Analyzed Growth of Psophocarpus Tetragonolobus (L.) DC. Treated by Fertilizer, Pruning and Photoperiod

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Abstract

The growth analysis of *Psophocarpus tetragonolobus* (L.) DC. (winged bean) was carried out using the results of three experiments: fertilizer experiments, pruning and photoperiod experiments. An analyzed growth result showed that relative growth rate of pruning experiment was the highest (0.012872 g g^{-1} day^{-1}). However, net assimilation rate and leaf area ratio of photoperiod experiment were the maximum rate (9.16702 g cm^{-2} day^{-1}) and (26.2619 cm^2 g^{-1}) under field conditions. Among three experiments, the leaf area of photoperiod treatments was higher than the other two experiments. It was observed that the analyzed growth of plant was increased in initial period and it was slowly decreased in the later part of growth. Besides, correction analysis also showed that leaf area and tuber yield was highly correlated owing to the R^2 value of 0.9.

Keywords: *Psophocarpus tetragonolobus* (L.) DC., relative growth rate (RGR), leaf area ratio (LAR), net assimilation rate (NAR) and growth and regression correlation analysis

Introduction

Psophocarpus tetragonolobus (L.) DC. (winged bean) was widely grown in Tropical Asia from Myanmar in the West to Pupa New Guinea in the East (Khan, 1982). The possibility of Papua New Guinea, PNG, as a centre of origin is disputed by Khan (1976) who believed that it reached the Northern Lowlands of Papua New Guinea from the Indonesian Archipelago. In many areas it has the status of a minor vegetable, but in Myanmar and Papua New Guinea, it is skillfully managed as a tuber crop (Khan, 1976). Masefield (1973) quotes that all plants bear edible tuberous roots. The winged bean is basically adapted to the climatic conditions occurring in the equatorial tropics. It is grown from equator to 25˚ latitude in temperatures ranging from 15.4-27.5 ˚C (Duke, 1981).

Plant species may differ considerably in biomass production. This can be caused by differences in seed weight, in the length of the growing period or may be related to environmental conditions (Poorter and Remkes, 1990). In addition, the maximum relative growth rate (RGR), the dry weight increase per unit of biomass per unit of time under optimal conditions, may vary between species (Grime and Hunt, 1975).

A growth analysis will provide a first clue to answer these questions (Evans, 1972) : the RGR (relative growth rate) is the product of NAR (net assimilation rate) and LAR (leaf area ratio), where NAR is largely the net result of carbon gain from the process of photosynthesis and carbon losses from the processes of respiration, exudation and volatilization, which was expressed per unit leaf area; the LAR is the ratio of leaf area and total plant weight and is the product of a morphological component (SLA, specific leaf area); the ratio of leaf area and leaf weight, and the leaf weight ratio (LWR), indicating the fraction of total plant weight allocated to the leaves (Evans, 1972).

Regression and correlation procedures can be classified according to the number of variables involved and the form of the functional relationship between the dependent variable and the independent variables. The procedure is termed simple if only two variables (one dependent and one independent variable) are involved and multiple, otherwise. The procedure is termed linear if the form of the underlying relationship is linear and nonlinear, otherwise (Gomez and Gomez, 1984). Based on the described points, the study is aimed to assess the

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plant growth such as number of leaves, leaf area, leaf length, leaf width and yield from different treatments of experiments, to analyze the growth from different treatments such as fertilizers, pruning and photoperiod of Psophocarpus *tetragonolobus* (L.) DC., to evaluate the proper treatment for *Psophocarpus tetragonolobus* (L.) DC..

Materials and Methods

Growth analysis of *Psophocarpus tetragonolobus* (L.) DC.

The growth and growth analysis of cultivated winged bean from different treatments were carried out based on the growth analysis procedure described by Noggle and Fritz (1983). Growth of a plant is measured by height since the first week until the flowering. The period of rapid growth is characterized by the production of leaves; hence the numbers of leaves are necessary to count to measure the growth. Moreover, with the establishment of enough leaf surface to support vigorous photosynthesis, further growth of roots, stems and leaves was accelerated. The plant growth is also measured by dry weight basis. Dry weight measurements follow a course similar to plant height except that the period of rapid increase occurs somewhat later. The growth analysis is a useful tool in studying the complex interactions between plant growth and the environment.

Relative growth rate (RGR)

The relationship between size (plant height, dry weight) increase and time is termed as relative growth rate. RGR is calculated using the following formula described by Noggle and Fritz (1983).

$$RGR = \frac{2.303\ (\log_{10}\ W_2 - \log_{10} W_1)}{t_2 - t_1}$$

Net assimilation rate (NAR)

The rate of increase of dry weight (root and shoot) per unit time per unit area of leaf surface. NAR is calculated using the following formula described by Noggle and Fritz (1983).

$$NAR = \frac{(W_2 - W_1)\ 2.303\ (\log_{10}\ A_2 - \log_{10} A_1)}{(t_2 - t_1)\ (A_2 - A_1)}$$

Leaf area ratio (LAR)

The ratio of leaf area was calculated by the leaf area (cm^2) per dry weight (g). The dry weight (g) per square (cm) of leaf surface per week (g cm^{-2} wk^{-1}). LAR is calculated using the following formula described by Noggle and Fritz (1983).

$$LAR = \frac{(A_2 - A_1)\,2.303\ (\log_{10}\ W_2 - \log_{10} W_1)}{2.303\ (\log_{10}\ A_2 - \log_{10} A_1)\,(W_2 - W_1)}$$

Where W_1, W_2, and A_1, A_2 represent dry weight and leaf areas at time intervals t_1 and t_2. W_1 and A_1 referred to the initial dry weight and leaf area while W_2 and A_2 referred to the final dry weight and final leaf area. Similarly t_1 represented the initial growth duration and t_2 as the final duration.

Regression, correlation of *Psophocarpus tetragonolobus* (L.) DC.

Regression correlation between plant height and tuber yield, leaf number and tuber yield, leaf area and tuber yield, fresh weight and tuber yield and dry weight and tuber yield from fertilizer treatments, pruning technique and photoperiod treatments were studied.

Data collection and statistical analysis

The analyzed growth such as RGR, NAR, and LAR of fertilizer trials, pruning and photoperiod experiments were carried out owing to evaluate the growth of winged bean. The data were analyzed using IRRISTAT software package, version 4, developed by International Rice Research Institute (IRRI), the Philippines.

Results

Growth analysis of *Psophocarpus tetragonolobus* (L.) DC.

Relative growth rate (RGR) by different fertilizer treatments

The results of relative growth rate in this different fertilizers experiment showed that the relative growth rate of winged bean was the maximum of nitrogen (0.010898 g $g^{-1}day^{-1}$) and the minimum of compound NPK and cow dung (0.007202 g $g^{-1}day^{-1}$) (Table 2.1, Figure 2.1).

Table 2.1 Comparison of relative growth rate from different fertilizer treatments

Treatment	Relative Growth Rate (g g^{-1} d^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	0.01503	0.01225	0.01011	0.00367	0.00283	0.008778
N	0.02588	0.01283	0.01042	0.00331	0.00205	0.010898
P	0.0137	0.01066	0.00982	0.0039	0.00308	0.008232
K	0.01642	0.00979	0.00833	0.00341	0.00246	0.008082
NPK	0.01317	0.01231	0.00946	0.00379	0.00261	0.008268
NPK+CD	0.01508	0.00827	0.00767	0.00317	0.00182	0.007202
F-test	**	**	**	**	**	_
5 % LSD	0.00361	0.00246	0.00145	0.0009	0.00081	_
cv %	13.3	12.3	8.6	14.0	18.0	_

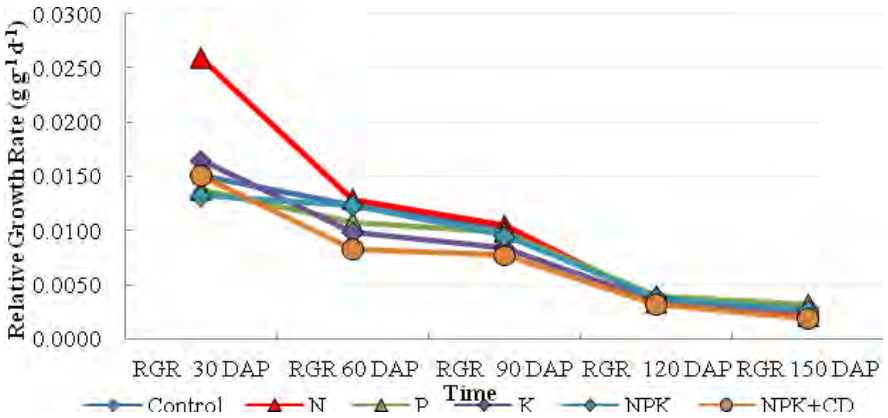

Figure 2.1 Comparison of relative growth rate from different fertilizer treatments

Net assimilation rate (NAR) by different fertilizer treatments

The results of net assimilation rate in this different fertilizers experiment showed that the net assimilation rate of winged bean was the highest of compound NPK (4.21124 g cm^{-2} day^{-1}) and the lowest of control (3.32156 g cm^{-2} day^{-1}) (Table 2.2, Figure 2.2).

Leaf area ratio (LAR) by different fertilizer treatments

The results of leaf area ratio in this different fertilizers experiment showed that the leaf area ratio of winged bean was the maximum of nitrogen (7.95492 cm^2 g^{-1}) and the minimum of control (5.81398cm^2 g^{-1}) (Table 2.3, Figure 2.3).

Table 2.2 Comparison of net assimilation rate from different fertilizer treatments

Treatment	Net Assimilation Rate (g cm^{-2} d^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	4.3962	4.3402	3.8736	2.4416	1.5562	3.32156
N	6.1084	5.668	5.1527	2.4566	0.6917	4.01548
P	5.72	4.2347	4.0277	3.9078	1.224	3.82284
K	8.3924	3.9323	2.5903	1.8556	0.9608	3.54628
NPK	7.2895	5.2998	4.3135	3.0884	1.065	4.21124
NPK+CD	8.9351	3.5658	2.6303	1.8819	0.8212	3.56686
F-test	**	**	**	**	**	-
5 % LSD	3.77926	2.12228	1.20927	1.86934	1.28669	-
cv %	30.5	25.9	17.7	39.4	67.2	-

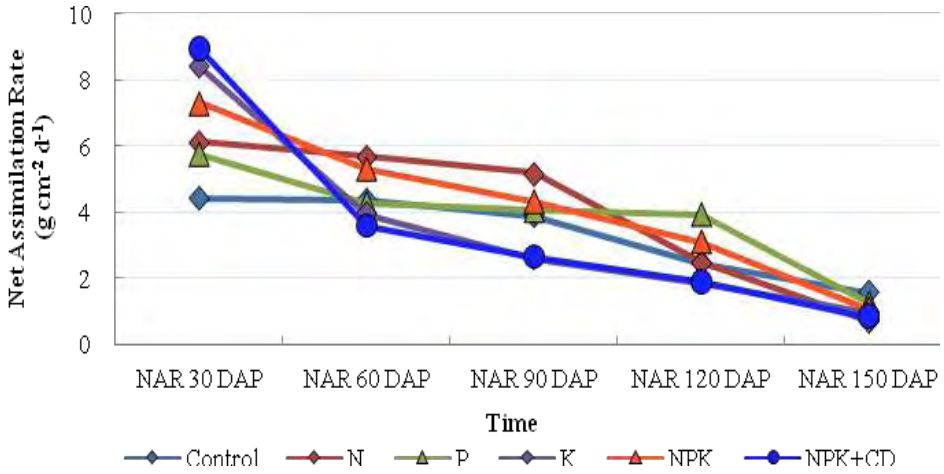

Figure 2.2 Comparison of net assimilation rate from different fertilizer treatments

Table 2.3 Comparison of leaf area ratio from different fertilizer treatments

Treatment	Leaf Area Ratio (cm^2 g^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	11.1859	8.9512	6.6149	1.5018	0.8161	5.81398
N	16.5819	12.5275	9.0524	1.3736	0.2392	7.95492
P	13.3372	7.7972	6.7780	2.6789	0.5924	6.23674
K	23.9769	6.6079	3.6662	1.0826	0.4260	7.15192
NPK	16.1968	11.0947	6.9435	1.9810	0.4533	7.33386
NPK+CD	22.9936	5.0159	3.4507	1.0203	0.2212	6.54034
F-test	**	**	**	**	**	-
5 % LSD	11.83000	5.53522	2.32189	1.47258	0.66131	-
cv %	37.4	35.1	21.0	50.4	79.4	-

***Growth analysis of Psophocarpus tetragonolobus* (L.) DC.**

Relative growth rate (RGR) by pruning treatments

The results of relative growth rate in this pruning experiment showed that the relative growth rate of winged bean was the highest of reproductive pruning (0.012872 g $g^{-1}day^{-1}$) and the lowest of control (0.012348 g $g^{-1}day^{-1}$) (Table 2.4, Figure 2.4).

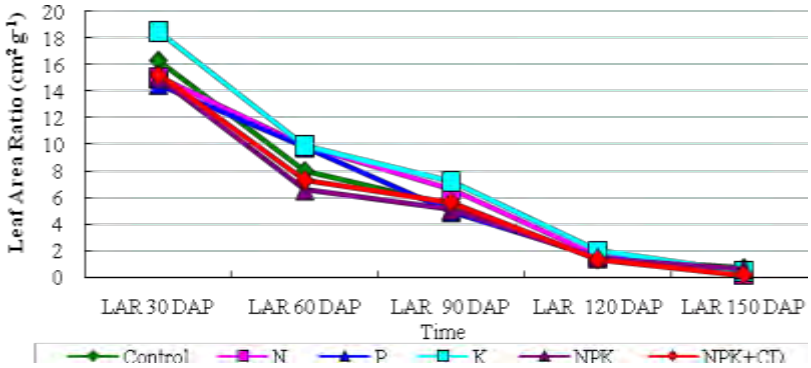

Figure 2.3 Comparison of leaf area ratio from different fertilizer treatments

Table 2.4 Comparison of relative growth rate from pruning treatments

Treatment	Relative Growth Rate (g g^{-1} d^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	0.02106	0.01409	0.01157	0.00904	0.00598	0.012348
Vegetative pruning	0.02248	0.01653	0.01137	0.00773	0.00542	0.012706
Reproductive pruning	0.02349	0.01546	0.01098	0.00840	0.00603	0.012872
F- test	**	**	**	ns	**	-
5%LSD	0.00279	0.00298	0.00357	0.00377	0.00111	-
cv%	5.5	8.6	13.9	19.8	8.4	-

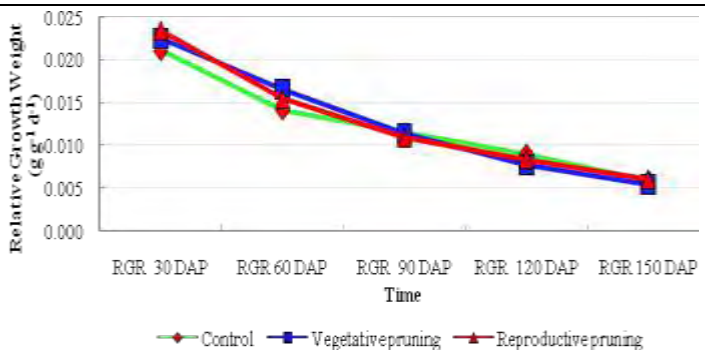

Figure 2.4 Comparison of relative growth rate from pruning treatments

Net assimilation rate (NAR) by pruning treatments

The results of net assimilation rate in this pruning experiment showed that the net assimilation rate of winged bean was the highest of reproductive pruning (5.94344 g cm^{-2} day^{-1}) and the lowest of control (5.26076 g cm^{-2} day^{-1}) (Table 2.5, Figure 2.5).

Leaf area ratio (LAR) by pruning treatments

The results of leaf area ratio in this pruning experiment showed that the leaf area ratio of winged bean was the maximum of reproductive pruning (15.2455 cm^2 g^{-1}) and the lowest of control (13.4355 cm^2 g^{-1}) (Table 2.6, Figure 2.6).

***Growth analysis of Psophocarpus tetragonolobus* (L.) DC.**

Relative growth rate (RGR) by photoperiod treatments

The results of relative growth rate in this photoperiod experiment showed that the relative growth rate of winged bean was the maximum of 12 hours (0.01193 g $g^{-1}$$day^{-1}$)and the minimum of 10 hours (0.01115g g^{-1} day^{-1}) (Table 2.7, Figure 2.7).

Table 2.5 Comparison of net assimilation rate from pruning treatments

Treatment	Net Assimilation Rate (g cm^{-2} d^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	8.25040	8.37150	4.22050	3.28100	2.18040	5.26076
Vegetative pruning	8.78060	7.22700	7.76740	3.47850	2.19740	5.89018
Reproductive pruning	9.28330	7.21630	5.18150	4.71820	3.31790	5.94344
F- test	**	**	**	ns	**	-
5%LSD	3.80821	4.88210	5.26572	1.95265	2.36017	-
cv%	19.2	28.4	40.7	22.6	40.7	-

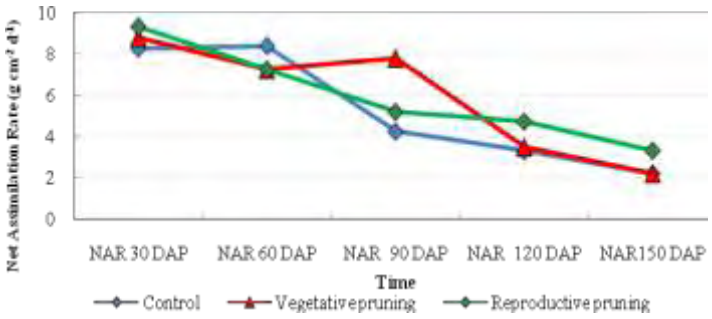

Figure 2.5 Comparison of net assimilation rate from pruning treatments

Table 2.6 Comparison of leaf area ratio from pruning treatments

Treatment	Leaf Area Ratio (cm^2 g^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	30.57330	20.54750	8.39320	5.43387	2.22940	13.4355
Vegetative pruning	33.47650	20.28960	15.59510	4.56440	1.99129	15.1834
Reproductive pruning	37.44570	18.78440	9.91630	6.74460	3.33630	15.2455
F- test	**	**	*	*	*	-
5%LSD	15.87720	15.74120	12.94070	5.28470	2.30830	-
cv%	22.7	35.0	50.6	41.8	40.5	-

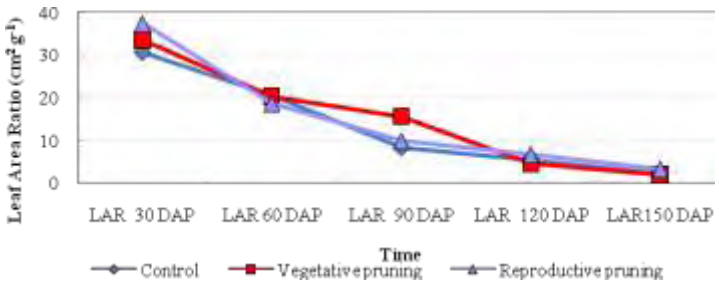

Figure 2.6 Comparison of leaf area ratio from pruning treatments

Net assimilation rate (NAR) by photoperiod treatments

The results of net assimilation rate in this photoperiod experiment showed that the net assimilation rate of winged bean was the highest of control (9.16702 g cm^{-2} day^{-1}) and the lowest of 10 hours (8.53192g cm^{-2} day^{-1}) (Table 2.8, Figure 2.8).

Leaf area ratio (LAR) by photoperiod treatments

The results of leaf area ratio in this photoperiod experiment showed that the leaf area ratio of winged bean was the maximum of control (26.2619 cm^2 g^{-1}) and the minimum of 10 hours (22.8009cm^2 g^{-1}) (Table 2.9, Figure 2.9).

Table 2.7 Comparison of relative growth rate from photoperiod treatments

Treatment	Relative Growth Rate (g g^{-1} d^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	0.021379	0.01872	0.009234	0.005492	0.004587	0.01188
10 hours	0.019558	0.01664	0.011040	0.004462	0.00406	0.01115
11hours	0.020214	0.01504	0.011790	0.006281	0.005215	0.01171
12 hours	0.019886	0.01839	0.012730	0.004573	0.004064	0.01193
F- test	**	**	**	**	*	-
5%LSD	0.005442	0.005783	0.005833	0.003364	0.002583	-
cv%	15.3	3.9	3.8	5.0	6.7	-

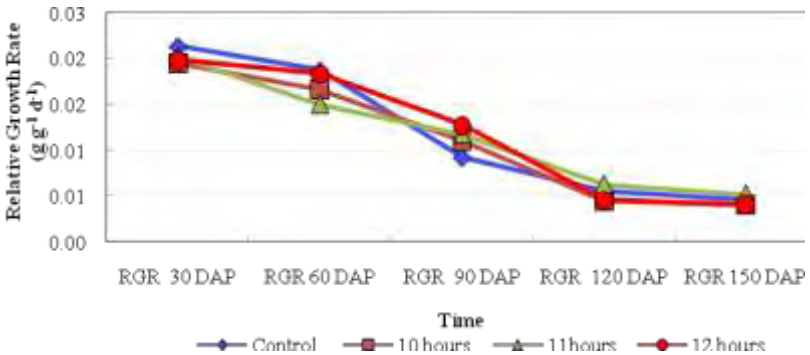

Figure 2.7 Comparison of relative growth rate from photoperiod treatments

Table 2.8 Comparison of net assimilation rate from photoperiod treatments

Treatment	Net Assimilation Rate (g cm^{-2} d^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	20.77590	12.87690	4.93510	3.97350	3.27370	9.16702
10 hours	22.68610	10.28730	4.45000	2.96100	2.27520	8.53192
11hours	20.78760	11.45510	5.37500	4.67920	3.50130	9.15964
12 hours	22.45280	10.09180	5.84030	2.86930	2.40970	8.73278
F- test	**	**	**	**	*	-
5%LSD	8.91913	8.06529	3.48460	2.56570	2.33720	-
cv%	20.4	27.1	22.9	23.3	18.4	-

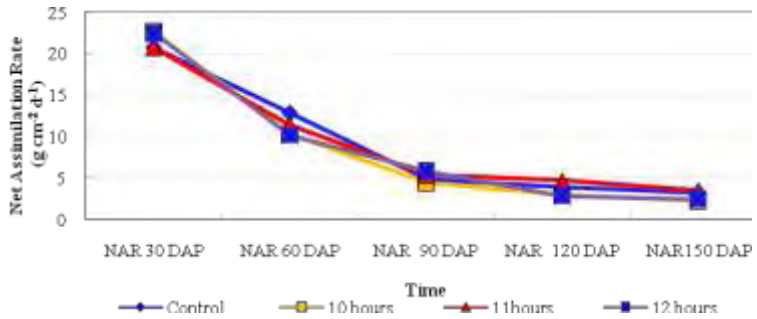

Figure 2.8 Comparison of net assimilation rate from photoperiod treatments

Analyzed results showed that relative growth rate of pruning experiment were the highest (0.012872 g g^{-1} day^{-1}). However, net assimilation rate of photoperiod experiment was the

maximum rate (9.16702 g cm^{-2} day^{-1}). Leaf area ratio results also showed that the highest value was obtained by photoperiod experiment (26.2619 cm^2 g^{-1}) (Table 2.10).

Table 2.9 Comparison of leaf area ratio from photoperiod treatments

Treatment	Leaf Area Ratio (cm^2 g^{-1})					Mean
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	
Control	75.90770	41.02000	7.71112	3.96000	2.71081	26.2619
10 hours	73.86460	28.17830	8.12510	2.24140	1.59490	22.8009
11hours	71.12500	27.63350	10.27740	5.32170	3.31550	23.5346
12 hours	74.95680	31.38580	13.74110	2.20970	1.68480	24.7956
F- test	**	**	**	**	*	-
5%LSD	33.58310	20.07270	10.73720	4.26657	2.90650	-
cv%	24.8	24.1	21.6	25.1	18.4	-

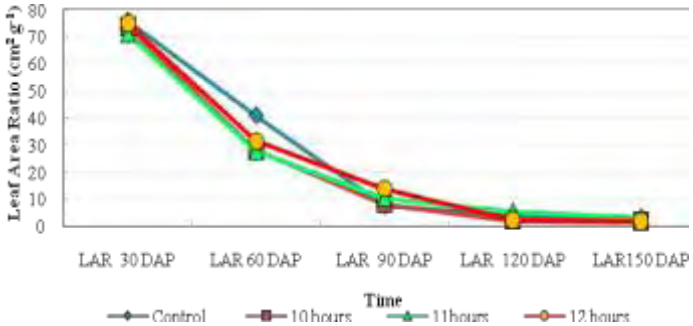

Figure 2.9 Comparison of leaf area ratio from photoperiod treatments

Table 2.10 Comparison of relative growth rate, net assimilation rate and Leaf area ratio from experiments

Experiment	Relative Growth Rate (g g^{-1} d^{-1})	Net Assimilation Rate (g cm^{-2} d^{-1})	Leaf Area Ratio (cm^2 g^{-1})
Fertilizer	0.010898	4.21124	7.95492
Pruning	0.012872	5.94344	15.2455
Photoperiod	0.01193	9.16702	26.2619

Regression, correlation of *Psophocarpus tetragonolobus* (L.) DC.

Regression, correlation analysis on different fertilizer schedule

Regression correlation between plant height and tuber yield, leaf number and tuber yield, leaf area and tuber yield, fresh weight and tuber yield and dry weight and tuber yield were studied from different fertilizer technique.

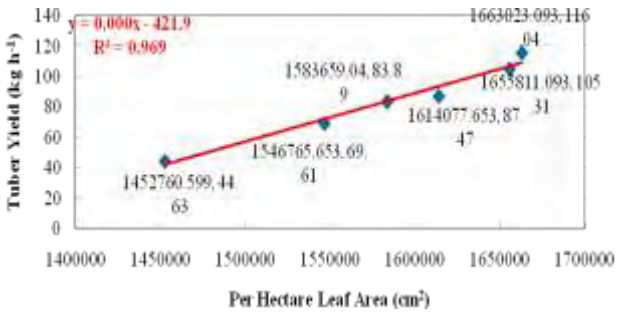

Figure 2.10 Correlation between per hectare leaf area and tuber yield of winged bean upon treating with different fertilizers

Correlation between leaf area and tuber yield

The regression correlation analyses on per hectare leaf area and tuber yield revealed that both factors were significantly correlated each other. Per hectare leaf area and tuber yield were highly correlated owing to their existence on linear position of the trendline and thus R^2 became 0.969 (Figure 2.10).

Correlation between dry weight and tuber yield

The regression correlation analyses on dry weight and tuber yield revealed that both factors were significantly correlated each other. Dry weight and tuber yield were highly correlated owing to their existence on linear position of the trendline and thus R^2 became 0.975 (Figure 2.11).

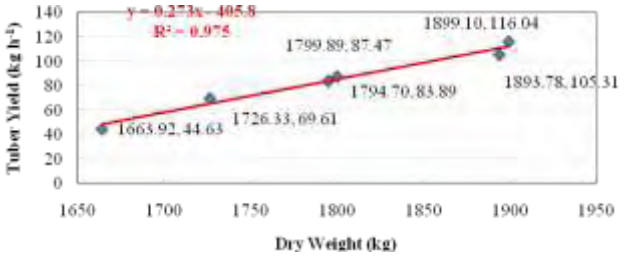

Figure 2.11 Correlation between leaf number and tuber yield of winged bean upon treating with different fertilizers

Regression, correlation analysis on pruning schedule

Regression correlation between leaf area and tuber yield, fresh weight and tuber yield and dry weight and tuber yield were studied from pruning technique.

Correlation between leaf area and tuber yield

The regression correlation analyses on per hectare leaf area and tuber yield revealed that both factors were significantly correlated each other. Per hectare leaf area and tuber yield were highly correlated owing to their existence on linear position of the trendline and thus R^2 became 0.968 (Figure 2.12).

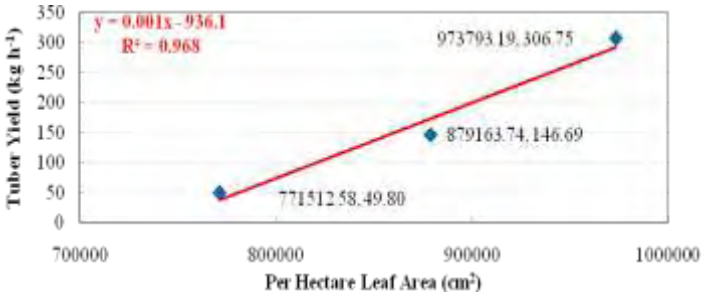

Figure 2.12 Correlation between per hectare leaf area and tuber yield of winged bean upon treating with pruning

Correlation between dry weight and tuber yield

The regression correlation analyses on dry weight and tuber yield revealed that both factors were weakly correlated each other. Dry weight and tuber yield were weakly correlated owing to their existence on linear position of the trend line and thus R^2 became 0.001 (Figure 2.13).

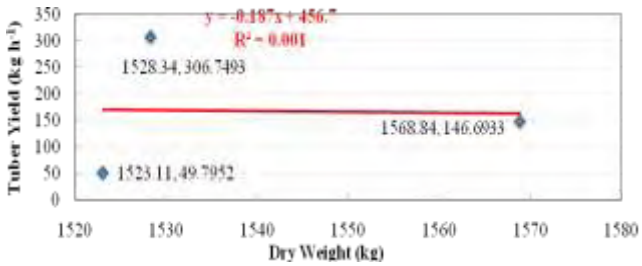

Figure 2.13 Correlation between dry weight and tuber yield of winged bean upon treating with pruning

Regression, correlation analysis on photoperiod schedule

Regression correlation between leaf area and tuber yield, fresh weight and tuber yield and dry weight and tuber yield were studied from photoperiod technique.

Correlation between leaf area and tuber yield

The regression correlation analyses on per hectare leaf area and tuber yield revealed that both factors were significantly correlated each other. Per hectare leaf area and tuber yield were highly correlated owing to their existence on linear position of the trendline and thus R^2 became 0.912 (Figure 2.14).

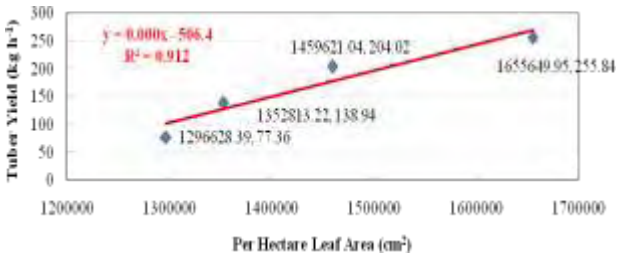

Figure 2.14 Correlation between leaf number and tuber yield of winged bean upon treating with photoperiod

Correlation between dry weight and tuber yield

The regression correlation analyses on dry weight and tuber yield revealed that both factors were weakly correlated each other. Dry weight and tuber yield were weakly correlated owing to their existence on linear position of the trendline and thus R^2 became 0.017 (Figure 2.15).

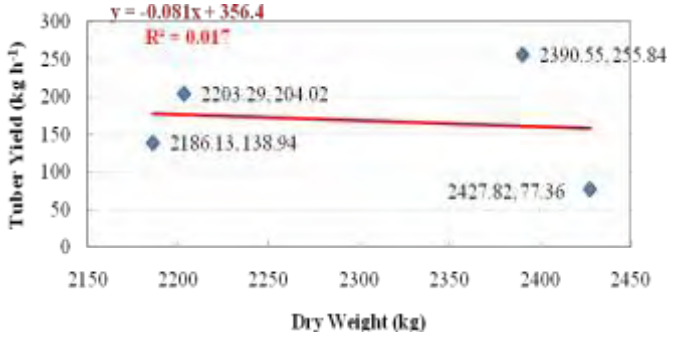

Figure 2.15 Correlation between dry weighty and tuber yield of winged bean upon treating with photoperiod

Discussion and Conclusion

The results of the analyzed growth revealed that the RGR, NAR and LAR of fertilizer treatments, pruning treatments and photoperiod treatments were higher at the first month of growth but these were gradually reduce in the successive months.

Growth analysis is made on the basis of dry weight. Leaf area is increased with time; however, relative growth rate were decreased with time. The rate in the first period of growth was in acceleration but when the plants became aged, the rate was not in acceleration and it was fall down. It may be due to aging. Similarly, leaf area is increased with time; however, net assimilation rate were decreased with time. The rate in the first period of growth was in acceleration but when the plants became aged, the rate was not in acceleration and it was fall down. It may be due to aging. Leaf area is increased with time; however, leaf area ratio was decreased with time. The rate in the first period of growth was in acceleration but when the plants became aged, the rate was not in acceleration and it was fall down. It may be due to aging.

The absolute growth rate is the slope of the curve. Relative growth rate is the slope of a curve that represents logarithmic growth over a period of time. An exponential growth rate is not sustainable over time. The curve typically flattens out, representing saturation in growth at a certain point in time. The crop growth rate calculation is dependent on the values of NAR (Net Assimilation Rate) and LAI (Leaf Area Index) of the crop (http://www.how-745965-calculate-crop-growth).

The RGR of the pruning experiment was the highest. However, the NAR and LAR of photoperiod treatment were higher than that of fertilizer and pruning experiments. It may be due to photoperiod treatment possessed maximum leaf areas than that of fertilizer treatment and pruning (Corre, 1983).

Originally, the relative growth rate was termed the 'efficiency index of dry weight production' (Blackman, 1919). Today, many still believe that relative growth rate is the most important index of productivity (South, 1995).

The dry weight and tuber yield were highly correlated owing to the R^2 value of 0.9 with different fertilizers. The leaf area and tuber yield were highly correlated owing to the R^2 value of 0.9 with pruning. The dry weight and tuber yield were weakly correlated owing to the R^2 value of 0.001 with pruning. The leaf area and tuber yield were highly correlated owing to the R^2 value of 0.9 with photoperiod. The dry weight and tuber yield were weakly correlated owing to the R^2 value of 0.017 with photoperiod. In the present study, the leaf area and tuber yield were highly correlated owing to the R^2 value of 0.9. LAI of a plant has significantly positive and linear relationship ($R^2 = 0.9142$) with yield of winged bean (Motior *et al.,* 1997).

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References

Blackman, V. H. 1919. **The compound interest law and plant growth**. Ann. Bot. 33: 353 - 360.

Corre, W. J. 1983. **Growth and morphogenesis of sun and shade plants**. The combined effects of light intensity and nutrient supply. Acta Bot Neerl 32: 277 - 294.

Duke, J. A. 1981. **Handbook of legumes of world economic importance.** Plenum press, New York, London, pp.345.

Evans, G. C. 1972. **The Quantitative Analysis of Plant Growth**. Blackwell Scientific Publications, Oxford.

Gomez, K. A. and A. A. Gomez. 1984. **Statistical Procedures for Agricultural Research**. 2nd ed. A Wiley-Interscience Publication, John Wiley and Son, Inc. Singapore.

Grime, J. P and R. Hunt. 1975. **Relative growth-rate: its range and adaptive significance in a local flora**. J Ecol 63: 393 - 422.

Khan, T. N. 1976. Papua New Guinea**: A centre of genetic diversity in winged bean (*Psophocarpus tetragonolobus* (L.) DC.)**. Euphytica, 25: 693 - 706.

Khan, T.N. 1978. **Proceedings of International Winged Bean Workshop**, Los Banos, Laguna, Philippines.

Khan, T. N. 1982. **Winged bean production in the tropics**. Western Australian department of agriculture, Rome.

Masefield, G. B. 1973. **'*Psophocarpus tetragonolobus,* a crop with a future'**. Field Crop Abstracts, 26: 157 - 160.

Motior, M. R., W. O. Mohamad, K. C. Wong and Z. H. Shamsuddin. 1997. **Growth analysis and seed yield of winged bean under various support systems**. Thai J. Agric. Sci. 30 (July): 289 - 298.

Noggle, G. R. and G. J. Fritz. 1983. **Introductory Plant Physiology**. Second edition. Prentice-Hall, Inc., Eaglewood Cliffs, New Jersey.

Poorter, H. and C. Remkes. 1990. **Leaf area ratio and net assimilation rate of 24 wild species differing in relative growth rate.** Department of Plant Ecology and Evolutionary Biology, Netherlands.

South, D. B., L. G. Mexal and J. P. Van Buijtenen. 1995. **The relationship between seedling diameter at planting and long term volume growth of loblolly pine seedlings in east Texas**. pp. 192 - 199. *In*: Worrall, J., J. Loo-Dinkins and D. P. Lester (eds.). North Am. For. Biol. Workshop. Univ. British Columbia, Vancouver. pp. 364.

Websites: http://www.how-745965-calaulate-crop-growth