developing seeds. The above conditions are quite common in tropical and subtropical regions of the world (Andrews, 1982).

The predominant unsaturated fatty acid composition is known to be a major cause of seed deterioration (Saenong, 1987). These unsaturated fatty acids cause the deterioration in the quality of soybean seeds, thus maintaining seed quality has become a great problem during storage. Soybean sced qualities in the tropics are low, due to its high rate of deterioration and have more seed damages because of their physiological characteristics (Tekrony et aL, 1987). Moreover, seed moisture content, temperature, relative humidity, pest and disease infestation, and pre-harvest and post-harvest management practices also affect seed quality maintenance.

High temperatures during the seed filling period (Keigley and Mullen, 1986) and at the time of maturity (Burdett, 1997) contributed directly to early deterioration of sceds. The harvesting time is one of the critical steps in soybean seeds production. Unavoidable delays or those resulting from careless farmer's attention cause the exposition of the seeds to unfavorable environmental conditions and the acceleration of the deterioration process. Therefore, it is necessary to harvest at a time as close as possible to the physiological maturity, that is, after the stabilization of dry matter translocation to the seeds, when they reach the maximum germination and vigor potential (Jacintho and Carvalho, 1974; Marcos-Filho et al., 1981).

Seed shrinkage and loss of green color from pod have been suggested as indicators of physiological maturity for soybean [*Glycine max* (L.) Merr.] by Crookston and Hill (1978), Tekrony et al. (1979), and Gibkpi and Crookston (1981). Fraser et al. (1982) reported that moisture content represents an accurate indicator of physiological maturity for soybean. The use of high quality seed is essential for good stand establishment and yield for vegetable soybean.

One of the most important aspects for oil seed production is rapid emergence and good seedling establishment in field. In the other hand germination and emergence are important issues in plant production and they have significant effect on the next stages of plant growth in field. Rapid and uniform field emergence is essential to achieve high yield with having good quality and quantity in annual crops (Yari et al., 2010).

Seed priming has been successfully demonstrated to improve germination and emergence in seeds of many crops, particularly seeds of vegetables and small seeded grasses (Heydecker and Coolbaer, 1977; Bradford, 1986). The beneficial effects of priming have also been demonstrated for many field crops such as wheat, sugar beet, maize, soybean and sunflower (Parera and Cantliffe, 1994; Singh, 1995; Sadeghian and Yavari, 2004).

In the other hand on seed priming the amount of water absorption is controlled so as necessary metabolic activities occurred for germination but radical emergence is prohibited. This technique used for improvement of germination speed, germination vigor, seedling establishment and yield (Talebian et al., 2008; Bodsworth and Bewley, 1981). There is different treatment for seed priming which polyethylene glycol (PEG) is one of the most prevalent treatment. This treatment does not have any physiological responses to seed and in order to having more molecular weight cannot pass the cell wall and so it be used for water potential adjustment in germination experiments (Seyed Sharifi and Seyed Sharifi, 2008; Emmerich and. Hardgree, 1990).

Poor germination and low seed viability are among the serious problems in the production of soybean. There are more reports about seed priming effects on different plants. It was reported that soybean seed priming made better seedling emergence and yield improvement (Arif et al., 2008). Vigorous seeds germinate rapidly, uniformly and are able to withstand environmental adversity after sowing (Ajouri et al., 2004; Marwat and Nafziger, 1990). Seed priming had significant effected on increment of germination percent, germination speed and seedling dry weight of sunflower vice versa of producing abnormal seedling decrement in drought condition (Demir et al., 2006).

Seed priming is commonly used to reduce the time between seed sowing and seedling emergence (Parera and Cantliffe, 1994). Earlier works showed that the success of seed priming is influenced by the complex interaction of factors including plant species, water potentiality of the priming agent, duration of priming, temperature, seed vigor and dehydration, and storage conditions of the primed seed (Mubshar et al., 2006; Parera and Cantliffe, 1994). It is very important and essential to get necessary information concerning vegetable soybean seed priming to develop an appropriate priming method and technique applicable to the farmers of developing countries.

Objectives

The objectives of this research are

1. To observe the physiological maturity between two varieties of vegetable soybean
2. To improve germination rate and uniformity of vegetable soybean
3. To determine the vegetable soybean seed production by means of seed technology

CHAPTER 2

LITERATURE REVIEW

2.1 Importance of vegetable soybean

Soybean (*Glycine max* (L.) Merrill) is a worldwide economic crop which originated in China and is the most important cultivated legume. The cultivation of soybean crop dated as far back as 5,000 years ago. Now its cultivation extends from temperate to tropical countries and is a highly successful modern crop. Asia is the most important region in the world for soybean research because of its richness in soybean genetic resources and its long history of soybean use for human food. Soybean is an excellent source of major nutrients; the average approximate composition of the soybean is 40% protein, 21% oil, 34% carbohydrate, and 5% ash. It is highly efficient producer of protein and oil, both of which are very well adapted to the nourishment of animal or man (Roupsouy, 1995).

There are many soybean varieties but only a small number of them can be grown as vegetable soybean. Vegetable soybean is popular in China, Japan and Korea for its unique taste and high nutritional value as a source of vitamin A, B, B_2, C, fat and minerals such as phosphorus, calcium, iron and fiber. It is a potentially valuable commodity for other developing countries because it can be a good source of income for small farmers, can easily fit into their cropping systems, be a potential source of fodder for livestock, and enhance soil properties at the same time. The use of vegetable soybean is completely different from grain bean. Most vegetable soybean cultivars currently grown are important from Japan and Taiwan. Japan is the original source of improved vegetable soybean cultivars (Roupsouy, 1995).

Soybean is an important oilseed crop, listed as a poor storer. It looses viability rapidly under warm and humid storage conditions. Seed longevity is greatly influenced by the relative humidity and storage temperature. Seed size has been recognized as one of the factors that influence seed vigor, plant growth and ultimately yield of soybean.

2.2 Factors influencing seed quality

Physiological maturity (PM) is defined as the time when seeds attain maximum dry weight, maximum germination, and maximum vigor (Andrews, 1966; Delouche, 1958; Mejia, 1985; Rajanna and Andrews, 1970). Seed quality is maximum at the time of PM is reached; therefore, being able to identify this stage of development can aid a seed grower in optimizing subsequent operations such as harvesting and drying to maximize the germination and vigor of seed produced. Among the most important factors that affect the physiological quality of soybean seeds stand the adequate definition of the sowing season, the determination of the most suitable regions for seed production, the use of high quality seed cultivars, harvesting at the right time, mechanical damage, insect attack, infection caused by microorganisms and inadequate storage (Costa et al., 1995). At PM, the seed has its highest vigor, thereafter declining to senescence and eventually no longer able to germinate (Harrington, 1972).

Seed maturation may be regarded as a positive process during seed development encompassing additive changes in seed characteristics, which include increase in seed size, dry weight, viability, and vigor (Rajanna and Andrews, 1970).

Seed development in southern pea [*Vigna unguiculata* (L.) Walp.] occurs more rapidly than in some other species. Oropeza (1976), working with two cultivars of southern pea, found maximum dry weight was attained 17 to 19 days after anthesis. Banyankiye (1993) found PM of sorghum seed was reached in 27 to 30 days under rainfed conditions in Mississippi. Caceres (1977) identified PM of Lee 68 soybean seed 68 days after anthesis. PM represents an important growth stage of crop plants, since it is normally assoeiated with maximum accumulation of dry seed weight and yield. PM of an individual soybean seed or pod occurs when the seed or pod is completely yellow; however, indicators of PM on a whole plant basis arc not availablc. This investigation was conducted to relate several visual indicators of soybean pod development to PM and yield of field populations.

The period soybean seeds remain in the field after reaching PM is an important deterioration factor, caused especially by an increase in the incidencc of pathogens or by a reduction in germination and vigor. Soybean seeds from late cultivars that reach maturation after the period when the weather is hot and dry. exhibit greater vigor than seeds from early cultivars that undergo maturation during hot and dry weather (Green et al., 1965). Therefore, using cultivars that have high-quality seeds, together with choosing regions that have more favorable climatic characteristics, as well as staggering the sowing dates, can surely result in the production of seeds with better physiological quality and low deterioration rates, with higher yields in the commercial exploration of the crop.

This deterioration process has been characterized as inexorable and irreversible (Delouche, 1982). Such proeess is determined by genetic factors, insect attack, environmental eonditions in the post-maturation/pre-harvest period, harvesting and proeessing procedures, in addition to storage and transportation conditions. The rate of reduction in seed germination and vigor varies in consonance with the sowing season as well as temperature, relative humidity and rainfall conditions during the maturation and harvest stages (Tekrony et al., 1980).

2.2.1 Use of cultivar

(Quaeh et al., 2004) studied on five soybean genotypes differing in growth duration (TN12 and M103 as early, and CM 60, 95389 and MSBR 20 as late maturity types) were sown on three different dates. Grain yield was not different for the three sowing dates but varied among genotypes. Although experiencing high temperature, the late maturing genotypes sown early in the season (S1) had longer growth duration compared with the later sowing times (S2 and S3), the late maturing genotypes produced low yields at all sowing times. The late maturing genotypes (95389 and MSBR 20) produced low yields at all sowing time, while CM 60 produced consistently high yields, indicating that fluctuations in weather conditions did not have much effect on yield of soybean during the growing period. The soybean could be sown from July to early August in variable eropping system and CM 60 was the most promising variety for the region.

2.2.2 Seed size

Seed size is one of the factors that influence seed vigor, plant growth and ultimately yield of soybean (Smith and Camper, 1975). Seed size is another important factor affecting germination and stand establishment of most of the plant species specially soybean (Armstrong et al., 1988). Plants from large seeds had significantly greater yield than those from small seeds

(Smith and Camper, 1975; Fontes and Ohlrogge, 1972; Burris et al., 1973), others have found no effect of planted seed size on yield, if plots were grown at consistent population densities (Johnson and Luedders, 1974; Hoy and Gamble, 1987). Small seeds resulted in lower yield than medium, large and unscreened seeds in two out of three cultivars. Soil texture and seed size had a variable influence on seed emergence which did not translate into consistent significant yield differences (Morrison and Xue, 2006).

2.2.3 Sowing time

Soybean plants from early planting dates had seeds maturing during hot, dry weather. This produced poor seed quality. Seeds from later planting dates after hot, dry weather conditions, produced high in quality (Green et al., 1965). The sowing time varies depending on which other crops such as watermelon and maize are grown, and there has been no research on effects of sowing time on growth of soybean in this system (Long et al., 2001).

Soybean seed yield decreased by 33% when sowing time was delayed (Beaver and Johnson, 1981) from May to July and 50%, when delayed from April to July (Beatty et al., 1982) and 12% from Junc 15^{th} to July 15^{th} (Caviness and Collins, 1985). Hatam (1988) reported that delaying soybean planting from April to July 15, decreased seed yield and dry matter by more than 80%, low 100 seed weight being the major component of reduced seed yield.

Anderson and Vasilas (1985) reported that delayed planting decreased grain yield as a result of decrease in number of seeds. However, late planting increased the rate of dry matter accumulation between emergence and flower initiation (R_1) but decreased during reproductive stage. Pedersen and Lauer (2004) reported that early planted soybean produced higher dry matter than late planted soybean. They believed that planting date was an important mean to change the rate of seedling emergence and delay the time of flowering. Early planted soybean accumulated maximum dry matter at R_6, which was 5% higher than late planted soybeans.

Khalil et al. (2001) found that soybean seeds from January, February, and March planted crop produced heaver seeds, with higher infection of seed borne pathogens and lower germination. Seeds from July and August planted crops produced smaller seeds with higher germination and little infection with seed borne pathogens. Small seed size was associated with high germination and later dates of plating. Germination was inversely related to seed size.

Bhering et al. (1991) stated that seed quality was high in soybean seeds obtained from December planting than those from October planting. Low seed quality in October coincided with high rainfall and temperature during maturity.

2.2.4 Plant spacing

(1987) closer spacing between rows and plants gave higher seed yield than wider inter- and intra-row spacing. Egli et al. (1987) reported that increasing row spacing decreased seed yield, while closer spacing gave higher seed yield (Chaudhry et al., 1988 and Qayyum et al., 1988). Similarly, Agha et al. (1990) stated that wider row and plant spacing gave higher seed index and seed oil content, whereas seed yield was higher at closer row and plant spacing.

Pod number and seed number per plant increase with the decreasing number of plant per hectare. Seed yield increase with the increasing plant density up to the maximum level and declined when plant density was increased further. Results showed that use of high quality certified seeds are required to obtain adequate plant number per unit area for maximum yield. (Zaimoglu et al., 2004)

2.2.5 Irrigation

Irrigation is one of the important factors affecting soybean growth, yield and its related components. Grain and stover yield increased with irrigation applied at 20% available soil moisture depletion and showed that water stress reduced panicle length, plant height, panicle number, 500 seed weight, grain yield and total dry weight (Abdel – Gawad et al., 1983, Abdalla, Safia et al., 1992, Kassim and Shames El-Din, 1992, Mekki et al., 1993 and Ibrahim et al., 2005). The soybean suffers from drought too, which provokes mass abortion of the pods independent that it grows under the hot tropical and subtropical climate conditions, its development decreases over 35?C, accompanying with yield losses (Doorenbos et al., 1979). Soybean irrigation 6 or 7 times at various growth stages resulted in better crop growth and higher seed yield, dry matter and oil content (Naescu et al., 1984).

Soybean responses to irrigate and the temporal pattern of rainfall in more southern latitudes (Ashley and Ethridge, 1978; Elmore et al., 1988; Runge and Odell, 1960). Soybean seed yield increased with irrigation, although the degree of increase varied significantly depending upon the year, time of application, soil, and variety grown (Heatherly, 1985). Common bean is the most important food legume which is sensitive to drought stress (Acosta-Gallegos and Adams, 1991; Ramirez-Vallejo and Kelly, 1998). A moderate water stress has reduced common bean yield by 41% (Foster et al., 1995).

Two field experiments were conducted during two successive seasons to evaluate the effect of irrigation intervals (7, 14, 21 days) and plant spacing (10, 20 and 30 cm) on soybean plants grown in clay loam soil. Irrigation intervals significantly affected the growth, and yield parameter i.e. plant height, plant dry weight, no. of seeds/yields. The interaction between irrigation intervals and plant spacing between hills significantly affected all the growth and yield parameters expect number of branches/plant and number of seeds/pod. The interaction between irrigation intervals and plant spacing significantly affected the concentrations of N, P, K, Mn and Fe in soybean seeds. The highest values were obtained under irrigation intervals 14 day and plant spacing of 30 cm, while the lowest ones were attained under irrigation intervals of 7 days and plant spacing of 10 cm between hills (Ibrahim and Hala, Kandil, 2007).

Maximizing soybean yield is dependent on maintaining adequate soil moisture beginning at full bloom (bloom) or beginning pod (R_3), provided that the soil water deficit (SWD) does not exceed 75% prior to that growth stage (Thelen et al., 2004). Drought stress during seed development reduces seed quality (Dornbos et al., 1989; Smicklas et al., 1992; Heatherly, 1993). Kadhem et al. (1985) found that seed yield of soybean increased significantly with irrigation applied at all growth stages, while Ramseur et al. (1985) stated that irrigation at flowering stage favoured reproductive development and increased seed yield and oil content.

2.2.6 Fertilizer application

Nitrogen is one of the most important nutrient elements affecting the yield of soybean (Penas and Wiese, 1987). Nitrogen applications increased plant N concentration and plant N at R_6 but did not increase plant dry matter, grain N concentration, grain yield, or grain quality components. Nitrogen, as urea, was not an effective fertilization practice when applied at the beginning pod stage. Fertilizer N applied to soil during early reproductive stages as a method to increase soybean grain yield and quality (Barker and Sawyer, 2005). The in-season application of

N fertilizer at the R_3 growth stage did not positively impact soybean grain yield or grain quality components (Sawyer and Barker, 2001).

Soybean cultivar A-3935 was tested at four plant densities (70x5, 70x10, 70x15, 70x20 cm) and four different nitrogen doses (1, 30, 60 and 90 kg per ha). Different nitrogen doses and plant densities significantly affected some important yield and yield characters in soybean. A rise in plant density and nitrogen rate increased plant height, lowest pod height, harvest index and seed yield, whereas number of branches per plant, pod number per plant, seed yield per plant and 100 seed weight decreased as plant density. Soybean should be sown on row spacing of 70x10 cm (140286 plant per ha) with nitrogen application rate 60 kg per ha to obtain maximum return unit (Mehmet, 2008).

Soybean uses biological N_2 fixation to produce approximately half of its total N requirement (Harper, 1987). The remaining N is derived from soil inorganic N, mineralized organic matter, or residual N from the previous crop. Soil nitrate is the main N source utilized up to the beginning pod growth stage R_3 (Pedersen, 2004), with crop use depleting soil inorganic N. Nitrate utilization and reductase activity drops rapidly at this time (Shibles, 1998). Soil nitrate availability is therefore related to the length of the inorganic N utilization period. Significant N use does not occur from N_2 fixation until approximately beginning bloom (R_1), increases in the late full-bloom stage (R_2) and (R_3) stages, and continues slightly beyond the beginning seed stage (R_5) (Harper and Hageman, 1972). It has been shown that high soil nitrate levels delay *Bradyhizobia spp*. Infection and nodulation, thus reducing N_2 fixation capacity (Shibles, 1998).

A study conducted in Kansas with irrigated soybean found significant soybean yield response when N was applied between the R_3 and full pod stage R_4 (Wesley et al., 1998). Nitrogen topdressing after the flowering stage is effective in improving the yield of green soybean (Nishiok and Okumura, 2008). Best timing for N top-dressing during reproduction is at the flowering stage, which increased seed yield by 19 and 21%, compared to the treatment without N topdressing (Gan et al., 2003).

Nitrogen increases yield by influencing a variety of agronomic and quality parameters. In general, there was an increase in plant height and dry matter accumulation per plant in soybean (Manral and Saxena, 2003). Varon et al. (1984) reported an increase in plant height with the application of nitrogen fertilizer.

2.2.7 Harvest maturity

Harvesting too early may result in low yield and poor seed quality, whereas harvesting too late may result in shattering and reduced seed yield (Oplinger et al., 1989). Harvest time of soybean seed is very important due to its susceptibility to field conditions conductive to deterioration during seed development and maturation. Seeds of five cultivars were grown in research plots. At maturity stages R_7, R_8 1 and 2 weeks after R_8, the seeds from each cultivar were harvested and evaluated for viability (standard germination test), vigor (accelerated aging germination test) and seed moisture. Seed viability and seed vigor were highest at R_7 for all cultivars. Harvest stage significantly affected seed quality as reflected by viability and vigor

Dry matter yields were greatest during the late reproductive stage (Willard, 1925). High temperature, humidity and precipitation play a critical role on pre and post harvest weathering (Keigly and Mullen, 1986; Tekrony et al., 1980). Genotypic differences in resistance to pre and postharvest weathering have been reported (Marwanto, 2003).

Soybean seed quality can be reduced by a wide range of environmental factors during seed production both before and after seed reaches at harvestable moisture content (Rasyad et al., 1990, Pieta and Ellis, 1991a, 1991b, Demir and Ellis, 1992a, 1992b, Demir and Ellis, 1993, Tekrony et al., 1980). Seed deterioration during pre harvest stage is a serious problem where rainfall combined with high temperature, results in rapid loss of viability and vigor of seed in standing crop (Delouche, 1980). Repeated drying and wetting of soybean seed prior to harvest reduces seed quality and results in poor germination. Under extremely moist condition before harvest, seeds may germinate within pods (Banmurthy and Gupta, 1981).

Assaeed et al. (2000) investigated the effect of time of harvesting (50, 70 and 90 days from sowing) on forage production and quality of six forage soybean cultivars. Dry matter concentration and production has increased as time from sowing to harvesting increased. Sodium and phosphorus contents varied significantly between harvesting time but without fixed trends. Potassium and magnesium contents decreased as time progressed. Cultivars differed in their response to harvesting time as indicated by the significant interaction between harvesting time and cultivar treatments.

2.3 Some advanced technology to improve vegetable soybean seed germination

2.3.1 Seed priming (hydropriming and osmopriming)

Seed priming is a technique in which seeds are partially hydrated until the germination process begins, but radicle emergence does not occur (Bradford, 1986). Priming allows the metabolic processes necessary for germination to occur without actual germination. Primed seeds usually exhibit an increased germination rate, greater germination uniformity, and, at times, greater total germination percentage (Basra et al., 2005). Increased germination rate and uniformity have been attributed to metabolic repair during imbibitions (Bray et al., 1989), buildup of germination-enhancing metabolites (Basra et al., 2005), osmotic adjustment (Bradford, 1986) and for seeds that are not redried after treatment, a simple reduction in imbibitions lag time (Bradford, 1986). Many seed priming treatments have been used to accelerate the germination and seedling growth in most of the crops under normal and stress conditions (Basra et al., 2003).

Pre-sowing hydration treatments (priming) include non-controlled water uptake systems (methods in which water is freely available and not restricted by the environment) and controlled systems (methods that regulate seed moisture content preventing the completion of germination). Three techniques are used for controlled water uptake: priming with solutions or with solid particulate systems or by controlled hydration with water (Taylor et al., 1998). Some morphological changes also occur in the primed seeds, which are helpful in the later growth of embryo, e.g., a portion of the seed endosperm is hydrolyzed during priming that permits faster embryo growth (Burgass and Powell, 1984). Rao and Singh (1997) soaked soybean seeds with germination capacity of 90, 70, and 50% in water or different solutions or conditioned in moist sand before drying back to their

Harris et al. (2001a) reported that the direct benefits of seed priming in all crops included faster emergence, better, more and uniform stands, less need to re-sow, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield. Harris et al. (2001b) used participating rural appraisal techniques to identify crop establishment as a major constraint on rainfed crop production by farmers in India and Zimbabwe. Some farmers in both countries reported experience of soaking seeds in water before sowing in an attempt to improve establishment but the practice was neither widespread nor regularly followed. Armed with knowledge of safe limits for soaking, almost 1,250 on-farm trials were implemented by farmers in India for maize, upland rice and chickpea between 1995 and 1998 and 91 trials for maize and sorghum in Zinbabwe in 1997-1998. In each trial, farmers were soaked to soak seed overnight, surface-dry it and then sow it in the normal way in a plot next to a plot with dry seed. The farmers in each village evaluated the trials during farm walks and group discussions. These group methods allowed farmers to access the effect of seed priming over a wide range of soils and levels of managements. Direct benefits in all crops included: faster emergence, better, more uniform stands, less need to re-sow, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher germination yield.

In India, where a post-rainy season crop is often grown on residual soil moisture or using supplementary irrigation, indirect benefits reported were earlier sowing of following crops, earlier harvesting of those crops, which allowed earlier seasonal irrigation from the area in search of work from cash, increased willingness to use of time saved to grow a third crop (mungbean) instead of migrating. Subsequent uptake of on-farm seed priming by participating in the trials has been almost universal and spread from farmer to farmer exhibits characteristics similar to those of the spread of seed of desirable new varieties. On-farm seed priming is a key technology (that is low cost and with low risk) to produce an immediate benefit, unlocking the farming system and giving the farmer reasonable access to further benefits.

The duration and extent of imbibitions for seed germination depends on the cultivar, species and relative availability of moisture (Copeland and McDonald, 1995). Polyethylene glycol (PEG) 8000 improves emergence and enhances grain yield of soybean. The soybean seeds primed for 6, 12 and 18 hrs using PEG 8000 solutions with concentrations of 0, 100, 200, 300, 400, 500 and 600 g/L water at 25 °C (Muhammad et al., 2008). The primed seeds were washed with running tap water (Lee and Kim, 1999).

Seeds were soaked in distilled water. After soaking seeds were redried to the original weight with forced air under shade (Bennett and Waters, 1987). Redrying after priming is a critical step for maintaining seed quality. Rapid drying following priming can damage seeds resulting in the loss of advancement obtained during priming (Parera and Cantliffe, 1992). Mechanical embryo damages have been reported in soybean, pine, and larch as a result of drying after osmotic priming (Armstrong and McDonald, 1992; Huang and Zou, 1989).

CHAPTER 3

MATERIALS AND METHODS

3.1 Seed materials

Two vegetable soybean varieties, AGS 292 and No.75 were selected for this study. Two vegetable soybean varieties were obtained from seed production of Chiang Mai Field Crops Research Center, Sansai, Chiang Mai. AGS 292 vegetable soybean variety is a large seeded size (50 g/ 100 seeds in this study) and has yellow color seed coat. No.75 vegetable soybean variety is a medium-seeded size (36 g/ 100 seeds) with green color seed coat.

3.2 Methods

3.2.1 Field experiments (physiological maturity of vegetable soybean)

PM of vegetable soybean was conducted for two environments in dry season (from January to March, 2010) and in rainy season (from June to August, 2010).

Seeds of two varieties (AGS 292 and No.75) were planted on January and June, 2010, in a randomized complete block design (RCBD) with two replications. Each variety was sown in 40 different plots consisting of single raised bed. The size of each plot was 1 m wide and 8 m long with 50 cm spacing between rows and 20 cm spacing between plants. Two rows were planted on each plot. Five seeds were sown in each hill, thinning was done and only one seedling was left. Normally vegetable soybeans start to bloom at 26th day after emergence. At the maximum peak flowering time, the flowers were tagged for 20 plots at the same time and another 20 plots in the next time. And then plots were harvested plot by plot 5 days interval until 10 times.

PM was determined when seeds reached maximum dry weight. The color of pods and seeds were monitored at PM to provide some morphological indicators for determining time to harvest. Flower, pod and seed color, dry matter and moisture eontent were measured every 5 days interval.

Figure 1 Field of vegetable soybean, grown in dry season (January to March, 2010).

Figure 2 Tagging of flowers after flowering.

The quality of seeds was tested on seed moisture content, seed dry matter, percentage of germination of normal seedling, seedling growth rate and pod size.

3.2.1.1 Moisture content test

Seed moisture content was determined by the hot air-oven method according to the international seed testing association (ISTA) rules (1985). Five gram of fresh vegetable soybean seeds were ground and then dried in hot-air oven at 103°C for 17 hr. Dry weight was recorded. Seed moisture content was calculated using the following formula:

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight of seed- Dry weight of seed}}{\text{Fresh weight of seed}} \times 100$$

3.2.1.2 Dry matter test

Seed dry matter was determined by the hot air-oven method. Twenty five pods of fresh vegetable soybean were dried in hot-air oven at 103°C for 17 hr and then dry weight was recorded.

3.2.1.3 Germination test

Three replicates of fifty vegetable soybean seeds were allowed on a rolled sheet of paper towel moistened with distilled water and then were put in germinator at 25°C and relative humidity 95%. Evaluation was done as described by ISTA (1999). First eount germination was done at 5 days after seeding (DAS) and final count was done at 7 DAS. In seed laboratory practices, germination is defined as the emergence and development of those essential structures that are indicative of normal seedlings under favourable conditions. Similar process was also done to test germination percentage for seed priming of vegetable soybean. Germination percentage was calculated by:

$$\text{Germination \%} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds}} \times 100$$

3.2.1.4 Seed vigor test

Seedling growth rate (SGR)

For seedling growth rate data collection was recorded together with germination test. The number of normal seedlings was counted after the germination test finished and then dried in hot-air oven at 80 °C for 24 hr. The dry weight of the seedlings was recorded and expressed in milligram per seedling. Similar process was also tested seedling growth rate for seed priming of vegetable soybean. Seedling growth rate was calculated by:

$$\text{Seedling growth rate (mg/seedlings)} = \frac{\text{Normal seedlings (dry weight)}}{\text{No. of normal seedlings}}$$

3.2.1.5 Pod size

Two replicates of ten vegetable soybean pods were measured in length, width and thickness and then data was recorded in centimeter (cm).

3.2.1.6 Experimental design and statistical analysis

All data were subjected to analysis of variance (ANOVA) appropriate to a RCBD. The experimental model was used to analyze seed dry matter, moisture content, pod size and the seed quality (germination and seed vigor). Treatment means were tested by Duncan's Multiple Range Test (DMRT).

3.3 Laboratory experiment (seed priming of vegetable soybean)

The experiment was a factorial arrangement with two factors (PEG 6000 concentration and soaking time) on the basis of a completely randomized design (CRD) with three replications. Before priming, seeds were weighed for each replication. Each replication had 50 seeds. Seeds were primed in 250 ml of beaker for 3 hr, 6 hr, 9 hr and 12 hr using 0, 2.4, 4.7, 6.5 g PEG / 100 ml. distilled water. After priming, the seeds were washed with distilled water for about two minutes and dried on a filter paper to original weight at room temperature. Germination test was conducted.

50 seeds / replication

↓

PEG concentration: 0, 2.4, 4.7, 6.5 g / 100 ml. distilled water

↓

Soaking Time

3, 6, 9, 12 hr

↓

Washing

↓

Drying

↓

Germination test (between papers)

Figure 3 Flow chart of chemical priming method (PEG 6000).

Seed quality analysis was conducted in the following categories:

3.3.1 Electrical conductivity (EC)

Conductivity measurements were carried out on 50 seeds per replicate for three replications as described by Matthews and Powell (1987). Seeds were soaked in a 250 ml. beaker with 100 ml. distilled water. The flasks were stirred to remove air bubbles and floating seed and were kept at normal room temperature. Conductivity of seed leachates was measured after soaking seeds for different soaking time durations using a direct reading conductivity meter to determine the electrolyte leakage of the seeds. The dip cell was rinsed in distilled water and then dried on filter paper before and after each replicate was tested. The results were expressed µS/ seeds rather than per gram of seeds as in the original methods.

3.3.2 Data analysis

The collected data was analyzed statistically by test using a CRD with a two-factorial arrangement of treatments. Treatment factors were PEG concentration and soaking time. Treatment means were compared using the Least Significance Difference (LSD) and Duncan's Multiple Range Test (DMRT).

3.4 Experimental site

Field experiments were conducted in the field of Maejo University, Sansai, Chiang Mai, Thailand. Laboratory experiment and seed quality determination were done at Orchid and Ornamental Horticulture Center and Department of Postharvest Technology, Faculty of Engineering and Agro-Industry, Maejo University, Sansai, Chiang Mai, Thailand.

3.5 Seed treatment

Vegetable soybean seeds were treated with PEG 6000 concentration in normal room temperature.

3.6 Meteorological data

Meteorological data were obtained from seed production of Chiang Mai Field Crops Research Center, Sansai, Chiang Mai, and presented in Appendix Figure 5 and 6.

CHAPTER 4

RESULTS

4.1 Field experiment (physiological maturity of vegetable soybean)

4.1.1 Seed moisture content (SMC)

Analysis of variance showed that harvesting time of two seasons (dry season and rainy season) significantly affected on seed moisture eontents of vegetable soybean varieties AGS 292 and No.75. Two seasons affected seed moisture contents of AGS 292 and No.75 seeds after planting. SMC changed significantly with days after planting (Table 1, 2, 3 and 4). Seed moisture contents of both varieties increased after planting in dry season and decreased slowly to 74 days and 76 days after planting and then decreased rapidly during to 84 days and 86 days after planting in dry season (Appendix Figure 1 and 2).

Seed moisture contents of both varieties in rainy season were higher than in dry season after planting and then lower slowly during to 78 days and 79 days after planting in rainy season (Appendix Figure 3 and 4).

Among varieties, initial seed moisture contents were not different. After PM stage, seed moisture contents of both varieties in dry season were lower than those of others in rainy season. However, at PM stage under dry season, seed moisture content of AGS 292 was higher at 69 days after planting than those of No.75 at 71 days after planting (Table 1 and 2). Under rainy season, seed moisture content of AGS 292 was also higher at 68 days after planting than those of No.75 with 69 days after planting at PM stage (Table 3 and 4).

4.1.2 Seed dry matter (SDM)

It was observed that harvesting time of two seasons (dry season and rainy season) significantly influenced on seed dry matter of vegetable soybean varieties AGS 292 and No.75. Seed dry matter gradually increased until PM period and it was not significantly different among varieties.

After PM period, seed dry matter deereased rapidly in dry season (Table 1, 2 and Appendix Figure 1, 2). However, seed dry matter deereased slightly after PM period in rainy season (Table 3, 4 and Appendix Figure 3, 4).

At PM period, the highest seed dry matter observed in the vegetable soybean varieties AGS 292 and No.75 at 69 and 71 days after planting under dry season condition (Appendix Figure 1 and 2) and at 68 and 69 days after planting under rainy season condition (Appendix Figure 3 and 4). Seed dry matter declined progressively after PM period. Lowest seed dry matter was obtained in both varieties near to harvest. On an average the seed dry matter of the vegetable soybean varieties AGS 292 and No.75 recorded at the beginning and end of growing period was 0.7 g, 0.7 g and 2.6 g, 3.2 g, respectively in dry season (Table 1 and 2).

The seed dry matter due to growing season varied significantly. At initial month of growing period significantly the highest seed dry matter of the vegetable soybean varieties AGS 292 and No.75 was recorded at the beginning and end of growing period was 0.5 g, 0.5 g and 49.2 g, 50.1 g, respectively in rainy season (Table 3 and 4).

4.1.3 Germination percentage (Ger %)

The results on germination percentage of vegetable soybean AGS 292 and No.75 at different harvesting time as influenced by dry season and rainy season effects during growing period are presented in Appendix Table 1, 2, 3 and 4.

Germination percentage increased progressively after PM period (Appendix Figure 1, 2, 3 and 4). At the end of growing season, significantly higher germination of vegetable soybean AGS 292 and No.75 was recorded in higher quality seed (94.0 % and 90.0%) and lower germination was recorded in lower quality seed (26.7% and 30.2%) in dry season (Table 1 and 2). The germination percentage of vegetable soybean AGS 292 and No.75 recorded at the beginning and end of growing period was 19.4, 16.4 and 49.6, 40.8 per cent, respectively in rainy season (Table 3 and 4). The germination percentage differed significantly due to seed quality at all the months of growing period. It was noticed that the germination percentage during growing time varied significantly at all the months of period.

Effect of seasons on germination was found in vegetable soybean varieties AGS 292 and No.75 after first flower tagging among seasons. Germination percentage of both varieties was lower before PM period among seasons. After PM period, their germination percentages were higher at dry season than at rainy season. Germination differences among varieties were not found under dry season and under rainy season.

4.1.4 Seedling growth rate (SGR)

Analysis of variance showed that harvesting time of two seasons (dry season and rainy season) influenced on seedling growth rate of vegetable soybean varieties AGS 292 and No.75. Seedling growth rate increased progressively after PM period (Table 1, 2, 3 and 4). On an average the seedling growth rate of vegetable soybean varieties AGS 292 and No.75 recorded at the beginning and end of growing period was 130.8, 167.1 and 207.6, 230.6 mg, respectively in dry season (Table 1 and 2).

The seedling growth rate due to growing season varied significantly. The highest seedling growth rate of vegetable soybean varieties AGS 292 and No.75 was recorded in 131.9 mg at 73 days and 143.9 mg at 69 days after planting under rainy season (Table 3 and 4).

It was found that seedling growth rate of vegetable soybean varieties AGS 292 and No.75 was higher at dry season condition than at rainy season condition.

4.1.5 Pod size

Pod length, width and thickness of vegetable soybean varieties AGS 292 and No.75 were analyzed at 5 days interval after flowering along growing period under dry season and rainy season conditions and the data is presented in Table 5, 6, 7 and 8.

The pod length in vegetable soybean varieties AGS 292 was increasing up to 64 days and 58, 63 days after planting among dry and rainy seasons in which there is a peak in the size of pod among all observations throughout the growing period and then, decreasing (Table 5 and 7). The width and thickness of pod increased considerably at 64 days and 59 days after planting in dry season (Table 5). In Table 7, pod thickness was higher from 48 days to 78 days but for pod width at 63 days after planting in the rainy season.

Significant variations among all harvesting time were found in pod length, width and thickness of vegetable soybean variety No.75. The pod length in vegetable soybean varieties No.75 increased at 51 days in dry season and 44 days after planting in rainy season (Table 6 and

8). The width and thickness of pod increased considerably from 66 to 81 days and 56 days after planting in dry season (Table 6). In Table 8, pod thickness was higher from 49 to 79 days but for pod width at 69 days after planting in the rainy season. At these observations, the highest pod length, width and thickness of vegetable soybean varieties No.75 was noted with 71 days after planting in dry season and 69 days after planting in rainy season (Table 6 and 8).

Table 1 Changes of seed dry matter (SDM), seed moisture content (SMC), germination percentage (Ger %) and seedling growth rate (SGR) in dry season of vegetable soybean (AGS 292).

Days after planting	Seed dry matter (SDM) gram	Seed moisture content (SMC) %	Germination percentage (Ger) %	Seedling growth rate (SGR) mg/seedling
39	0.7 d	0.0	0.0	0.0
44	7.0 d	66.0 a	0.0	0.0
49	30.7 c	66.0 a	0.0	0.0
54	35.7 c	63.0 a	0.0	0.0
59	44.8 b	58.5 b	0.0	0.0
64	53.6 a	57.5 b	0.0	0.0
69	54.0 a	57.0 b	26.7 c	130.8 b
74	46.2 ab	56.0 b	60.7 b	158.2 b
79	5.2 d	28.3 c	90.0 a	201.4 a
84	2.6 d	20.0 d	94.0 a	207.6 a
F- test	**	**	**	**
CV (%)	11.9	2.9	17.1	22.0

**= Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

Table 2 Changes of seed dry matter (SDM), seed moisture content (SMC), germination percentage (Ger %) and seedling growth rate (SGR) in dry season of vegetable soybean (No.75).

Days after planting	Seed dry matter (SDM) gram	Seed moisture content (SMC) %	Germination percentage (Ger) %	Seedling growth rate (SGR) mg/seedling
41	0.7 e	0.0	0.0	0.0
46	4.6 e	66.7 a	0.0	0.0
51	26.3 d	64.9 a	0.0	0.0
56	33.0 cd	64.2 a	0.0	0.0
61	42.2 bc	60.7 ab	0.0	0.0
66	51.4 ab	58.1 bc	0.0	0.0
71	61.4 a	56.2 bc	30.2 d	167.1 b
76	54.0 a	54.6 c	60.0 c	205.9 b
81	5.3 e	29.4 d	80.5 b	226.9 a
86	3.2 e	20.2 e	90.0 a	230.6 a
F- test	**	**	**	**
CV (%)	15.8	4.7	11.7	6.2

**= Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

Table 3 Changes of seed dry matter (SDM), seed moisture content (SMC), germination percentage (Ger %) and seedling growth rate (SGR) in rainy season of vegetable soybean (AGS 292).

Days after planting	Seed dry matter (SDM) gram	Seed moisture content (SMC) %	Germination percentage (Ger) %	Seedling growth rate (SGR) mg/seedling
33	0.5 g	0.0	0.0	0.0
38	4.2 g	64.2 b	0.0	0.0
43	20.0 f	68.0 a	0.0	0.0
48	30.5 e	66.8 a	0.0	0.0
53	42.9 d	64.5 b	0.0	0.0
58	46.8 cd	63.1 b	0.0	0.0
63	52.7 b	60.0 c	0.0	0.0
68	60.1 a	57.7 d	19.4 c	104.2 c
73	53.5 b	57.4 d	38.6 b	131.9 a
78	49.2 bc	56.5 d	49.6 a	122.5 b
F- test	**	**	**	**
CV (%)	5.6	1.7	9.7	9.2

**= Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

Table 4 Changes of seed dry matter (SDM), seed moisture content (SMC), germination percentage (Ger %) and seedling growth rate (SGR) in rainy season of vegetable soybean (No.75).

Days after planting	Seed dry matter (SDM) Gram	Seed moisture content (SMC) %	Germination percentage (Ger) %	Seedling growth rate (SGR) mg/seedling
34	0.5 g	0.0	0.0	0.0
39	2.5 g	62.4 cde	0.0	0.0
44	19.9 f	68.5 a	0.0	0.0
49	27.8 e	66.8 ab	0.0	0.0
54	37.8 d	64.9 bc	0.0	0.0
59	44.7 c	64.2 cd	0.0	0.0
64	50.4 bc	61.7 de	0.0	0.0
69	58. 8 a	60.0 ef	16.4 c	143.9 a
74	53.6 ab	58.4 fg	29.4 b	144.6 a
79	50.1 ab	57.1 g	40.8 a	143.8 b
F- test	**	**	**	**
CV (%)	7.6	1.9	56.3	14.7

**= Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

Table 5 Fresh pod size at different stages of seed development of vegetable soybean (AGS 292) in dry season.

Days after planting	Length of pod (cm)	Width of pod (cm)	Thickness of pod (cm)
39	1.2 d	0.3 e	0.2 c
44	3.3 c	0.7 d	0.6 ab
49	5.0 b	1.2 c	0.7 ab
54	5.1 b	1.3 ab	0.7 a
59	5.3 ab	1.3 ab	0.7 a
64	5.5 a	1.4 a	0.6 ab
69	5.3 ab	1.4 a	0.6 ab
74	5.2 ab	1.4 a	0.6 ab
79	5.2 ab	1.2 bc	0.5 b
84	5.1 b	1.2 bc	0.5 b
F- Test	**	**	**
CV (%)	3.0	4.7	12.4

**= Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

Table 6 Fresh pod size at different stages of seed development of vegetable soybean (No. 75) in dry season.

Days after planting	Length of pod (cm)	Width of pod (cm)	Thickness of pod (cm)
41	1.2 c	0.4 e	0.3 c
46	3.2 b	0.6d	0.5 b
51	5.1 a	1.2 c	0.7 ab
56	5.2 a	1.3 ab	0.8 a
61	5.3 a	1.3 ab	0.7 ab
66	5.3 a	1.4 a	0.6 b
71	5.5 a	1.4 a	0.6 b
76	5.3 a	1.4 a	0.8 b
81	5.2 a	1.3 ab	0.6 b
86	5.1 a	1.2 bc	0.5 b
F- Test	**	**	**
CV (%)	3.8	4.4	13.8

**= Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

Table 7 Fresh pod size at different stages of seed development of vegetable soybean (AGS 292) in rainy season.

Days after planting	Length of pod (cm)	Width of pod (cm)	Thickness of pod (cm)
33	0.9 d	0.2 f	0.1 d
38	2.3 c	0.4 e	0.2 c
43	4.4 b	1.0 d	0.3 b
48	5.0 ab	1.1 c	0.4 a
53	5.1 ab	1.2 bc	0.4 a
58	5.2 a	1.2 ab	0.4 a
63	5.2 a	1.3 a	0.4 a
68	5.1 ab	1.2 bc	0.5 a
73	5.1 ab	1.2 ab	0.4 a
78	5.1 b	1.2 ab	0.4 a
F- Test	**	**	**
CV (%)	6.7	3.8	6.5

**= Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

Table 8 Fresh pod size at different stages of seed development of vegetable soybean (No.75) in rainy season.

Days after planting	Length of pod (cm)	Width of pod (cm)	Thickness of pod (cm)
34	0.8 c	0.2 f	0.1 d
39	2.2 b	0.3 e	0.2 c
44	4.5 a	1.1 d	0.3 b
49	5.0 a	1.1 d	0.4 a
54	5.0 a	1.1 cd	0.4 a
59	5.0 a	1.2 bc	0.4 a
64	5.0 a	1.2 ab	0.4 a
69	5.2 a	1.3 a	0.4 a
74	5.1 a	1.2 ab	0.4 a
79	5.0 a	1.2 ab	0.4 a
F- Test	**	**	**
CV (%)	7.4	3.8	0.0

**= Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

Figure 4 Changing pod color of vegetable soybean variety AGS 292 in dry season.

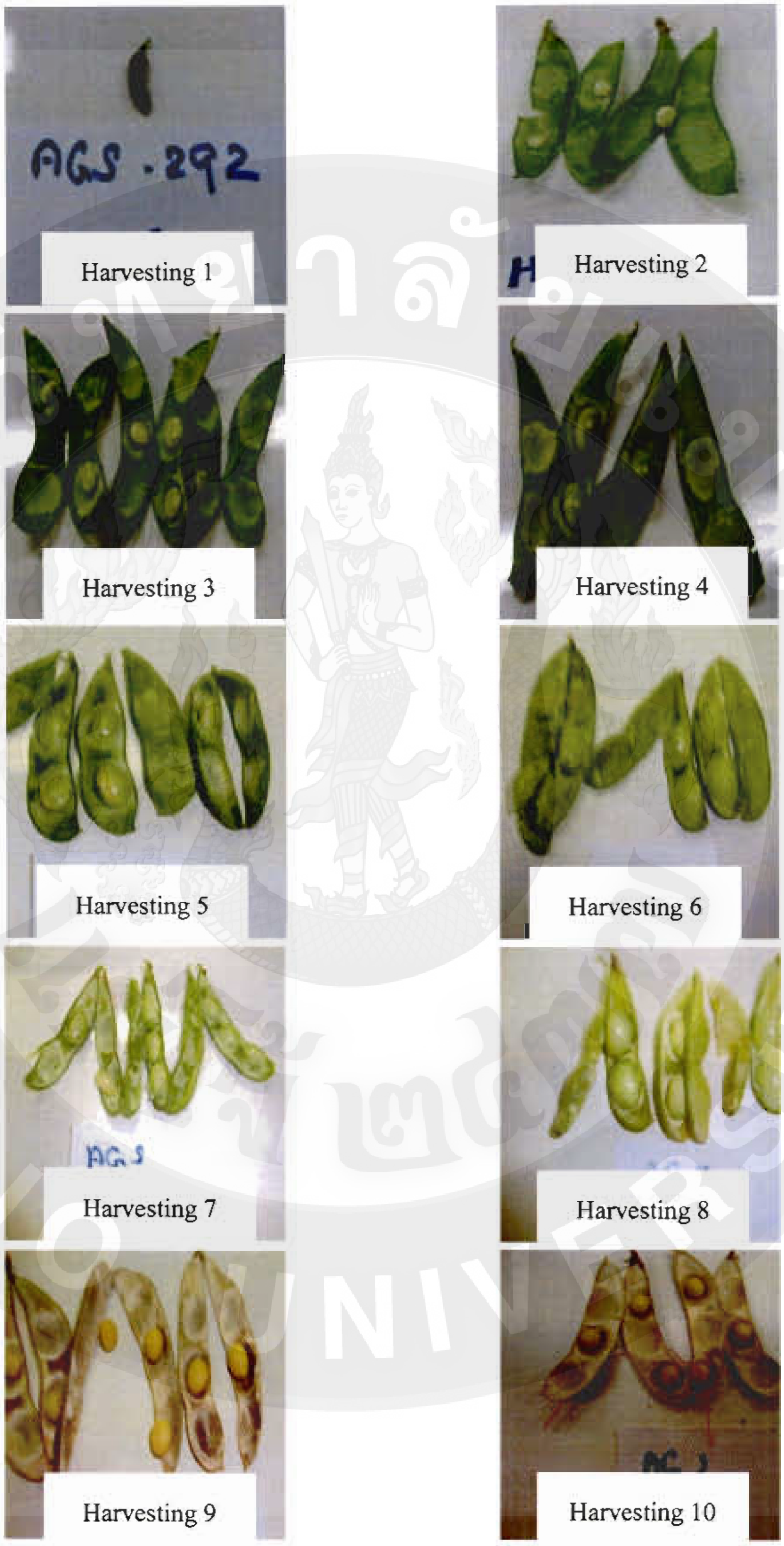

Figure 5 Changing seed color of vegetable soybean variety AGS 292 in dry season.

Figure 6 Changing pod color of vegetable soybean variety No. 75 in dry season.

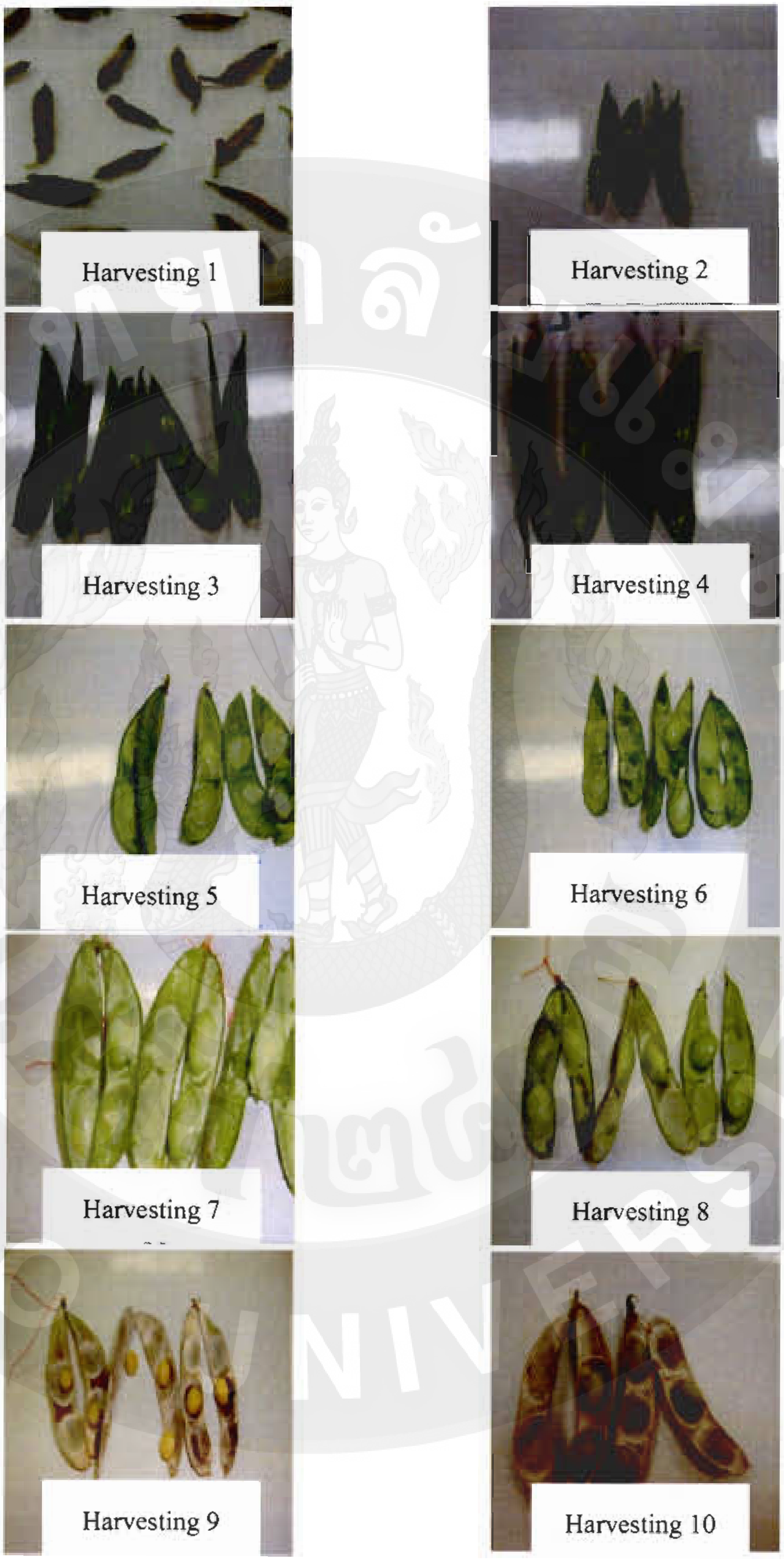

Figure 7 Changing seed color of vegetable soybean variety No.75 in dry season.

Figure 8 Changing pod color of vegetable soybean variety AGS 292 in rainy season.

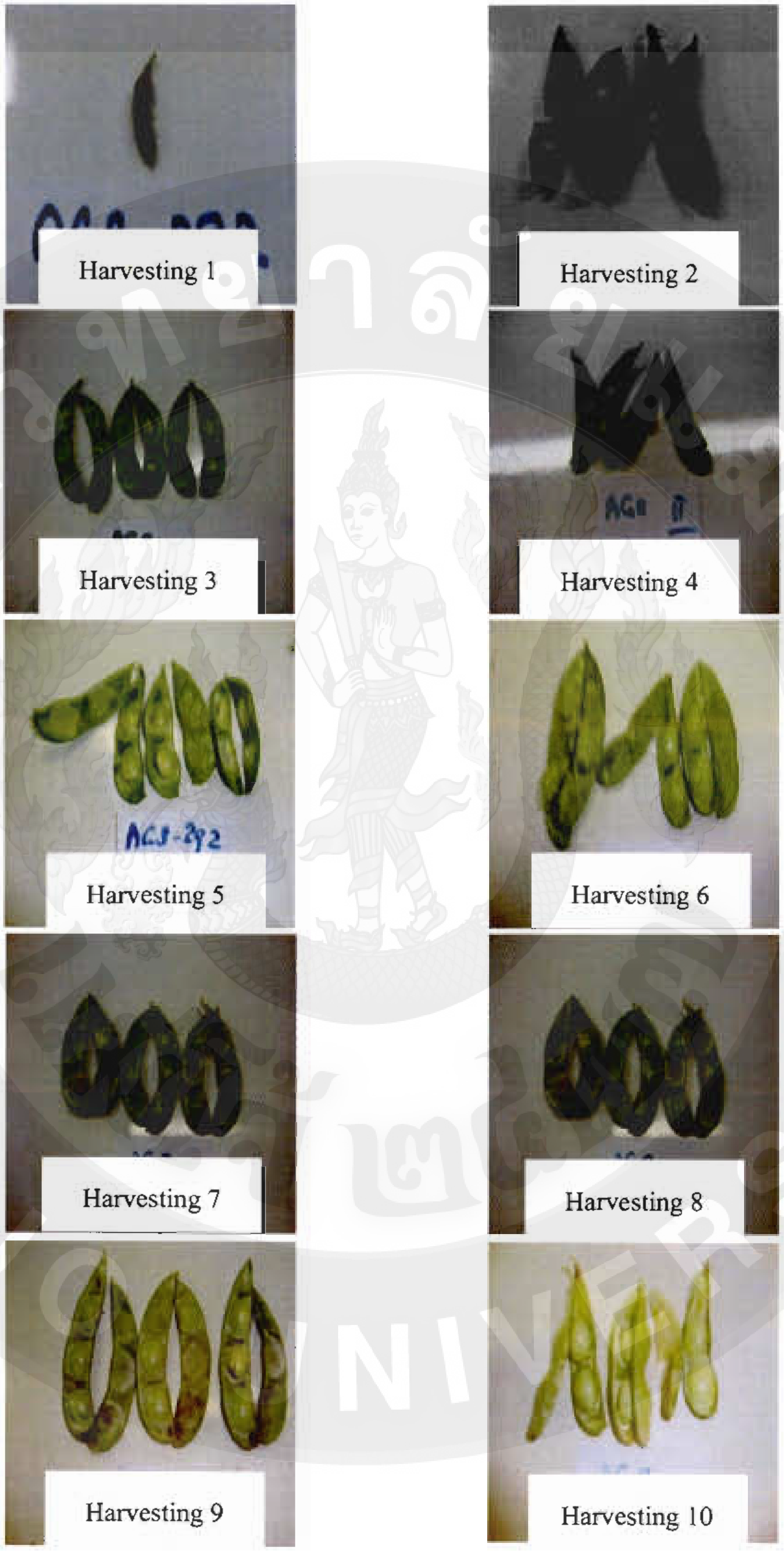

Figure 9 Changing seed color of vegetable soybean variety AGS 292 in rainy season.

Figure 10 Changing pod color of vegetable soybean variety No.75 in rainy season.

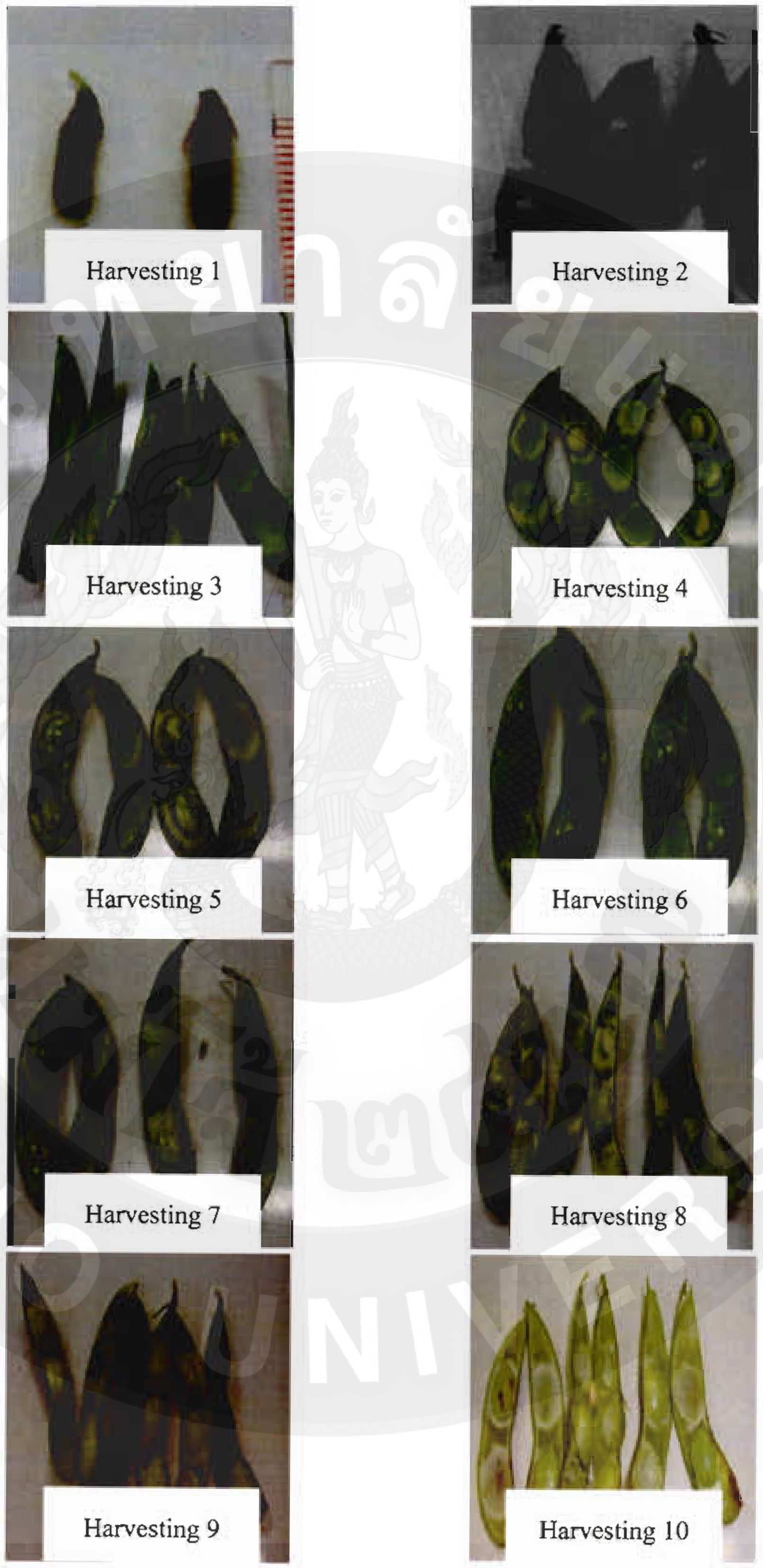

Figure 11 Changing seed color of vegetable soybean variety No.75 in rainy season.

4.2 Laboratory experiment (seed priming of vegetable soybean)

4.2.1 Germination percentage (Ger %)

Results from statistical analysis showed that PEG concentration influence germination of vegetable soybean AGS 292 seed (Appendix Table 5). However, analysis of the data revealed that vegetable soybean No.75 seed was not influenced by PEG concentration (Appendix Table 6).

It was noticed that the difference between seed treated with PEG and non PEG of vegetable soybean AGS 292 was significant. Seeds treated with PEG resulted in higher germination percentage as compared with non PEG. Maximum germination was recorded by seeds treated with PEG followed by 2.4, 4.7 and 6.5 g PEG/100 ml. distilled water. Minimum germination was recorded by non treated with PEG (Table 9). It was also found that the difference between seed treated with PEG and non PEG of vegetable soybean No.75 was no significant on germination percentage (Table 12).

Germination of seed treated with PEG and non PEG decreased with longer soaking time duration for both vegetable soybean varieties AGS 292 and No.75. It was not significantly affected among PEG treatments and soaking time (Table 9 and 12).

4.2.2 Seedling growth rate (SGR)

Analysis of variance showed that seedling growth rate was not affected by PEG concentration and soaking time duration on vegetable soybean variety AGS 292 and No.75 (Appendix Table 5 and 6).

The results on seedling growth rate as not influenced by seed priming and soaking time duration effects during priming period are presented in Table 10 and Table 13. Both varieties, there were no significant differences in seedling growth rate among PEG concentration and seed soaking time. The lowest seedling growth rate was found in PEG 0 g + 12 hr treatment and PEG 2.4 g + 12 hr treatment for vegetable soybean variety AGS 292 and No.75 (Table 10 and 13).

The seedling growth rate of both vegetable soybean seeds treated with PEG concentrations, 0, 2.4, 4.7 and 6.5 g/ 100 ml. distilled water for 3, 6, 9 and 12 hr did not differ significantly. Moreover, under PEG priming condition, seedling growth rates were not different between varieties.

4.2.3 Electrical conductivity (EC)

The data on electrical conductivity of vegetable soybean variety AGS 292 and No.75 as influenced by PEG priming and soaking time durations are presented in Appendix Table 5 and 6.

Statistical analysis also indicated that electrical conductivity values were different among PEG concentrations and soaking time durations. Electrical conductivity value of treating seeds with PEG was lower than those of non treated with PEG for both vegetable soybean varieties. After treating seeds with non PEG, the values of electrical conductivity became the highest under normal room temperature at the different PEG concentrations (Table 11 and Table 14). It was also found that the difference in EC between seed treated with PEG and non treated with PEG was highly significant.

The electrical conductivity of seed leachates was significantly influenced by the soaking time durations. Significantly lowest electrical conductivity values (10.4 ? S/cm/seed) and 9.4 ? S/cm/seed) were recorded with seeds primed in 3 hr for vegetable soybean variety AGS 292 and No.75 and whereas significantly highest electrical conductivity values (25.1 ? S/cm/seed) and (24.2 ? S/cm/seed) were recorded with seeds primed in 12 hr for vegetable soybean variety AGS 292 and No.75 (Table 11 and Table 14). It was observed that electrical conductivity values were also increased by treating seed with longer soaking time duration.

4.2.4 Combined analysis of vegetable soybean (AGS 292 and No.75)

4.2.4.1 Germination percentage (Ger %)

The germination percentage of seeds treated with PEG concentrations under soaking time durations among vegetable soybean variety AGS 292 and No.75 were also observed in Appendix table 7.

According to combined analysis, vegetable soybean variety No.75 seeds treated with different PEG concentrations and different soaking timc durations showed higher germination percentage than AGS 292 vegetable soybean variety. It was found that seed gcrmination was the highest in No.75 (62.4 %) and the lowest in AGS 292 (53.7 %) (Table 15).

Among PEG concentration, treatment of seeds improved percentage of germination and promoted root growth. There were significant differences in percentage of germination among seeds treated with PEG concentrations and the lowest germination percentage was found in seeds treated with non PEG (Figure 12 and 13). The germination percentage was significantly influenced by the PEG concentration. Significantly the highest germination was recorded in seeds treated with PEG 4.7g/100 ml. distilled water and while the lowest germination was recorded in the seeds primed for non treated PEG (Table 15).

Germination of seed treated with PEG and non PEG decreased with increasing soaking time duration. Seed soaking time durations for 12 hr drastic declined in germination percentage (Table 15, Figure 14 and 15).

4.2.4.2 Seedling growth rate (SGR)

The data on seedling dry weight of vegetable soybean variety AGS 292 and No.75 was not influenced by the PEG priming and soaking time durations and presented in Appendix Table 7.

The seedling dry weight was not significantly influenced by the PEG priming. The highest seedling dry weight (211.6 mg/seedling) was recorded with 6.5g PEG/100 ml. distilled water, followed by 0 g PEG (201.5 mg/seedling) and 4.7 g PEG (200.6 mg/seedling) while the lowest seedling dry weight (197.1 mg/seedling) was recorded with seeds treated for 2.4 g PEG (Table 15).

There were no significant effects in seedling dry weight among soaking time treatments. For decreasing soaking time, there were no significant differences in seedling dry weight among 3 hr and 6 hr. At 12 hr increasing soaking time, the lowest seedling dry weight was found (Table 15).

4.2.4.3 Electrical conductivity (EC)

The data analysis (Appendix Table 7) showed that PEG concentration treatments. soaking time durations and varieties influenced on electrical conductivity values of vegetable soybean seeds (AGS 292 and No.75).

Under PEG concentration and soaking time duration, electrical conductivity values of vegetable soybean varieties AGS 292 and No.75 seeds were not significant (Table 15).

The effect of PEG concentration on electrical conductivity values was observed significantly. It was also found that non treated with PEG showed the highest electrical conductivity value while seeds treated with PEG significantly decreased electrical conductivity value. The highest electrical conductivity value (21.8 µS/cm/seed) occurred in both vegetable soybean seeds with non treated PEG. The lowest electrical conductivity value (14.0 µS/cm/seed) was obtained in both vegetable soybean seeds treated with 6.5 g PEG (Table 15).

Under PEG concentration condition, vegetable soybean varieties AGS 292 and No.75 increased in their electrical conductivity values with longer soaking time. Maximum electrical conductivity value was observed in 12 hr soaking time and minimum electrical conductivity value was found in 3 hr soaking time (Table 15).

Moreover, the interaction of PEG concentration and soaking time duration had highly significant effected only electrical conductivity values (Table 16 and Figure 16).

Table 9 Effect of PEG concentration and soaking time on germination percentage of vegetable soybean variety AGS 292.

PEG –conc.(A) g/ 100 ml. H_2O	Germination (%) Soaking time (B) hr 3	6	9	12	Mean
0	49.8	47.3	53.2	39.8	47.5 b
2.4	52.2	52.7	59.0	50.1	53.5 a
4.7	59.7	52.3	57.9	56.6	56.6 a
6.5	57.7	56.1	58.1	57.0	57.2 a
Mean	54.8	52.1	57.0	50.9	

F-test PEG- conc. (A) **

Soaking time (B) ns

A x B ns

ns = Not significantly different *(P > 0.05)*.

** = Significantly different at *P < 0.01*.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based on the LSD procedure.

Table 10 Effect of PEG concentration and soaking time on seedling growth rate (SGR) of vegetable soybean variety AGS 292.

PEG –conc.(A) g/ 100 ml. H_2O	SGR (mg/seedling) Soaking time (B) hr				Mean
	3	6	9	12	
0	193.8	184.6	193.8	168.3	185.1
2.4	187.5	198.6	190.1	180.8	189.2
4.7	182.3	176.4	198.8	201.6	189.8
6.5	208.8	206.8	199.6	206.1	205.3
Mean	193.1	191.6	195.6	189.2	

F-test	PEG- conc. (A)	ns
	Soaking time (B)	ns
	A x B	ns

ns = Not significantly different *($P > 0.05$)*.

Table 11 Effect of PEG concentration and soaking time on electrical conductivity (EC) of vegetable soybean variety AGS 292.

PEG –conc.(A) g/ 100 ml. H_20	EC(? S/cm/seed) Soaking time (B) hr 3	6	9	12	Mean
0	12.6 hi	19.8 de	27.8 b	33.7 a [1]/	23.5 w [2]/
2.4	10.7 hi	15.8 efgh	19.9 de	26.2 bc	18.2 x
4.7	9.3 i	14.0 fghi	19.1 def	21.9 cd	16.1 y
6.5	9.0 i	13.3 ghi	15.9 efgh	18.7 defg	14.2 z
Mean	10.4 s	15.7 r	20.6 q	25.1 p	

F-test PEG- conc. (A) **

Soaking time (B) **

A x B *

* = Significantly different at $P < 0.05$.

** = Significantly different at $P < 0.01$.

[1]/ Means followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT procedure.

[2]/ Means within column and row followed by the same letter are not significantly different at the 0.05 probability level based on the LSD procedure.

Table 12 Effeet of PEG concentration and soaking time on germination percentage of vegetable soybean variety No.75.

PEG –conc.(A) g/ 100 ml. H_2O	Germination (%) Soaking time (B) hr				Mean
	3	6	9	12	
0	60.7	62.1	58.1	57.6	59.6
2.4	62.8	64.4	57.3	63.6	62.0
4.7	68.1	62.7	65.6	62.2	64.7
6.5	61.3	68.6	59.4	64.3	63.4
Mean	63.2	64.4	60.1	61.9	

F-test	PEG- conc. (A)	ns
	Soaking time (B)	ns
	A x B	ns

ns = Not significantly different *($P > 0.05$)*.

Table 13 Effect of PEG concentration and soaking time on seedling growth rate (SGR) of vegetable soybean variety N0.75.

PEG –conc.(A) g/ 100 ml. H_20	SGR (mg/seedling) Soaking time (B) hr 3	6	9	12	Mean
0	225.6	219.6	212.2	214.2	217.9
2.4	199.9	210.2	213.9	195.5	204.9
4.7	212.6	205.6	223.8	203.9	211.5
6.5	220.2	227.8	218.1	205.1	217.8
Mean	214.6	215.8	217.0	204.7	

F-test	PEG- conc. (A)	ns
	Soaking time (B)	ns
	A x B	ns

ns = Not significantly different *($P > 0.05$)*.

Table 14 Effect of PEG concentration and soaking time on electrical conductivity (EC) of vegetable soybean variety No.75.

PEG –conc.(A) g/ 100 ml. H_2O	EC(? S/cm/seed) Soaking time (B) hr 3	6	9	12	Mean
0	10.1gh	17.0 cdef	24.0 ab	29.1 a[1/]	20.1 w[2/]
2.4	9.7 gh	14.0 efgh	20.4 bcd	27.6 a	17.9 x
4.7	8.6 h	12.6 fgh	16.1 cdef	21.2 bc	14.6 y
6.5	9.1 h	11.4 fgh	15.2 defg	19.0 bcde	13.7 z
Mean	9.4 s	13.8 r	18.9 q	24.2 p	

F-test PEG- conc. (A) **

Soaking time (B) **

A x B *

* = Significantly different at $P < 0.05$.

** = Significantly different at $P < 0.01$.

1/ Means followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT procedure.

2/ Means within column and row followed by the same letter are not significantly different at the 0.05 probability level based on the LSD procedure.

Table 15 Effect of different PEG concentration and soaking time treated with two vegetable soybean varieties (AGS 292 and No.75) on germination % (Ger %), seedling growth rate (SGR) and electrical conductivity (EC).

Variety	Conc: (g/100 ml. H_2O)	Soaking time (hr)	Ger %	SGR (mg/seedling)	EC (µS/cm/seed)
AGS 292			53.7 b	192.4	18.0
N0.75			62.4 a	213.0	16.6
F- test			**	ns	ns
	0		53.6 b	201.5	21.8 a
	2.4		57.8 a	197.1	18.0 b
	4.7		60.6 a	200.6	15.4 c
	6.5		60.3 a	211.6	14.0 d
F- test			**	ns	**
		3	59.0	203.8	9.9 d
		6	58.3	203.7	14.7 c
		9	58.6	206.3	19.8 b
		12	56.4	196.9	24.7 a
F- test			ns	ns	**

ns = Not significantly different *($P > 0.05$)*.

** = Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based on the LSD procedure.

Table 16 Effect of PEG concentration and soaking time on germination % (Ger %), seedling growth rate (SGR) and electrical conductivity (EC) of vegetable soybean (AGS 292) and (No.75).

Concentration (g/100 ml. H_2O)	Soaking Time (hr)	Ger %	SGR (mg/seedling)	EC (µS/cm/seed)
0	3	55.3	209.7	11.4 ij
0	6	54.7	202.1	18.4 de
0	9	55.6	203.0	25.9 b
0	12	48.7	191.3	31.4 a
2.4	3	57.5	193.7	10.2 jk
2.4	6	58.6	204.4	14.9 gh
2.4	9	58.1	202.0	20.1 cd
2.4	12	56.9	188.1	26.9 b
4.7	3	63.9	197.4	9.0 k
4.7	6	57.5	191.0	13.3 hi
4.7	9	61.7	211.3	17.6 ef
4.7	12	59.4	202.8	21.6 c
6.5	3	59.5	214.5	9.0 k
6.5	6	62.3	217.3	12.3 i
6.5	9	58.7	208.8	15.6 fg
6.5	12	60.6	205.6	18.8 de
F- test		ns	ns	**

ns = Not significantly different *($P > 0.05$).*

** = Significantly different at $P < 0.01$.

Means within column followed by the same letter are not significantly different at the 0.05 probability level based by the DMRT.

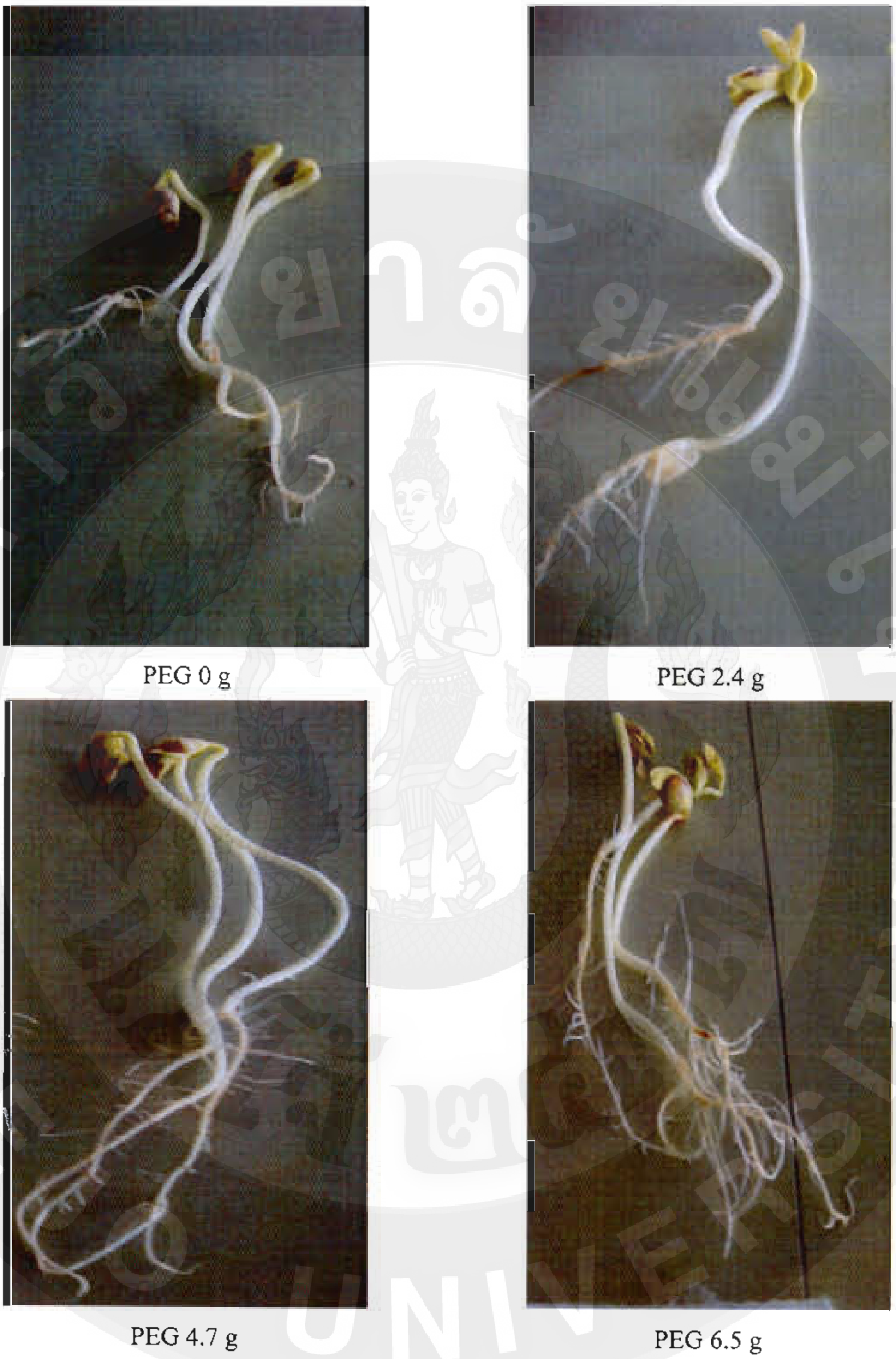

Figure 12 Seed germination and root development of vegetable soybean seeds from AGS 292, treated with different concentrations of PEG.

PEG 0 g

PEG 2.4 g

PEG 4.7 g

PEG 6.5 g

Figure 13 Seed germination and root development of vegetable soybean seeds from No.75, treated with different concentrations of PEG.

3 hr

6 hr

9 hr

12 hr

Figure 14 Seed germination and root development of vegetable soybean seeds from AGS 292, treated with different soaking time.

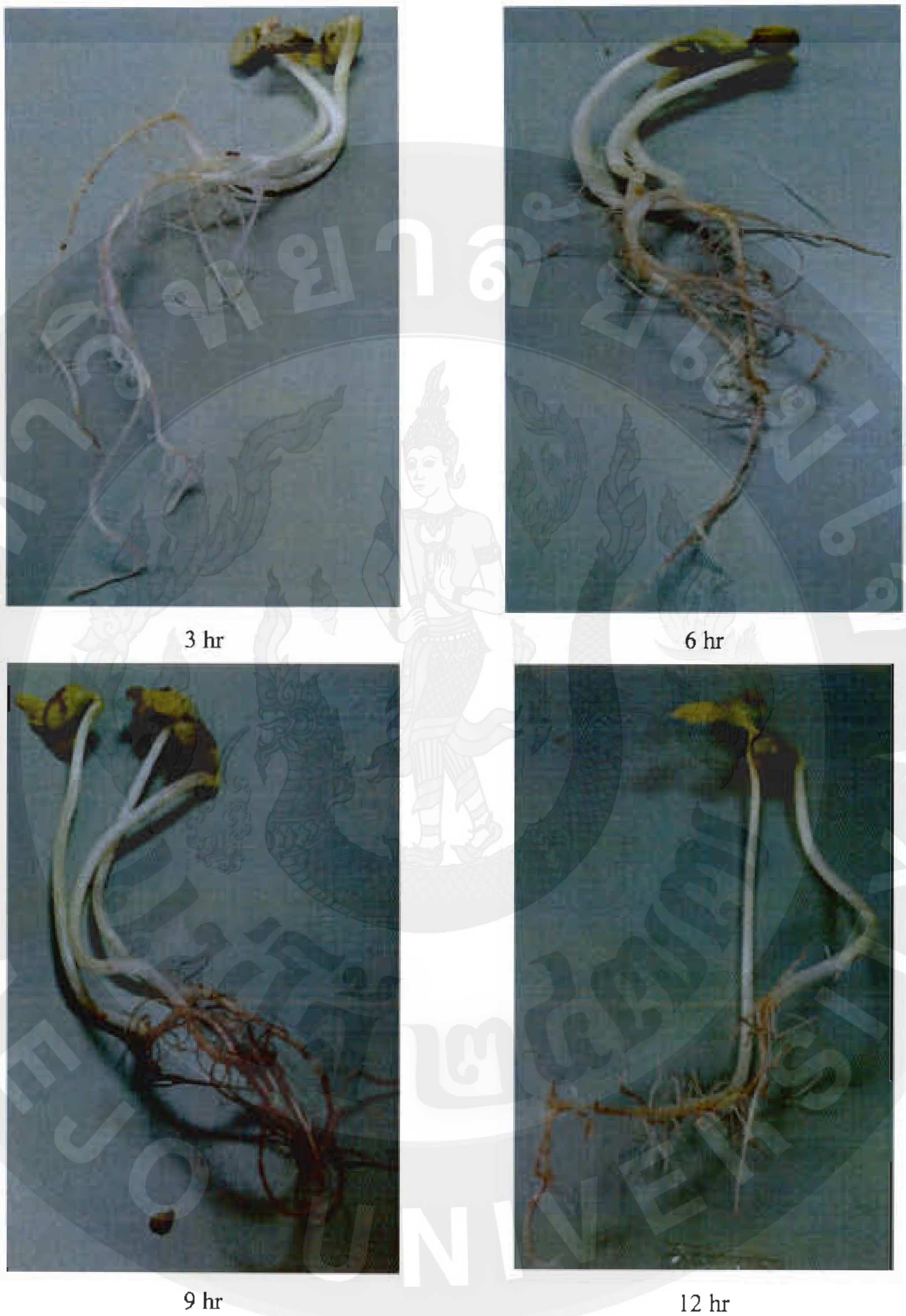

Figure 15 Seed germination and root development of vegetable soybean seeds from No.75, treated with different soaking time.

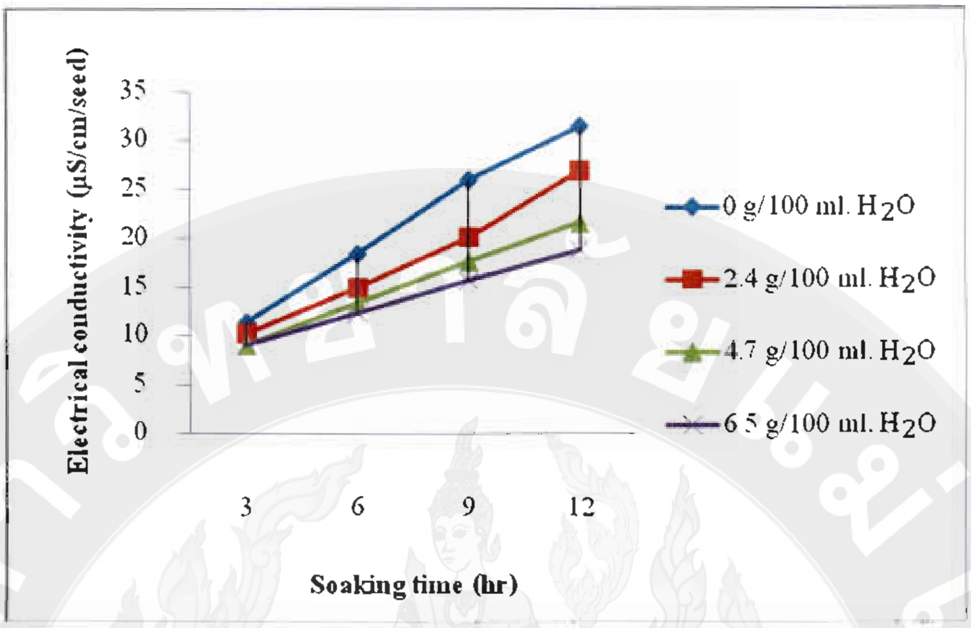

Figure 16 Effect of PEG concentrations and soaking time duration on electrical conductivity test of vegetable soybean (AGS 292 and No.75).

CHAPTER 5

DISCUSSION

5.1 Physiological maturity of vegetable soybean

In this study, the change in seed moisture content of both cultivars was significantly affected by sampling date. At the early stages of pod growth, the moisture content of seeds was so high and decreased slowly to PM period after planting and then decreased rapidly near to harvest after planting. Therefore, it could be assumed that initial seed moisture contents of both varieties were affected to seed quality. The effects of dry season and rainy season on seed moisture content were observed (Appendix Figure 1, 2, 3 and 4). It is found that there may be slightly differences in growing season between dry and rainy season.

The differences between dry and rainy seasons and the disadvantage of seed moisture content over rainy season were observed in lowering seed quality. Rapid loss of seed quality in vegetable soybeans would probably be due to the effect of rainy season. The high seed moisture content during seed development in rainy season was reduced in total germination and seedling growth rate (seed vigor), and the low quality seeds were more susceptible to damage by high seed moisture content.

Seed germination and seedling growth rate (seed vigor) were higher under dry season than under rainy season. It was found in this study that growing seasons influenced germination and vigor of vegetable soybean var. AGS 292 and No.75. However, the results confirmed that dry season resulted in higher germination and seedling growth rate (seed vigor) than rainy season. As a result of incomplete of seed development, the initial germination and seedling growth rate (seed vigor) of both vegetable soybean varieties was significantly lower than the others, though seed moisture contents were high.

Variation in dry matter, moisture content, germination percentage and seedling growth rate (seed vigor) between seasons was different due to temperature and / or precipitation in the growing seasons. The weather conditions during seed development and maturation could cause significant change in the moisture content level at PM. Thus, moisture content represented a more accurate indicator of PM than seed dry matter in soybean (Fraser et al., 1982) and seed moisture content in onion (Steiner and Akintobi, 1986).

Seed moisture content is extremely vulnerable to rapid deterioration of vegetable soybean seeds. Therefore, it could be assumed that initial seed moisture contents of vegetable soybean cultivars were high enough to affect seed quality. Ketring (1971) also supported the effect of high relative humidity that peanut seeds at high relative humidity (80%) were reduced in total germination, vigor and ethylene production, and the low quality seeds were more susceptible to damage by high relative humidity. It was found in this study that the effect of seed moisture content was especially obvious at PM stage. The seed moisture content affected germination and seedling growth rate (seed vigor).

It was found that, seeds attain maximum quality (germination and vigor) at PM (Miles et al., 1983). This may be explained by the physiological changes (e.g., hormonal mechanism) that occur after PM, which can promote germination (Khan, 1971). As a result of immature seed, the initial germination of both vegetable soybean varieties before PM was significantly lower, though seedling growth rate (seed vigor) was also low. After PM, germination and seedling growth rate (seed vigor) of both vegetable soybean varieties seemed to be the highest as indicated by low seed moisture content. At harvesting time, germination percentage and seedling growth rate (seed vigor) were still high in all vegetable soybean varieties. However, germination percentage and seedling growth rate (seed vigor) seed vigor was the highest in dry season and the lowest in rainy season as shown by Table 1, 2, 3 and 4. After PM stage, differences in germination and seedling growth rate (seed vigor) became obvious among the two seasons.

It was noted that there were different seasons among seeds of two vegetable soybean varieties. Seed quality of both vegetable soybean varieties fluctuated depending on growing season. Seeds of both vegetable soybean varieties could maintain their initial seed quality under dry season condition. However, under rainy season condition, seed quality reduction found in all cultivars. It was found that both vegetable soybean varieties declined in germination and seed vigor after PM as measured by high moisture content in rainy season. The lower germination was related to the loss in seed vigor, because their seed vigor as indicated by SMC and SMC had already highered at this time. It was probably due to the number of abnormal seedlings that made a larger contribution to the failure of germination.

Weather conditions, especially precipitation, affected both the initiation of pod formation and the duration between pod formation and PM. Seed dry matter of AGS 292 and No.75 vegetable soybean varieties increased gradually following seed formation until PM. Gradual change in seed color was observed with progressive development and maturity among two seasons (Figure 5, 7, 9 and 11). At the very early stages of pod growth, the seeds were colorless and transparent. With further development, the seeds turned to light green and then darker green. At PM, the pods contained seeds with colors ranging from dark green or brownish green. As seed and pod color changed throughout the period of seed development and maturation, the seed dry matter also changed (Figure 4, 6, 8 and 10). Therefore, the change in seed color and in pod color could be dependable indicators in vegetable soybean. Visual indicators of PM had also been suggested for soybean (Crookston and Hill, 1978; Tekrony et al., 1979 and Gibkpi and Crookston, 1981).

Seed dry matter was influenced by days after planting (Table 1, 2, 3, 4 and Appendix Figure 1, 2, 3, 4). This indicates that there were increased in seed dry weights within the seed during seed development. Dry weight of AGS 292 and No.75 vegetable soybean varieties reached the maximum value of 54.0 g at 69 days and 61.4 g at 71 days after planting in dry season, whereas the maximum value of 60.1 g at 68 days and 58.8 g at 69 days after planting were observed in dry weight of AGS 292 and No.75 vegetable soybean varieties under rainy season. After PM period, dry weight decreased rapidly in dry season and thereafter slightly decreased in rainy season. Maximum dry weight of vegetable soybean seeds was reached the PM stage at 69 days and 71 days after planting in dry season and at 68 days and 69 days after planting in rainy season. The fresh weight developed ahead of the dry weight, reflecting the movement of water into the cell to drive cell expansion before dry weight gain occurs in the latter part of seed expansion (Egli, 1997).

The decrease in SMC at early developmental stages was a result of the increase in dry matter (Egli, 1997). Seed moisture content plays an important role on seed germination. The greatest gain in dry weight occurred at PM period after planting which meant that seed no longer had a functional connection to the vascular system of the mother plant and assimilate no longer moved into the seed. This indicates that vegetable soybean seed reached PM period after planting. A similar pattern had been reported in other species such as carrot (Nascimento *et al.*, 2003) and eryngo (Ekpong and Sukprakarn, 2006). However, there was a considerable decrease in dry weight in the harvesting time. This reduction possibly at the final stage of maturity was due to respiration by the seed might have exceeded the net import of sugar or other substrates resulting in loss of dry matter (Bewley and Black, 1994).

As seed reached PM period, seed dry matter accumulation was higher, thus, seedling growth rate after germination was higher. Maximum seedling growth rate was reached after PM. Seed vigor reaches its maximum at PM in most crops (Tekrony, 2003).

In this study, pod length, pod width and pod thickness of vegetable soybean varieties AGS 292 and No.75 was highly significant under dry season and rainy season conditions. It was observed that there were increased in length, width and thickness of pod during seed development. Pod length of vegetable soybean varieties AGS 292 and No.75 reached the maximum value of 5.5 cm at 64 days and 5.5 cm at 71 days after planting in dry season. Maximum pod width of vegetable soybean seeds AGS 292 and No.75 was reached at 64 days and 66 days after planting in dry season. Maximum thickness of vegetable soybean seeds AGS 292 and No.75 was reached at 54 days and 56 days after planting under dry season. In dry season, AGS 292 and No.75 vegetable soybean varieties reached PM stage at 69 days and 71 days after planting, which had the highest pod sizes (Table 5, 6).

Under rainy season condition, pod lengths of vegetable soybean varieties AGS 292 and No.75 were higher in 5.2 cm at 58 days and 5.2 cm at 69 days. Pod thickness of vegetable soybean varieties AGS 292 and No.75 reached the maximum value of 0.4 cm at 48 days and 0.4 cm at 49 days after planting. Maximum pod width of vegetable soybean seeds AGS 292 and No.75 was reached at 63 days and 69 days after planting, whereas in rainy season, AGS 292 and No.75 vegetable soybean varieties reached PM stage at 68 days and 69 days after planting, which had the maximum pod length, width and thickness (Table 7, 8).

It was noted that visual indicators of (PM) have been used as an indicator of seed maturity. In soybeans, plant population and planting date influence the average seed size and yield (Pedersen and Lauer, 2004) and the length and width of the pod are at a maximum before seed growth begins (Andrews, 1966). Seed shrinkage and loss of green color from the pod have been suggested as indicators of PM for okra (Demir, 1994). Some easily identifiable criteria to characterize seed maturity (the relation between visual indicators and PM) include formation of black layer in corn (Daynard and Duncan, 1969).

5.2 Seed priming of vegetable soybean

Germination percentage of vegetable soybean variety AGS 292 seeds treated with PEG was increased where as different soaking time durations were not affected germination percentage. In this study, seeds treated with distilled water (non PEG) were lower germination than treated with PEG. However, it is possibly to prevent the germination process to be completed, and thus, resulted in poor germination and vigor under seed treated with non PEG eondition. It also revealed that seed treated with PEG is related to seed quality.

It was also noticed in this study that, at seeds treated with non PEG, germination percentage was low, and germination after seed treated with PEG for 2.4, 4.7 and 6.5 g per 100 ml. distilled water were high for AGS 292 vegetable soybean seeds, respectively. The PEG concentration showed higher germination percentage than non treated PEG seeds. These results were confirmed with the findings of Madakadze et al., (1993) and Odell et al., (1992) who reported improvement in the germination of PEG treated seeds than non treated seeds.

Seed treated with PEG was also increased emerged than seeds treated with distilled water (non PEG). Primed seeds germinated more rapidly than non primed seeds, which is the main benefit to priming. The probable reason for early emergence of the primed seed may be due to the completion of pre- germinative metabolic activities making the seed ready for radical protrusion (Heydecker and Coolbear, 1977).

In fact, improved seed performance induced by seed priming may be due to altered physiological condition of the embryo. It may be also due to libration of enzymes, thus rapidly increasing in the production of soluble food nutrients, the whole system is already in motion so that when the seeds are germinated developmental processes go on more rapidly than in case of non-primed seeds. There are several indications that many physiological mechanisms are involved in seed priming, the repair of the age related cellular and sub-cellular damage that could accumulate during seed development and an advancement of metabolic events during the prolonged lag phase-II imbibition that repairs the radicle protrusion.

Some morphological changes also occur in the primed seeds which are helpful in the later growth of embryo, e.g. a portion of the seed endosperm is hydrolyzed during priming that permits faster embryo growth. There are reports that seed priming permits early DNA replication, increase RNA and protein synthesis, enhances embryo growth, repairs deteriorated seed parts and reduces leakage of metabolites. Basra et al. (2003) and Salinas (1996) reported improvement in germination percent, emergence and seedling stand by using seed priming techniques. In fact priming induces a range of biochemical changes in the seed that required initiating the germination process i.e., breaking of dormancy, hydrolysis or metabolism of inhibitors, imbibitions and enzymes activation (Ajouri et al., 2004).

There was no significant effect of priming treatments and soaking time durations on seedling growth rate (seed vigor test) of vegetable soybean AGS 292. In vegetable soybean variety No.75, there was also no significant effect of priming treatments and soaking time durations on germination percentage and seedling growth rate (seed vigor test). Similarly, differences between cultivars of the same species were seen in this study, suggesting the natural variation in response to priming. It is apparent that there may be the differences in germination percentage between seeds treated with PEG and non PEG. However, it contradicts with Murray (1990) who observed in germination due to PEG. This may be due to the fact that response to the PEG treatment is depended on cultivars. It was found that osmopriming with PEG solutions was not successful for onion seed (Caseiro et al., 2004) but proved effective with watermelon (Demir and Van de Venter, 1999).

In the PEG treated vegetable soybean seeds, significant differences in electrical conductivity values were observed among treatments (Appendix table 5, 6 and 7). However, in both vegetable soybean varieties AGS 292 and No.75, seeds treated with PEG showed the lowest electrical conductivity value than non treated PEG. Maximum electrical conductivity values were observed from non treated PEG seeds. Higher conductivity readings indicate greater electrolyte leakage from cell membranes and hence lower vigor seeds. Based on this measure, PEG priming would be higher seed vigor of vegetable soybean than non treated PEG. Primed seeds might have better plasma membrane structure by slow hydration than non treated seeds (Jett et al., 1996). Priming also causes to reduce the adherence of seed coat due to imbibitions. which may permit to emerge out radical without resistance as Nascimento and West (1998) reported that the priming minimizes seed coat adherence during emergence of muskmelon seeds. There was no significant effect of PEG on seedling growth rate of both vegetable soybean varieties.

It was found that there was effected of different soaking time on seed quality of two vegetable soybean varieties. Seed quality of AGS 292 and No.75 fluctuated depending on PEG concentration and soaking time. Treating seed with longer soaking time duration also increased electrical conductivity values. Afzal et al., 2002 found that the highest value of electrical conductivity was observed with increasing time duration. Seeds treated with longer soaking time interval were deleterious. At 3 hr, seed germination and seedling growth rate (seed vigor) of both vegetable soybean varieties seemed to be the highest as indicated by low EC. At 12 hr, germination percentage and seedling growth rate were still low in both vegetable soybean varieties. At 12 hr, differences in germination, seedling growth rate and electrical conductivity value became obvious among the PEG concentration. This finding corroborate well with the report by Murray (1989) who concluded that over priming may cause oxygen deficiency and the buildup of inhibitors.

Even though, under PEG concentration, germination percentage of both varieties became the lowest at 12 hr soaking time. As well as, Copeland and McDonald (2001) reported that the deterioration of seeds is observable in their lowered performance during germination. Delayed seedling emergence is among the first noticcable symptoms, followed by a slower rate of seedling growth and development and decreased germination. Therefore, the low germination percentage of both varieties at 12 hr of soaking time probably indicated that when seed deterioration occurrcd, the germination percentage could be decreased.

According to combined analysis, vegetable soybean variety No.75 seeds trcated with different PEG concentrations and different soaking time durations showed higher germination percentage than AGS 292 vegetable soybean variety. Among the two varieties, No.75 was found to have higher germination pcrccntage under PEG priming concentration. It was found that there was different germination percentage among seeds of two vegetable soybean varieties. Howcvcr, small peanut sccd was fastcr in gcrmination (Kittitanasuan, 1990; Duangpatra et al., 1990).

It was observed that, though smaller sceds could germinate faster than rclativcly larger seeds (Duangpatra et al., 1990; Rujirawat, 1995), the bigger the seed size, the more vigorous were the seedlings and thc highcr was the seedling dry weight. Phruksanusak (1987) reported that seedling dry weight did not show any correlation to field emergence. Thus, seedling dry weight should not be regarded as an indicator in seed vigor, at least in this study.

Under combined analysis, the different concentrations and different soaking time durations to both vegetable soybean varieties showed significant differences in germination (Appendix Table 7). In this study, germination was higher under seed treated with PEG condition than under seed treated with non PEG condition. High percentages of germination of seed treated with PEG would be due to the effect of priming process that had already germinated thc vegetable soybean varieties dormancy. The finding showed that osmoprimed watermelon seeds soaked in PEG 6000 solution (-0.9 MPa) at 25 °C had 17% higher germination percentage than did unprimed seeds (Demir and Van de Venter, 1999).

Similar results of significant difference in germination percentage, seedling growth rate and electrical conductivity values were observed in seeds treated vegetable soybean as affected by PEG and non PEG conditions. In this experiment, the concentration of PEG, 4.7 g/100 ml. distilled water, could have a significant effect on germination percentage of both vegetablc soybean varieties. After 12 hr of soaking time under PEG priming condition, germination percentage of seeds of the two vegetable soybean varieties were poor.

However, thcre was not significantly effected of priming treatments and soaking time durations on seedling growth rate (seed vigor test). Sadeghian and Yavari (2004) also reported that seedling growth severely diminished with genetic differences was found in sugar beet. As well as, non treated with PEG showed the highest electrical conductivity value while longer soaking time significantly increased electrical conductivity value. Higher conductivity values indicated higher electrolyte leakage from cell membranes and hence lower vigor seeds. Both vegetable soybean variety seeds had greater leakage. The differences in electrolyte leakage due to PEG priming were observed. Seed treated with PEG 6.5 g/ 100 ml. distilled water lowered electrical conductivity values for both varieties, suggesting PEG reduced membrane leakage below that of non treated PEG seeds. Seed treated with PEG decreased electrical conductivity values of both varieties, probably due to some PEG concentration, but the difference between PEG and non treated PEG seeds was observed. These results suggest non treated PEG damaged seed membranes and would reduce germination percentage after PEG priming.

Seeds of both vegetable soybean varieties under PEG concentration appeared to be in deterioration at 12 hr soaking timc as indicated by increased EC. The electrical conductivity indirectly evaluates the concentration of electrolytes released by seeds during imbibition (Dias et al., 1996). An increase in electrical conductivity indicated an increase in solute leakage from the seeds (Asiedu and Powell, 1998). The degree of deterioration is associated with the concentration of seed exudates that may be found in the steep solution. These exudates are a reflection of the amount of membrane degradation that has occurred (Copeland and McDonald, 2001). In this study, it was found that electrical eonductivity was significantly effected in both vegetable soybean varieties.

Under PEG priming eondition, electrical conductivity values increased with increasing soaking time duration in both vegetable soybean varieties. It was very observing that there seemed to have negative relationship between germination percentage and electrical conductivity as electrical conductivity increased, germination decreased.

The loss in seed quality is dependent on soaking time process; seed quality reduced with increasing soaking time. However, it was found that with increasing soaking time duration, germination indices of all the two vegetable soybean varieties decreased with increasing soaking time under PEG priming condition. Therefore, there would be relationship between times of germination and seed vigor.

It seemed that if the seeds are soaked for some longer soaking time, seeds become more and more deteriorated; respiration becomes progressively weaker and weaker, and ultimately leads to the loss of germination and vigor (Copeland and MeDonald, 2001). Thus, the increasing germination indices seemed to increase with increasing respiration up to a point, and then, it would decrease again with decreasing respiration rate. Seed germination and seedling growth rate require the use of metabolic energy acquired from respiration. A decrease in the rate of respiration of germinating seeds has been shown to precede a decline in the rate of seedling growth (Copeland and McDonald, 2001).

This study was also emphasized by the effect of PEG concentration applied on germination percentage, seedling growth rate and electrical conductivity of both vegetable soybean varieties under four PEG concentrations and soaking time conditions. Of different PEG concentrations and different soaking time durations of treatments, the electrical conductivity value was greatly observed by 6.5 g PEG + 3 hr-treatment (Table 7). Apparently, the highest PEG concentration and the shortest soaking time duration in this study showed signifieant effect on reduction in EC of both vcgetable soybean varieties. Similarly, in seeds treatcd with PEG, significant differences in germination were recorded among all treatments. The significantly lowest germination percentage was also observed in PEG 0g/100 ml. distilled water while the highest germination percentage was recorded in seeds treated with PEG. And according to Mohammadi (2009) different seed treatments led to improved seed germination percentage of soybean.

The present study revealed that PEG had no toxic effect on seeds of both vegetable soybean varieties. Mehra et al. (2003) and Michel (1983) indicated that PEG molecules do not enter to seed and Khajeh-Hosseini et al. (2003) found that thcre was no toxicity of PEG. Seed priming exhibited positive effects on germination characteristic of vegetable soybean cultivars such as root length was increased due to seed priming.

CHAPTER 6

CONCLUSION

The influence of season conditions on quality of seed, varieties differences in dry season and rainy season, and vegetable soybean seed quality changes during seasons were studied.

Before PM stage, seed qualities as measured by moisture content and seed dry matter of all varieties were high in both seasons, but all varieties seemed to have low seed vigor as determined by seed germination and seedling growth rate before PM stage. After PM stage, seed quality became different among varieties depending on season conditions. Seeds of the two different vegetable soybean varieties could maintain high seed dry matter and low seed moisture content at PM stage during both seasons. Therefore, differences in seed quality among varieties were minimal under dry season and rainy season.

The result also showed that vegetable soybean seed var. AGS 292 and No.75 reached the PM stage at 69 days and 71 days after planting in dry season and at 68 days and 69 days after planting in rainy season, which had the highest of pod size in terms of pod length, width and thiekness. It was noted that the PM period of No.75 was prolonged under both seasons.

It was observed that the response of vegetable soybean varieties to dry season and rainy seasons very similar, though there were some slight differences. Vegetable soybean varieties during dry season could maintain seed quality whereas vegetable soybean varieties during rainy season could not maintain. Differences of seed quality among vegetable soybean varieties in accordance with both seasons confirmed that dry season is better to rainy season, and that PM period differs among vegetable soybean varieties.

It has been concluded from this study that AGS 292 and No.75 vegetable soybean varieties should be harvested within 2 weeks after PM to obtain maximum yield without any loss in quality.

The influence of priming condition on quality of seed, varieties differences in PEG concentration and soaking time, and vegetable soybean seed quality changes during PEG concentration and soaking time were studied. From this study, the effects of PEG concentration could be showed on germination percentage of vegetable soybean variety and the longest soaking time could be damaged on seed development of vegetable soybean varieties AGS 292 and No.75. Seed treated with PEG with the duration of 3 hr exhibited the least damaging of seeds. However, the higher germination was recorded in that treatment, PEG 2.4, 4.7 and 6.5g/ 100 ml. distilled water.

Although seedling growth rate was not significantly effected among priming treatments and soaking time, germination percentage was significantly different among priming treatments. The longer soaking time could also decrease germination percentage and seedling growth rate in both varieties. The effect of PEG concentration was also significant in electrical conductivity values of both vegetable soybean varieties whereas the lower eleetrical conductivity values was observed in seeds treated with PEG in compared to seeds treated with non PEG. Both varieties exhibited the lowest electrical conductivity values as a result of PEG priming.

In comparing the two vegetable soybean varieties AGS 292 and No.75, the germination percentage was significantly observed by PEG concentration in AGS 292 than No.75. Seed responses to priming are variable by varieties.

It can be concluded that from the results, PEG concentration can increase germination and longer soaking time can increase damaged of vegetablc soybean seeds. The practical benefits of PEG 6000 priming treatment resulted in longer root hairs on both varieties of vegetable soybean. Further study is necessary to determine differences in vegetable soybean varieties in response to germination and seed vigor by treating different PEG concentrations.

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APPENDIX

Appendix Table 1 Analysis of variance of seed dry matter (SDM), seed moisture content (SMC), germination percentage (Ger %) and seedling growth rate (SGR) of vegetable soybean (AGS 292) in dry season.

Source of Variation	d.f.	Mean Square			
		SDM (g)	SMC (%)	Ger (%)	SGR (mg/seedling)
Replication	1	0.5 ^{ns}	0.1 ^{ns}	20.9 ^{ns}	398.5 ^{ns}
Harvesting time	9	969.0**	1042.1**	2987.8**	17127.0**
Error	9	11.1	1.9	20.9	235.5
Total	19				

CV (SDM) = 11.9% CV (SMC) = 2.9 % CV (Ger) = 17.1% CV (SGR) = 21.9 %

ns = Not significantly different *($P > 0.05$)*

** = Significantly different at $P < 0.01$.

Appendix Table 2 Analysis of variance of seed dry matter (SDM), seed moisture content (SMC), germination percentage (Ger %) and seedling growth rate (SGR) of vegetable soybean (No.75) in dry season.

Source of Variation	d.f.	Mean Square			
		SDM (g)	SMC (%)	Ger (%)	SGR (mg/seedling)
Replication	1	54.8^{ns}	17.4^{ns}	7.2^{ns}	15.6^{ns}
Harvesting time	9	1108.4**	1033.4**	2684.0**	25057.7**
Error	9	19.9	5.0	9.1	29.0
Total	19				

CV (SDM) = 15.8% CV (SMC) = 4.7% CV (Ger) = 11.7% CV (SGR) = 6.2 %

ns = Not significantly different *($P > 0.05$)*

** = Significantly different at $P < 0.01$.

Appendix Table 3 Analysis of variance of seed dry matter (SDM), seed moisture content (SMC), germination percentage (Ger %) and seedling growth rate (SGR) of vegetable soybean (AGS 292) in rainy season.

Source of Variation	d.f.	Mean Square			
		SDM (g)	SMC (%)	Ger (%)	SGR (mg/seedling)
Replication	1	19.3 ns	0.2 ns	0.8 ns	21.1 ns
Harvesting time	9	903.1**	801.9**	704.6**	6752.7**
Error	9	4.0	0.9	1.1	10.9
Total	19				

CV (SDM) = 5.6% CV (SMC) = 1.7% CV (Ger) = 9.6% CV (SGR) = 9.2 %

ns = Not significantly different *(P > 0.05)*

** = Significantly different at *P < 0.01*.

Appendix Table 4 Analysis of variance of seed dry matter (SDM), seed moisture content (SMC), germination percentage (Ger %) and seedling growth rate (SGR) of vegetable soybean (No.75) in rainy season.

Source of Variation	d.f.	Mean Square			
		SDM (g)	SMC (%)	Ger (%)	SGR (mg/seedling)
Replication	1	32.3^{ns}	0.7^{ns}	52.9^{ns}	101.6^{ns}
Harvesting time	9	888.5**	810.8**	455.0**	9689.7**
Error	9	6.9	1.1	23.8	40.7
Total	19				

CV (SDM) = 7.6% CV (SMC) = 1.9% CV (Ger) = 56.3% CV (SGR) = 14.8 %

ns = Not significantly different *(P > 0.05)*

** = Significantly different at *P < 0.01.*

Appendix Table 5 Analysis of variance of germination percentage (Ger %), seedling growth rate (SGR) and electrical conductivity (EC) of vegetable soybean (AGS 292) as affected by PEG 6000 concentration and seed soaking time duration.

Source of Variation	d.f.	Mean Square		
		Ger %	SGR (mg/seedling)	EC (μS/cm/seed)
Concentration	3	235.9**	948.5^{ns}	191.8**
Soaking time	3	91.0^{ns}	85.5^{ns}	482.6**
Conc x Soaking	9	26.9^{ns}	339.0^{ns}	14.7*
Error	32	37.7	546.0	5.4
Total	47			

CV (Ger) = 11.4% CV (SGR) = 12.1% CV (EC) = 12.9 %

ns = Not significantly different *($P > 0.05$)*

* = Significantly different at $P < 0.05$

** = Significantly different at $P < 0.01$.

Appendix Table 6 Analysis of variance of germination percentage (Ger %), seedling growth rate (SGR) and electrical conductivity (EC) of vegetable soybean (No.75) as affected by PEG 6000 concentration and seed soaking time duration.

Source of Variation	DF	Mean Square		
		Ger %	SGR (mg/seedling)	EC (μS/cm/seed)
Concentration	3	55.7 ^{ns}	460.1 ^{ns}	104.4**
Soaking time	3	41.9 ^{ns}	382.3 ^{ns}	495.1**
Conc x Soaking	9	24.6 ^{ns}	153.7 ^{ns}	11.6*
Error	32	19.7	645.7	5.2
Total	47			

CV (Ger) = 7.1% CV (SGR) = 11.9 % CV (EC) = 13.8%

ns = Not significantly different *($P > 0.05$)*

* = Significantly different at $P < 0.05$

** = Significantly different at $P < 0.01$.

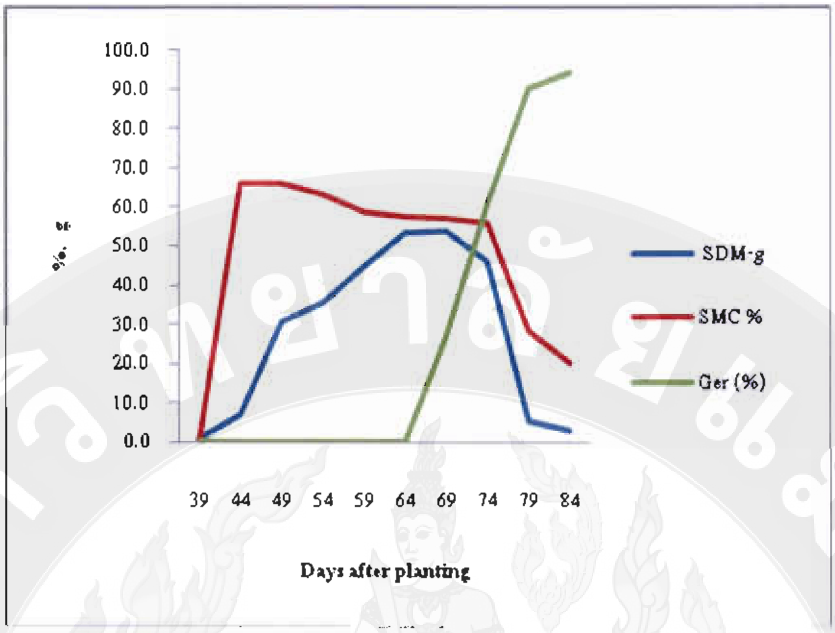
Appendix Table 7 Combined analysis of variance of germination percentage (Ger %), seedling growth rate (SGR) and electrical conductivity (EC) of vegetable soybean (AGS 292 and No.75) as affected by PEG 6000 concentration, seed soaking time duration.

Source of Variation	d.f.	Mean Square		
		Ger %	SGR (mg/seedling)	EC (μS/cm/seed)
Variety	1	1822.0**	10226.5 ns	47.5 ns
Reps with variety	4	18.3 ns	3767.0**	38.5**
Concentration	3	254.8**	928..5 ns	283.9**
Soaking time	3	31.4 ns	386.2 ns	976.1**
Conc x Soaking	9	32.0 ns	304.8 ns	24.3**
Trt x Variety	15	39.3 ns	225.1 ns	4.0 ns
Pooled error	60	29.4	384.4	3.1
Total	95			

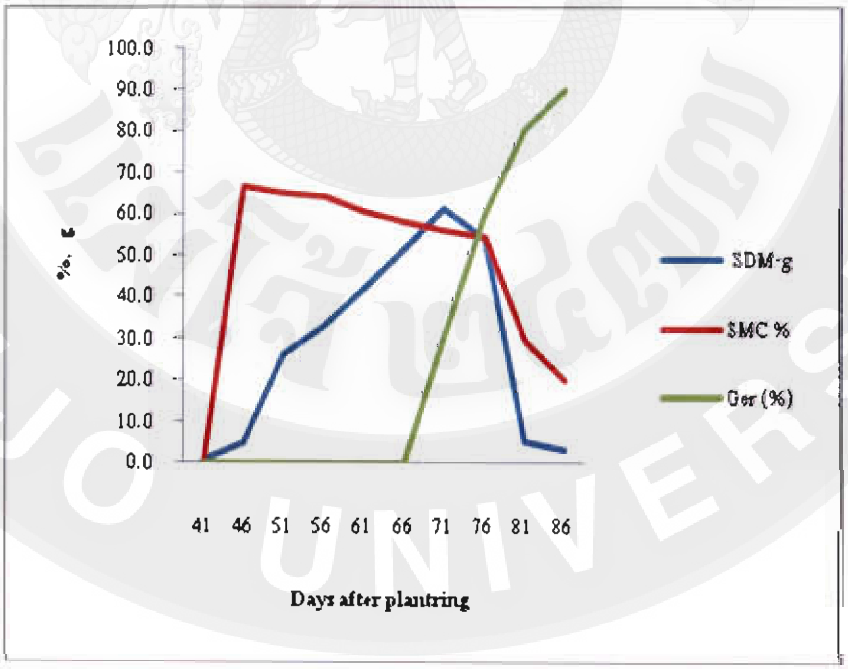
CV (Ger) = 9.3% CV (SGR) = 9.7% CV (EC) = 10.2 %

ns = Not significantly different *(P > 0.05)*

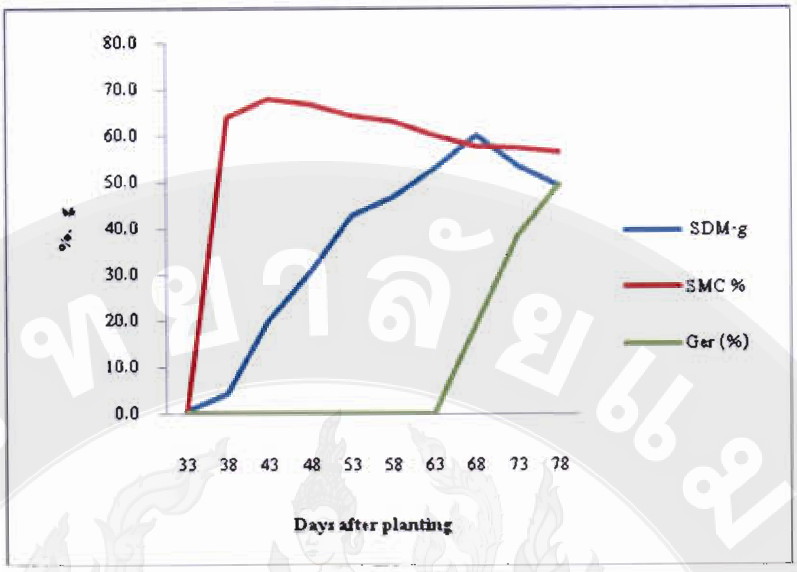
** = Significantly different at *P < 0.01*.



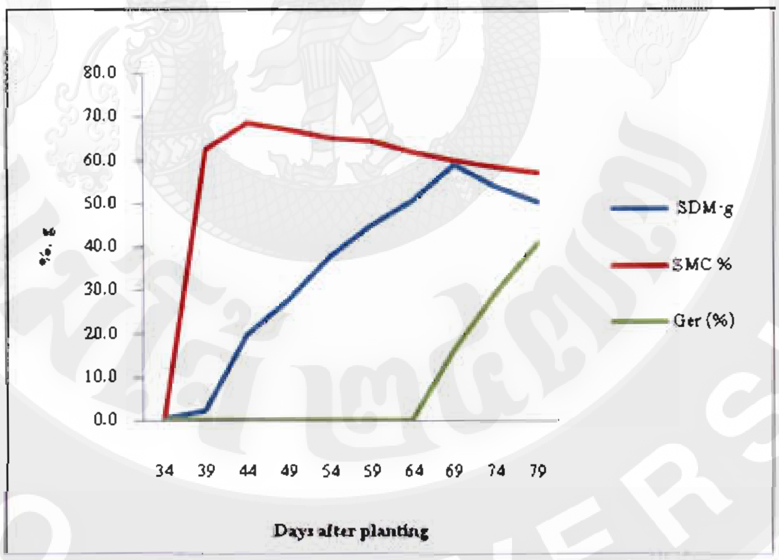
Appendix Figure 1 Seed dry matter (SDM), seed moisture content (SMC) and germinate percentage (Ger %) of vegetable soybean (AGS 292) during seed development in dry season.



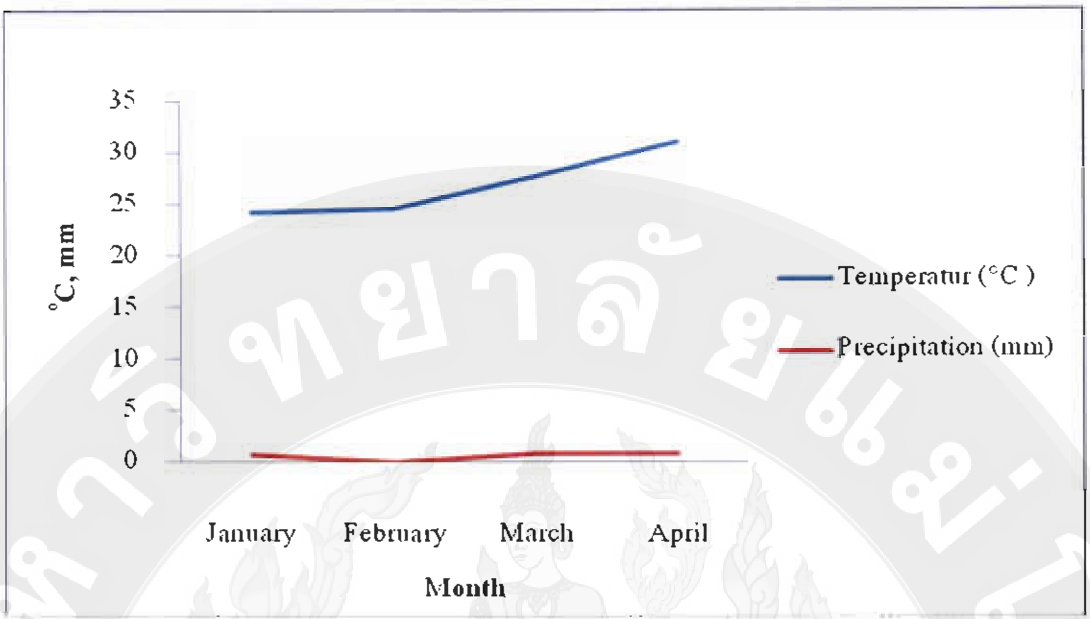
Appendix Figure 2 Seed dry matter (SDM), seed moisture content (SMC) and germinate percentage (Ger %) of vegetable soybean (No.75) during seed development in dry season.



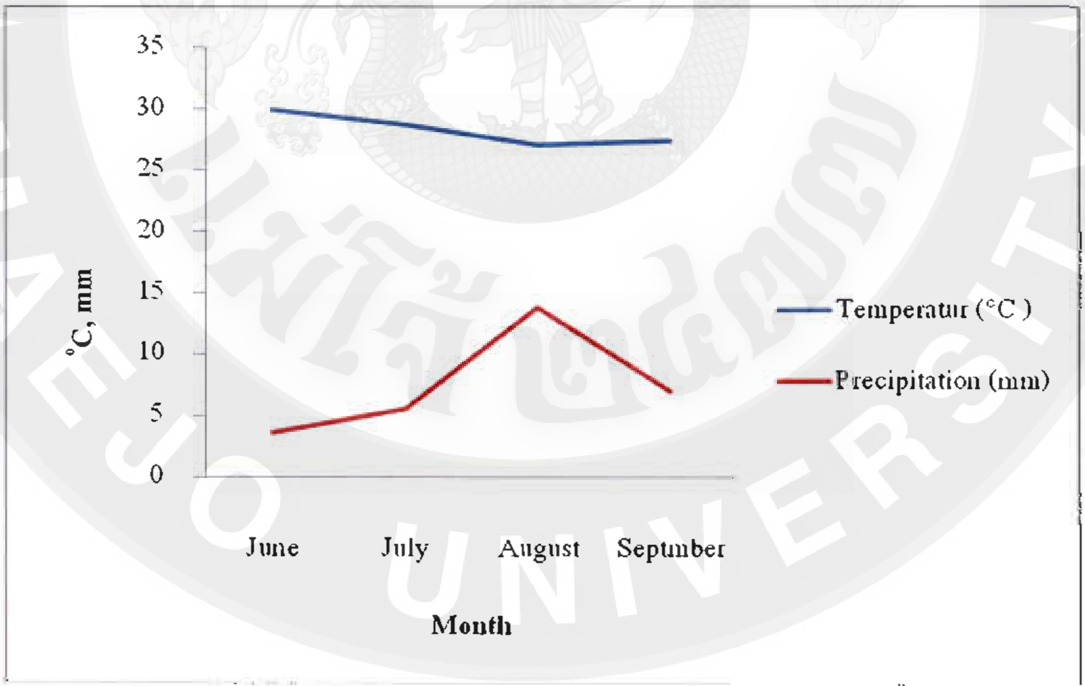
Appendix Figure 3 Seed dry matter (SDM), seed moisture content (SMC) and germinate percentage (Ger %) of vegetable soybean (AGS 292) during seed development in rainy season.



Appendix Figure 4 Seed dry matter (SDM), seed moisture content (SMC) and germinate percentage (Ger %) of vegetable soybean (No.75) during seed development in rainy season.



Appendix Figure 5 Temperature (°C) and precipitation (mm) in dry season during 2010- 2011.



Appendix Figure 6 Temperature (°C) and precipitation (mm) in rainy season during 2010- 2011.

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