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Response of Indonesian Tropical Legumes to PEG 6000 Drought Stress

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Abstract
Plant resistance to drought stress was primary factor for stability plant performance in dry condition. Poly ethylene glycol (PEG) was one kind of chemical material used for plant selection to drought stress. The study was conducted in Forage Science Laboratory, Animal Agricultural Faculty, Diponegoro University, Semarang, Indonesia. The objective of this study was understood about performance of drought stress for legumes. The study was used PEG-6000 for stressed treatment was arranged in factorial forms using completely randomized design with three replication. The treatment PEG-6000 in distilled water until 1000 ml (w/v) were 0 (control), 1,2,3,4,5,6,7,8,9 and 10 g on ten kinds of legume were Calopo (*Calopogonium mucunoides),* Crotalaria (*Crotalaria juncea),*Centro (*Centrosema pubescens),* Puero (*Pueraria phaseoloides),*Leucaena (*Leucaena leucocephala),* Gliricideae (*Gliricideae maculate),* Sesbania (*Sesbania glandifora),* green grams (*Vigna udulata*), kidney beans (*Vigna radiata*), and Soybeans(*Glycine max*). Parameter in this study were germination percentage, root length, shoot length, shoot weight, root weight and shoot/root ratio. Kidney beans have highest seedling percentage of shoot length, root length and shoot weight. *Gliricideae* have lowest seedling percentage of shoot length, root length, shoot weight and root weight. Kind of legumes have significance difference of shoot length affect by PEG-6000. The increased concentration of PEG will further lower the percentage of germination, shoot length, root length, shoot weight and root weight. The increasing concentration of PEG 6000 given declining percentage germination, shoot length, root length, shoot weight and root weight. Highest shoot/root ratio in legume was kidney beans and the lowest was *Gliricideae. Calopo, Centro* and *Gliricideae* was very sensitive to drought stress.
Keywords: legumes, poly ethylene glycol, seedling percentage, shoot, root

Introduction

Production forages on dry season in Indonesia was lower because drought stressed. In fact, water deficiency due to drought is one of the most severe environmental stresses affecting plants growth and development. Drought impact include growth, crude protein and crude fiber in Elephant and Napier grasses. Drought stress is to be considered to be a moderate loss of water which leads to stomata closure and limitations of gas exchange (Jaleel *et al*, 2009). In response to a biotic stresses, plants use different strategies to cope with which include changes in plants biochemical and physiological processes (Valifard *et al*, 2012).

The Poly ethylene glycol (PEG) was one kind of chemical material used for plant selection to drought stress (El Midaout *et al*, 2003; Jajarmi, 2009). Plant cells response to drought stress depend on tipe of organ, cell and plant and cell stage development. El Midaout *et al,* (2003) explained about role of rooting system on nutrient and uptakes depend on physiology status. Plant able to resistance on dry soil have three mechanism were (1) higher plant water status management along stress condition, (2) plant function management at below water status, and (3) recovery plant water status and function after doing stress(Xiuhai *et al*, 2005). According to Dudley *et al*. (2008) that solute concentration between 100 – 200 mM effect to nutrient uptake by root. Decreasing nutrient will affect to lower growth and yields. Jajarmi (2009) reported germination percentage of wheat cultivar induced PEG-6000 highest 78% in GV3-20 cultivar, and the lowest 36% in Arvand cultivar. The objective of this study were: (1) understand about performance of drought stress for legumes, (2) understand tolerance ability of legumes to . drought stress.

Material and Method

The study was conducted at Forage Science Laboratory, Animal Agriculture Science Faculty, Diponegoro University Indonesia. The study arrange for factorial forms using completely randomized design with five replication. Treatment drought stress with poly ethylene glycol (PEG) 6000 applied to ten kind of legumes base on weight per volume (w/v) were 0 (control), 1,2,3,4,5,6,7,8,9 and 10 g PEG-6000 in soluble water until 1000 ml. Ten kinds of legume were Calopo (*Calopogonium mucunoides),* Crotalaria (*Crotalaria juncea),*Centro (*Centrosema pubescens),* Puero (*Pueraria phaseoloides),*Leucaena (*Leucaena leucocephala),* Gliricideae (*Gliricideae maculate),* Sesbania (*Sesbania glandifora),* green grams (*Vigna udulata*), kidney beans (*Vigna radiata*), and Soybeans(*Glycine max*). Application of drought stress according to Rauf *et al* (2007) was done with rolling paper. First, paper washed in PEG solute treatment, than seed put on washed paper, and rolled. Rolled paper contain seeds put in germination chamber (Fujiwara Scientific, type III-E) at room thermometer (25^o C day and 22 ^{o}C night). Parameter in this study were (1). seedling percentage, (2) shoot length, (3) root length, (4) shoot weight, (5) root weight, (6) shoot/root ratio, and (7) drought sensitivity index (DSI) calculated modification from Dib *et al* (1994) formulation, was DSI= CI(control)-CNI(PEG stress/control). Data were collected and test for analysis of variance (ANOVA) using GLM SAS 6.2 Programe. Duncan's Multiple Range Test was used to compare the means where *F*-value indicated significant difference.

Result and Discussion

Result

The statistical analysis showed high significant difference for legumes and PEG-6000 treatment for all parameters. The interaction between the type of legume and PEG-6000 was not significant for all parameters except seedling percentage.

Drought stress effect to cell expansion and cell growth due to the low turgor pressure. The result of experiment showed kidney beans have highest seedling percentage, but Gliricidae have lower seedling percentage. Kind of legumes have significant difference of shoot length affect of PEG-6000 treatment. The ability of plants survived in the early growth was different depend on amount water available and ability legume seed imbibition.

Table 1. Percentage of seedling, shoot length, root length, ten legumes

Legumes	Seedling percentage	Shoot length (cm)	Root length (cm)
Calopo	64.8±0.88bc	6.0 ±0.4c	4.4±1.4e
Crotalaria	68.6±3.56ab	5.4±0.1d	11.4±3.6c
Centrosema	67.1±2.50bc	3.4±1.5e	2.7±2.6gh
Pueraria(Puero)	63.3±0.18c	2.8±1.9f	2.6±2.6gh
Leucaena	63.7±0.10c	1.9±2.5g	7.0±0.5d
Gliricidae	39.1±17.30d	1.1±3.1h	2.5±2.7h
Sesbania	65.7±1.51bc	7.4±1.4b	3.7±1.9f
Green grams	67.4±2.72bc	10.7±3.7a	12±4.0b
Kidney beans	72.4±6.25a	10.9±3.8a	14.2±5.6a
Soybeans	63.5±0.04c	5.2±0.2d	2.9±2.4g

Averages followed by the same letter in the column do not differ ence(P<0.05) by Duncan test

Green beans and kidney beans have highest shoot length, but Gliricideae have lowest shoot length(Table 1). Shoot length elongation was characteristic of plant to survive after seedling. Ability of seed to seedling determined morphology preview with elongation shoot. Ability of seed to seedling on drought stress condition (PEG-6000) was indication of their legume survive to drought stress. Kidney beans was kind legume have longest root length but Gliricideae, Centrosema and Pueraria have lowest. Root length of kidney beans (14.2) significant difference with all legumes. Gliricidea have root length (2.4 cm) have not significant difference with Centrosema (2.7 cm) and Pueraria (2.6 cm) but significant difference with Calopo (4.4 cm), Leucaena (7.0 cm), Sesbania (3.7 cm), soybeans (2.9 cm) and kidney beans.

In addition to the elongated shoot, the ability of legume to form roots when germinated seeds in a dry stress conditions (with PEG-6000) is an indication that the plant resistance to drought. Variations in legume root length is quite diverse.

Table 2. Shoot weight, root weight and shoor/root ratio of ten legumes

Legumes	shoot weight (mg)	root weight (mg)	Shoot/root ratio
Calopo	0.7±0.5e	0.3±4.0f	1.2 ± 0.03d
Crotalaria	2.5±0.8b	21.7±11.1a	0.5 ±0.47g
Centrosema	0.4±0.7f	2.4±2.5d	1.7 ±0.38c
Pueraria(Puero)	0.8±0.4e	0.4±3.9f	1.2±0.03de
Leucaena	0.4±0.7f	2.8±2.2d	0.5±0.47g
Gliricidae	0.4±0.7f	0.5±3.9f	0.4±0.54g
Sesbania	1.7±0.2c	0.3±4.0f	2.3±0.81a
Green grams	1.2±0.1c	13.1±5.0c	1±0.11ef
Kidney beans	5.4±2.8a	16.7±7.6b	0.8±0.25f
Soybeans	0.6± 0.6e	1.5±3.2e	2 0± 0.59b

Averages followed by the same letter in the column do not differ ence(P<0.05) by Duncan test

Table 3. Effect of PEG to percentage seedling, shoot length and root length of leguminose

PEG (ppm)	% seedling	Shoot length (cm)	Root length (cm)
0	81.8 ± 9.8 a	7.7± 1.6a	10.0 ± 2.6a
1	75.9 ± 8.3 b	6.4 ± 0.6b	9.0 ±1.9b
2	68.5 ± 7.2 c	6.5 ± 0.7b	8.7 ± 1.7b
3	68.2 ± 7.0 c	5.7 ± 0.1c	7.7 ± 1.0c
4	66.2 ± 6.7 cd	5.3 ± 0.1cd	7.2 ± 0.6d
5	62.4 ± 6.3 de	5.8 ± 0.2c	5.9 ± 0.3e
6	60.8 ± 6.5 ef	5 .0± 0.4d	4.9 ± 1.0f
7	57.7 ± 6.9 fg	4.8 ± 0.5d	4.7 ± 1.2f
8	57.3 ± 7.8 fg	5.3 ±0.1cd	4.2 ± 1.5g
9	54.7 ± 9.4 g	3.9 ± 1.1e	4.0 ± 1.7gh
10	44.6 ± 13.3 h	4.0 ± 1.1e	3.6 ± 1.9h

Averages followed by the same letter in the column do not differ ($P<0.05$) by Duncan test

Weight of shoots varied among legume species, kidney beans have the highest weight (5.4 g) was significant difference with all type of legumes. Centro, Leucaena and Gliricideae have the lowest weights (0,4 g), significant difference with soy beans (0.6 g), Calopo (0.7 g), Pueraria (0.8 g), Sesbania (1,7 g), green gram (1.2 g), Crotalaria (2.5 g) and kidney beans.

Weight of legume roots have another variation in which the weight of heaviest roots were Crotalaria (21.7 g) was significant difference with all legumes. Calopo, Pueraria and Gliricideae has the lowest root weights significantly different from seven other legume species 0.3, 0.2 and 0.5 g, respectively. Shoot/root ratio of Sesbania (2.26) significant difference with all of legume tested. Crotalaria, Gliricideae and Leucaena have lower shoot/root significant difference with seven those legumes.

Table 4. Effect of PEG to shoot weight, root weight and shoot/root ratio of leguminose

PEG (ppm)	Shoot weight (mg)	Root weight (mg)	Shoot/root Ratio
0	1.9± 0.35 a	8.8 ±2.0a	0.90±0.20d
1	1.6± 0.13b	8.3±1.7b	0.91±0.19d
2	1.6± 0.13b	7.8±1.3b	0.89±0.20d
3	1.4± 0.01bcd	6.9±0.7c	1.89±0.20d
4	1.3± 0.08cde	6.8±0.6c	1.02±0.11cd
5	1.5± 0.06bc	5.5±0.3d	1.27±0.07bc
6	1.3± 0.08cde	4.8±0.8e	1.38±0.14b
7	1.2± 0.15de	4.9±0.7e	1.65±0.33a
8	1.4± 0.01bcd	4.3±1.2f	1.64±0.33a
9	1.1± 0.22f	3.9±1.4f	1.06± 0.10cd
10	1.2± 0.15ef	3.3±1.9g	1.22 ±0.03cd

Discussion

Plants response to drought by way of morphology, physiology and metabolism modifications. Plants species can stay alive longer or shorter depend on efficiency and response to conditions of water deficit. Based Ouvrad *et al* (1996) contains a large number of genes depending on the nature of drought resistant crops.

As a result of PEG-6000, plants have significantly different shoot length(Table 3). Green beans and kidney beans have the highest shoot length, the shortest being Gliricideae. Shoot length is the ability of plants to keep growing after germinated. The ability of seeds to germinate indicated morphology with elongated buds. Sahai and Shanai (2012) report the effects of synthetic strygol analogs, GR-7, GR-24, and GR-28, were studied on seed germination, seedling growth and development in a tropical hemi-root parasite, *Sopubia delphinifolia*. All the three GR-compounds significantly stimulated seed germination but inhibited seedling growth, particularly the root growth.

Increased concentrations of PEG-6000 provided drought stress, fewer seeds can germinate. Germination is a critical stage of the plant life and resistance against drought during the germination makes a plant stable (Jajarmi *et al*, 2009). Sayar *et al* (2008) states germination test is one way of a physiological test to predict crop tolerance to drought stress in wheat (*Triticum durum* Desf.) Plants have significantly different shoot length affect of PEG-6000. Green beans and kidney beans have the highest shoot length, the shortest being Gliricideae. Shoot length is the ability of plants to keep growing after germinated. The ability of seeds to germinate indicated morphology with elongated buds.

Osmotic stress which causes dryness is one of environment stress which inhibitor of plant production. Osmotic stress caused concentration of salt (PEG-6000) resulted in germination barriers by altering plant metabolism and hormones that inhibit germination, both shown as shoots and roots. According to research Borsani *et al* (2002) carried out measurements of tomatoes root sprouts for screening to osmotic stress resistance caused by mannitol.

The biggest of shoot / root weights ratio was Sesbania (2.26) significantly different with all types of legumes. The smallest of shoot / root weight ratio was Crotalaria, Gliricideae and Lamtoro, were significantly different from the other seven types of legumes. Plant development is generally divided into three phases; germination, vegetative phase and maturity. Germination is reactivation activity growth in seed to later become seeds (Ali-Dib, 1994). Vegetative phase is growth was start after germination to time for flowering. In the vegetative phase stems and leaves have been formed so perfect and assimilation activities generally occur at the root of reserves as a result of assimilation (Johnson and Henderson, 2002) states that plant growth is influenced by genetic and environmental factors. Genetic factors affect physiological processes of plants, whereas environmental factors influenced by temperature, soil moisture and nutrients. Environmental factors that most affect plant growth are: 1) soil, which gives nutrients and moisture, 2) energy radiation in the form of heat and light, and 3) the air, resulting in carbon dioxide and oxygen. In the organs of the vegetative phase of plant growth and development. Growth can be measured in a quantitative way is by measuring length of plant, number of leaves, stem diameter and calculate biomass yield and dry matter production

Achieving genetic increase in yield in wet weather conditions are always a challenge for plant breeders produce the same capacity during the dry season. Lack of water can result in a lower leaf water potential, decreased turgor pressure stomata and photosynthesis resulting in decreased plant growth and yield. Early growth of a plant is very important because it can be used to know number seed needs. According to Rauf *et al* (2007) the ability of plants to germinate a determinant factor and yield at harvest. Decrease in the number of plants that germinate primarily affected by moisture.

In this study, PEG-6000 is used at the time of germination. Concentration of PEG increased will be even lower percentage of germination, shoot length, root length, shoot weight and root weight. PEG-6000 is a salt used to induce dry stress in early vegetative phases are very prone to stress. Seeds was resistant to high osmotic pressure remains capable of germination, as demonstrated by formation of buds and or roots. Increasing concentration of PEG-6000 given cause stress and hold a seed growing so little seeds are able to germinate. Sayar *et al* (2008) stated that germination test is one way a physiological test to predict tolerance of crop plants to drought in wheat (*Triticum durum* Desf.) Sedghi *et al* (2012) reported that the germination test is a rapid test method to evaluate a number of varieties of plants in a short time.

Shoot length decreased with increasing concentration of PEG-6000. The concentration of PEG-6000 was increasing osmotic pressure will increase that went into the seed. This results in dry seeds under stress, as a result, shoot growth is inhibited. Response decreased shoot length of each type of legume. Generally, the response decreased with increasing concentration of PEG-6000. Response ten kinds of legume linear with R^2 for Calopo, Crotalaria, Centro and Puero respectively 0.87, 0.60, 0.77 and 0.25. The coefficient of determination for Leucaena, Gliricidae and Sesbania were 0.81, 0.74 and 0.005, respectively. The legume food groups consist green beans, kidney beans and soybeans were 0.59, 0.41 and 0.75, respectively. When viewed long shoots, having R^2 values are generally small (<90%), suggesting determinants of emerging and growing shoots not only PEG-6000, but also temperature and ability of seeds to form roots. Seeds are formed early growth of shoots and roots, so can shoot first or root first.

Root length decreased with increasing concentration of PEG-6000. Result of my study research of root length contrast with El Midout *et al*, (2003) which is the concentration of osmotic pressure solution inner cell not enough to determine the occurrence osmosis regulation. Lower osmotic pressure of root growth did not differ in plant organs. Root growth is more sensitive than shoots due to decreased osmotic pressure. Changes in the osmotic pressure of plant was sign for plant to environment adaptation for dry and salinity. Osmotic regulation role managing turgor and cell volume those affects on plant growth, yield and plant resistance in dry areas or saline. Physiologically osmotic pressure affect essential processes in plan such protein synthesis and cell walls (Munns, 1988). Viscous solution will result in an imbalance osmotic potential and solute accumulation in response to water stress. Osmotic regulation will reduce turgor potential and in turn will affect plant growth (Morgan, 1984). The experimental results Mackay and Barber (1985) using corn indicate that groundwater levels are low resulting in low rate of diffusion of K toward the root, it causes low K uptake by plants

Table 5. Response of seedling percentage, shoot length and root length ten legumes affect by PEG 6000

Legumes	Seedling percentage	R^2	Shoot length	R^2	Root length	R^2
Calopo	Y=-0,36X+0,88	0.87	Y=0.046x^2-0.78x +6.91	0.78	Y=-0.38x^2+1.12x +75.78	0.84
Crotalaria	Y=-0,11x+6.32	0.60	Y=-0.96x +17.28	0.93	Y=-2.68x+84.77	0.89
Centro	Y=-0.42x+5.99	0.77	Y=0.58x+6.23	0.88	Y=-2.96x+84.91	0.91
Puero	Y=-0.13x +3.68	0.25	Y=-0.29x+4.43	0.82	Y=0.39x^2-7.52x +90.46	0.87
Leucaena	Y=-0.24x+3.37	0.81	Y=-1.62x+16.76	0.92	Y=-3.38x+84.06	0.81
Gliricideae	Y=0.15+2.11	0.74	Y=-0.39x+4.93	0.88	Y=0.11x2-2.29x +47.97	0.61
Sesbania	Y=0.04x+7.28	0.005	Y=-0.16x+4.74	0.41	Y=-3.61x+87.45	0.82
Green grams	Y=-0.46x+13.53	0.59	Y=-1.12x+ 18.81	0.82	Y=-0.223x^2-0.045x +79.32	0.63
Kidney beans	Y=-0.32x+12.91	0.41	Y=-0.81x+ 19.12	0.78	Y=-4.79x+101.2	0.97
Soy beans	Y=-0.85x+10.41	0.75	Y=-0.59x+6.61	0.82	Y=0.42x^2-7.43x +88.71	0.78

Seedling percentage of ten type legumes were linier. Puero legume has the lowest correlation (0,25). Percentage of seedling of puero suggest effect water, temperature, and relative humidity. Lack of water or there was salt on water solution only affect 25%.

The response of shoot length affect of PEG 6000 treatment were linier especially calopo legumes, there was quadratic response. Correlation of ten legumes more than 50%, there was means PEG 6000 treatment significant effected for shoot length, especially sesbania (41%). Another factor those effect on shoot length of Sesbania were temperature, relative humidity and time of studies.

Response of ten type legumes for root length generally decreased linearly with the increasing concentration of PEG-6000 treatment (Table 5), especially Calopo has shaped quadratic reduction. R^2 value of Calopo, Crotalaria, Centro were 0.78, 0.93, 0.88 and 0.81, respectively. Furthermore, root length of Leucaena, Sesbania and Gliricidae have R^2 0.82, 0.82 and 0.61, respectively . Group of food legumes food as green grams, kidney beans and soybeans have R^2 of root length 0.63, 0.97 and 0.78, respectively. Response of growth as indicated by root length of te root has a higher R^2 than shoot length, suggesting that PEG-6000 affects root growth more than shoot growth of legumes.

In this study, PEG-6000 used at the time of germination. The increased concentration of PEG will increasingly lose weight shoots. PEG- 6000 is a salt used to drough stress inducing in early vegetative phases are particularly vulnerable to stress. Growth is a process of adding size and progressive enlargement of the cell that reflects the growth of protoplasm. Plant growth is shown by the increase of plant height and number of leaves and dry weight were not reversible. Growth is a series of physiological processes in plants such as changes in shape and size as a result of cell division and enlargement which is the interaction of genetics with the environment, time and management, manifestations measured by productivity. Growth determined by the activity of photosynthesis besides also determined by root growth due to root growth determines the ability of plants to take up nutrients and water .

The growth of the plant consists of two phases, namely vegetative phase and generative phase. Vegetative phase mainly in the development of roots, leaves and new stems. This phase is associated with three important processes, namely: 1) cell division, 2) extension of the cell, and 3) the first stage of cell differentiation. Generative phase occurs in the formation and development of flower buds, fruit, flowers, and seeds or the enlargement and maturity structures of food storage, the roots and stems are fleshy.

Growth is the result of daughter-cell production by meristem cell divisions and sub sequent massive expansive of the young cell (Anjum *et al*, 2011). Plant growth can be divided into three phases; germination, vegetative and generative. Early growth of plants use more reserve substances inside the stem. Vegetative growth occurred mainly in the development of roots, leaves and stems. Generative growth occurs in the formation of flowers and seeds.

The results of weight of shoots have an inconsistent pattern of decline, although there is a decrease compared with the control, but the concentration of PEG-6000 compared to lower concentrations of PEG- 6000 at 5 and 8 p p m produces a slightly increased weight of shoots. It is not known why.

Osmotic stress which causes dryness is one of the stressful environment plant production inhibitor. Osmotic stress caused by the concentration of salt (PEG- 6000) resulted in the germination barriers by altering plant metabolism and hormones that inhibit germination, both shown as shoots and roots. According to research Borsani *et al* (2002) carried out measurements of tomatoes root sprouts resistance to osmotic stress caused by mannitol.

Unlike the weight of shoots, root weight legume has another variation where the weight of the heaviest roots are Crotalaria (21.7 g) were significantly different from all legumes. Calopo, Pueraria and Gliricideae has the lowest root weight significantly different from the other seven types of legumes, with respective weights 0.3, 0.2 and 0.5 g for Calopo, Pueraria and Gliricideae

Root weights decreased with the increasing concentration of PEG-6000. Rapid growth and heavy influence dry matter levels, generally rapid growth in the rainy season is always followed by a decrease in dry matter content, whereas slightly elevated levels of protein. Plant growth influenced by genetic factors and environmental factors. Genetic factors affect physiological processes of plants, whereas environmental factors influenced by temperature, soil moisture and nutrients. Environmental factors affected plant growth were: 1) soil, which gives nutrients and moisture, 2) energy radiation in the form of heat and light, and 3) air, resulting in carbon dioxide and oxygen. In the glasshouse, high litter cover and very low light levels reduced seedling emergence of most species, suggesting an adaptation to delay seed germination until the wet season when soil water availability is high and leaf litter rapidly decomposes (Salazar *et a*l, 2012)

Drought Sensitivity Index (DSI)

Results Drought sensitivity variance parameter index (DSI) showed that the legume and the concentration of PEG 6000 showed significantly different. Interaction between the two treatments were also significantly different.

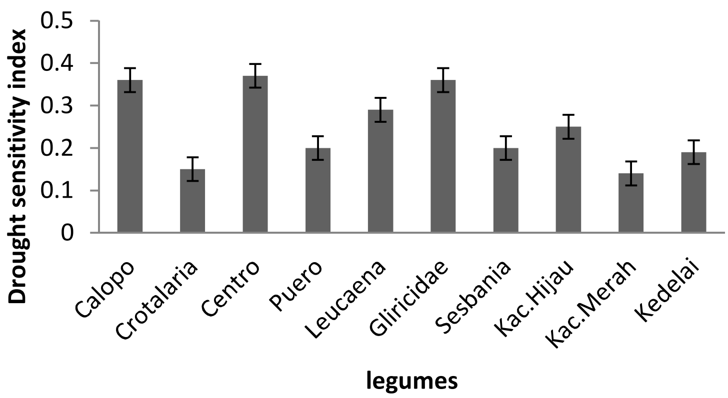

Figure 1 . Drought sensitivity index of ten legumes

DSI is sensitivity index which was sensitive if plant have high value. Calopo, Puero and Gliricidea have value higher than another seven type legumes. This means three legume were more sensitive to drought compare another seven type legumes. Legumes has little drought sensitivity index were Crotalaria and Kidney beans with DSI value 0.15 and 0.14, respectively. This means Crotalaria and kidney beans not sensitive to drought stress. Osmotic stress cause dryness of the plant to produce crops. Osmotic stress can also lead to high salt concentrations in the media so that the water needed by plants is reduced (Borsani *et al,* 2002). Three conditions caused germination of seeds were: (1) viable, (2) was not dormant, and (3) environment supported. Processes of germination according Pearson and Ison (1997) include (1) water flows to inner seeds, a physical process occured in seeds Dry beans seed have 100 M Pa pressure (equivalent to 1000 atm). Germination absorbed water for germination in 4-8 hours, then (within 12 hours) seeds have a 25-35% humidity and the pressure dropped to -1.5 M Pa, (2) Starting hormone activity, especially gibberellins and cytokinine and enzymes and respiratory activity , (3) catabolism (demolition) and translocation to deposits in seed embryo, (4) Assimilation of deposits energy source which activity soluble cellular and embryo growth and (5) embryo growth by cell division occurred mainly in the primary root tip in seeds.

Conclusion

From the research results can be concluded that kidney beans most resistant to dry stress induced by PEG 6000. Increasing concentration of PEG 6000 given declining seedling percentage, shoot length, root length, shoot weight and root weight. The highest shoot/root ratio was reached in kidney beans.

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