http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 18 (3): 129-134, 2015
ISSN 1028-8880

RESEARCH ARTICLE OPEN ACCESS

DOI: 10.3923/pjbs.2015.129.134

Effect of Bio-fertilizer and Chemical Fertilizer on Growth and Yield in Cucumber (*Cucumis sativus*) in Green House Condition

[1]Kamil Sabier Saeed, [2]Sarkawt Abdulla Ahmed, [3]Ismael Ahmaed Hassan and [3]Pshtiwan Hamed Ahmed
[1]Department of Ornamental Plants, Agricultural Technical Institute of Bakrajo, Sulaimania Polytechnic University, Iraq
[2]Department of Industrial Crops, Agricultural Technical Institute of Bakrajo, Sulaimania Polytechnic University, Iraq
[3]Department of Protected Agriculture Green House, Agricultural Technical Institute of Bakrajo, Sulaimania Polytechnic University, Iraq

ARTICLE INFO
Article History:
Received: December 07, 2014
Accepted: April 25, 2015

Corresponding Author:
Sarkawt Abdulla Ahmed
Department of Industrial Crops,
Agricultural Technical Institute of Bakrajo,
Sulaimania Polytechnic University, Iraq

ABSTRACT
A comparative study on the effect of chemical fertilizers and bio-fertilizers was done on growth and biochemical parameters in cucumber plant (*Cucumis sativus*). An experiment was conducted in Randomized Completely Blocks Design (RCBD) with four replicates. The treatment were (T1 = Control, T2 = Bio-fertilizer, T3 = Chemical and T4 = Combination treatment (biofertilizer and 1/2 chemical)) at Agricultural Technical Institute of Bakrajo, Sulaymania, Iraq during 2014. The bio-fertilizer used in this study was Azoto barwar1 and chemical fertilizer was urea. The material consisted of one cultivar of cucumber sayfe species. The results indicated that there were significant difference between the application bio-fertilizer and chemical fertilizer for yield and yield component traits. Comparison means were conducted by Duncan method. This study indicated that a combination treatment of bio-fertilizer and chemical fertilizer had significant effect and increased the yield and growth traits of cucumber. The correlation analysis showed that the strongest positive relationship was between fruit yield and total fruit weight per plant (r = 0.89). The results of regression analysis by stepwise method for fruit yield in cucumber indicated that individual fruit weigh can justify 50.9% of the fruit yield variation. According to this study using bio-fertilizers has increased yield and yield component of cucumber significantly.

Key words: Bio-fertilizers, chemical fertilizers, compare means, correlation, cucumber, regression analysis

INTRODUCTION

Cucumber (*Cucumis sativus*) is a widely cultivated plant in the gourd family Cucurbitaceae is an agricultural crop that is has demanded all around the year (Peyvast, 2009). Cucumber (*Cucumis sativus* L.) is one of the most important vegetable crops in Kurdistan and Iraq, it is a warm season crop with required growing conditions of 26-30°C and plenty of sunlight has been commonly cultivated in Iraq during the summer and fall as well as in low tunnels and plastic and greenhouses (Matlob *et al*., 1989). In the last century, chemical fertilizers were used in agriculture. Farmers were happy of getting increased yield in agriculture in the beginning. Biofertilizers is a large population of a specific or a group of beneficial microorganisms for enhancing the productivity of soil. In recent decades the use of chemical fertilizers has been a common practice, whereas bio-fertilizers were neglected but nowadays by reason of irregular application of chemical fertilizers and their detrimental effects on human and soil health a lot of emphasis is being

paid and organisms to provide nutrition requirement of plants (Astarai and Kochaki, 1996). A lot of emphasis is being paid to biofertilizers and it has emerged as one of the alternatives to application of chemical inputs for needs of fertilizers. Their use in agriculture in preference to chemical fertilizers offers economic and ecological benefits by improving soil health and fertility. Nitrogen is required for cellular synthesis of enzymes, proteins, chlorophyll, DNA and RNA and is therefore required for plant growth and production of food and feed. Inadequate supply of available N frequently results in plants that have slow growth, depressed protein levels, poor yield of low quality and inefficient water use (Hayat *et al*., 2010). When the chemical fertilizers were first introduced into the agriculture field, most of the problems faced by farmers to increase yield of their plantation have been solved. However, chemical fertilizers slowly started to show their side effect on human and environment (Zakaria, 2009). Bio-fertilizers will be the best solution to replace chemical fertilizers. They are the carrier-based preparations containing mainly effective strains of microorganisms in sufficient number which are useful for nitrogen fixation. Bio-fertilizers have several advantages over chemical fertilizers, they are non pollutant, in-expensive, utilize renewable resources. In addition to their ability of using free available solar energy, also they use atmospheric nitrogen and water. Amongst biofertilizers, Azotobacter strains play a key role in harnessing the atmospheric nitrogen through its fixation in the roots. They have been shown also to improve fertility condition of the soil (Mahato *et al*., 2009). As shown from the result that the bio-fertilizer in all parameter was higher than the control, this indicated that bio-fertilizer helped plant growth and has been able to provide the plant with nitrogen which is one of the most needed nutrients for plant growth. But the lack of other nutrients such as potassium and phosphorus make growth less than that of the growth of plants with a chemical fertilizer (Khan *et al*., 2009). Chemical fertilizers have several negative impacts on environment and sustainable agriculture. Therefore, biofertilizers are recommended in these conditions and growth prompting bacteria have been used as a replacement of chemical fertilizers (Wu *et al*., 2005). Growth promoting bacteria induced increasing plant yield as clone in plants root (Gholami *et al*., 2009) and they include *Azotobacter*, *Azospirillum* and *Pseudomonas* (Zahir *et al*., 2004; Turan *et al*., 2006; Banerjee *et al*., 2006). Biofertilizers are becoming increasingly popular in many countries and for many crops. They are defined as products containing active or latent strains of soil microorganisms, either bacteria alone or in combination with algae or fungi that increase the plant availability and uptake of mineral nutrients (Vessey, 2003). Biofertilizer is a natural product carrying living microorganisms derived from the root or cultivated soil. So they don't have any ill effect on soil health and environment. Besides their role in atmospheric nitrogen fixation and phosphorous, these also help in stimulating the plant growth hormones providing better nutrient uptake and increased tolerance towards drought and moisture stress. A small dose of biofertilizer is sufficient to produce desirable results because each gram of carrier of biofertilizers contains at least 10 million viable cells of a specific strain (Anandaraj and Delapierre, 2010). Biofertilizer is a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth promoting substances. Biofertilizers can be expected to reduce the use of chemical fertilizer and pesticides. The microorganisms in biofertilizers restore the soil's natural nutrient cycle and build soil organic matter. Biofertilizers can symbiotically associate with plant root. Involved microorganisms could readily and safely convert complex organic material to simple compounds, so that plant could easily utilize them. The microorganism improves soil fertility. It maintains the natural habitat of the soil. It has been shown that it increases crop yield by 20-30%, replace chemical nitrogen and phosphorus by 25% in addition to stimulating plant growth. Finally it could provide protection against drought and some soil borne diseases. Biofertilizers in comparison with chemical fertilizers have enormous economic and environmental advantages. The biological fertilizers have been shown to have a special importance as appropriate replacement for chemical fertilizers, through to improving of soil fertility and providing nutrition requirement of plant (Shahdi Komalah, 2010).

The purpose of this study was to compare different levels of chemical and biofertilizer on growth and yield of cucumber, also evaluate the relationship between quantitative traits of cucumber. One of the goals was to examine morphological traits effects on fruit yield using multivariate analysis and to investigate the improvement of cucumber nutrition and improvement of produce of highest yield via application of biofertilizers so if possible to able to recommend this fertilizers as replacement to the chemical fertilizers.

MATERIALS AND METHODS

Morphological characters: An experiment was conducted in Randomized Complete Blocks Design (RCBD) with four replication and four treatment (T1 = Control, T2 = Biofertilizer, T3 = Chemical and T4 = Biofertilizer, 1/2 chemical) at Agricultural Technical Inistitute of Bakrajo, Sulaymania, Iraq during 2014. The material consisted of one cucumber sayfe species. The biofertilizer used was azoto barwar1. The seeds sown in the spring season and cucumber were grown in four row plots, each plot included two ridges and each ridge was 2.5 m in length and 50 cm apart. Agronomic characteristics included plant height, number of fruit per plant, individual fruit weight per plant, total fruit weight per plant, fruit size and fruit yield per green house.

Data were recorded on 4 competitive plants of each plot was calculated for the entire plot. Selected chemical and physical characteristics of experimental the soil are presented in Table 1.

Chemical component of plants: Jones and Case (1990), reported a block-digestion procedure using a mixture of HNO_3 and $HClO_4$ for digestion of plant samples. Vanadomolybdophosphoric acid method was used to determine P concentration in plant extraction (Kuo, 1996). For determination of total nitrogen Kjeldahl digestion was used. Bremner (1996), reported the use of Kjeldahl method for determination of total N in soils (note: the same method used for N in plant).

Data analysis: For quantitative characters, data were analyzed for simple statistics using the compare means and correlation analysis and regression analysis with the help of computer software SPSS.

RESULTS

Analysis of variance: Result of analysis of variance (Table 2) showed that there were significant difference between the application bio-fertilizer and chemical fertilizer for yield and yield component traits. The data showed high potential of these fertilizers to improve cucumber yields. The results indicated that the effect of bio fertilizer and chemical fertilizer on characters such as, individual fruit weight, total fruit weight, fruit size and fruit yield per green house was significant at 1% probability and plant height and potassium content at 5% probability and effect of bio fertilizer and chemical fertilizer on characters number of fruit per plant, nitrogen content and phosphor content was not significant (Table 2).

Compare means: Compare means for studied traits in cucumber conducted by Duncan method. The results indicated that bio-fertilizer and 1/2 chemical fertilizer treatments had significant difference for yield and growth traits and the highest yield and growth traits of cucumber was obtained with this treatment (Table 3). The best treatment was bio-fertilizer and 1/2 chemical fertilizers that have the highest led to individual and total fruit weight and fruit yield per green house.

Plant height: The results of mean comparing of traits are shown in Table 3. There were significant difference between the majorities of the traits exist. The data recorded in Table 3 showed that plant height increased across the treatments; there were some significant differences in the plant heights. The minimum plant height was recorded in the biofertilizer, 1/2 chemical fertilizers and the maximum plant height was recorded in chemical fertilizers.

Individual fruit weight: The data recorded in Table 3 showed that individual fruit weight increased across the treatments; there were significant differences in the individual fruit weight. The minimum individual fruit weight was recorded in the biofertilizer and the maximum individual fruit weight was recorded in bio-fertilizer, 1/2 chemical fertilizers.

Total fruit weight: The results of mean comparing of traits are shown in Table 3 between all treatments; significant difference exist. The data recorded in Table 3 showed that the

Table 1: Soil physical and chemical properties

Properties	Sample value
Soil texture	Clay
Sand (%)	12.17
Silt (%)	45.72
Clay (%)	42.11
EC	0.36
pH	7.00
N (%)	0.12
Available P (ppm)	56.97
Soluble K^+ (Meq L^{-1})	0.24
Soluble Na^+ (Meq L^{-1})	0.22
Soluble Ca^{2+} (Meq L^{-1})	12.30
Soluble Mg^{2+} (Meq L^{-1})	3.30
Cl^- (Meq L^{-1})	2.50
$CaCO_3$ (%)	22.50
HCO_3 (Meq L^{-1})	2.50
CO_3^{2-}	0.00
o.m (%)	2.06

Table 2: Analysis of variance (RCBD) for studied traits

		MS								
S.O.V	df	Plant height	No. of fruit per plant	Individual fruit weight per plant per gram	Total fruit weight per plant per gram	Size fruit	N (%)	P (%)	K (%)	Fruit yield per green house
Replication	3	20.242	0.677	4.983	488.258	14.229	0.212	0.001	0.012	19.630
Treatment	3	306.470*	8.125	32.102**	281834.610**	205.896**	0.336	0.001	0.046*	11274.200**
Error	9	78.650	3.006	3.974	1193.264	11.562	0.621	0.001	0.012	47.661

*, **Significant differences

Table 3: Mean comparing in cucumber for studied treatments

	Traits name								
Treatment	Plant height	No. of fruit per plant	Individual fruit weight per plant per gram	Total fruit weight per plant per gram	Size fruit	N (%)	P (%)	K (%)	Fruit yield per green house/kg
Control	271.32^{b}	30.05^{a}	76.54^{b}	2149.1^{c}	75.5^{a}	2.86^{a}	0.206^{ab}	1.13^{a}	4298.3^{c}
Bio-fertilizer	265.12^{ab}	32.29^{ab}	73.33^{a}	2170.3^{b}	92.7^{c}	3.00^{a}	0.231^{b}	1.70^{b}	4340.6^{b}
Chemical	273.25^{a}	31.94^{ab}	77.67^{bc}	2193.6^{a}	87.0^{b}	2.72^{a}	0.203^{ab}	1.51^{ab}	4387.2^{a}
Bio-fertilizer, 1/2 chemical	253.82^{b}	33.49^{b}	80.16^{c}	2671.7^{d}	85.5^{b}	2.40^{a}	0.190^{a}	1.36^{ab}	5343.4^{d}

Significant differences at $p<0.05$ are indicated with different letter (a-b)

total fruit weight increased across the treatments, there were significant differences in the total fruit weight. The minimum total fruit weight was recorded in the control and the maximum total fruit weight was recorded in bio-fertilizer, 1/2 chemical fertilizers.

Fruit size: The data recorded in Table 3 showed that fruit size increased across the treatments; there were some significant differences in the fruit size. The minimum fruit size was recorded in the control and the maximum fruit size was recorded in bio-fertilizer.

Potassium content: The data recorded in Table 3 showed that potassium content increased across the treatments; there were some significant differences in the potassium content. The minimum potassium content was recorded in the control and the maximum potassium content was recorded in bio-fertilizer.

Fruit yield per green house: The data recorded in Table 3 showed that fruit yield per green house increased across the treatments; there were significant differences in the fruit yield per green house. The minimum total fruit yield per green house was recorded in the control and the maximum fruit yield per green house was recorded in biofertilizer, 1/2 chemical fertilizers. The fruit yield in cucumber has been significantly influenced by the application of bio fertilizer with 1/2 chemical at all stages of plant growth. The treatment receiving bio-fertilizer 100 g ha^{-1} barwar1 azetobacter and chemical fertilizer urea recorded the highest fruit yield production increase over control.

Correlation analysis: The knowledge of the relationship among plant characters is useful while selecting traits for yield improvement. To determine association between studied traits we calculated coefficient of correlation. Data showed in Table 4 indicated that fruit yield had the strongest relation with total fruit weight per plant (r = 0.89) also found strong association between individual fruit weight per plant. After this traits the fruit size (r = 0.446) and potassium content (r = 0.439) showed the most correlation with fruit yield (Table 4). Significantly positive correlations were also observed for individual fruit weight per plant and total fruit weight per plant. In general a significant positive correlation was observed between some of the traits. However, negative correlation was also found among certain characters in the present study. The results are in agreement with Serquen *et al*. (1997) who reported a positive and significant correlation between fruit number per plant and branch number per plant, fruit number per node had negative and significant correlation with branch number per plant and shoot diameter, however a positive correlation with vigor of plant was found. Cramer and Wehner (1998) reported that most correlations between yield components and components and fruit yield were weak and strong correlations varied between populations, seasons and yield components. Selection weakened indicated many strong correlations between yield components and between yield and components. Wehner *et al*. (2000) reported a positive and significant correlation (r = 0.7*) between number of branches per plant with total yield. Correlations between fruit number per node and branch per plant and shoot diameter revealed that an increase in fruit number per node resulted in a decrease in branch number per plant and shoot diameter and an increase in vigor of plant. Although correlation between fruit yield and branch number per plant was weak in this study, however Wehner and Guner (2004) showed that among vegetative traits, number of nodes/branch and branches/plant were correlated with early yield, indicating that early yield was higher when the plants were able to grow longer branches and having more nodes.

Regression analysis: The results of regression analysis by stepwise method for fruit yield in cucumber (Table 5) indicated that individual fruit weigh can justify 50.9% of the fruit yield variation. So it might this was be seen that traits the most important component of fruit yield in cucumber. Fruit size and potassium content made 90.04% of the fruit yield variation. Presence of high significance and the positive correlation, between individual fruit weight and fruit size with

Table 4: Correlation analysis of studied traits in cucumber

Traits name	Plant heigh	No. of fruit per plant	Individual fruit weight per plant	Total fruit weight per plant	Size of fruit	N (%)	P (%)	K (%)	Fruit yield per green house
Plant height	1								
No. of fruit per plant	-0.206	1							
Individual fruit weight per plant	-0.217	0.388	1						
Total fruit weight per plant	-0.507*	0.197	0.509*	1					
Fruit size	-0.341	0.339	-0.193	-0.446	1				
N (%)	-0.148	0.328	-0.191	-0.397	0.172	1			
P (%)	0.378	0.159	-0.306	-0.348	0.252	0.382	1		
K (%)	0.251	0.271	-0.183	-0.439	0.484	0.275	0.469	1	
Fruit yield per green house	-0.508*	0.197	0.508*	0.89**	0.446	0.397	0.348	0.439	1

*, **Significant correlations

Table 5: Regression analysis of studied traits in cucumber

Traits name	Regression coefficient	t-test	Significant level	Coefficient of determination component	Coefficient of cumulative determination
Intercept	2/36	3.742	0.006		
Individual fruit weight per gram	0.194	1.010	0.003	50.90	50.90
Fruit size	0.779	3.494	0.004	27.80	78.70
Potassium content	0.092	0.672	0.008	11.34	90.04

fruit yield indicate that the results of the stepwise regression were in harmony with the correlation results. The stepwise regression analysis showed that improvement of fruit weight per plant and fruit size could be a good breeding way for increasing fruit yield. Based on regression analysis, if one had to choose just one trait for predicting fruit grade weights due to lack of resources, total fruit weight with fruit number could be used.

DISCUSSION

Our results in Table 3 showed that combination use of biofertilizers and chemical fertilizers has increased fruit yield (5343.4 kg) individual fruit weight and total fruit weight and fruit size biofertilizer was the highest. It can be concluded that barwar1 azotobacter with urea treatment had the most yield. Mahfouz and Sharaf-Eldin (2007) have indicated that the use of biofertilizer combined with chemical fertilizers has increased the shoot fresh weight and shoot dry weight of corn. The problem associated with the use of chemical fertilizers is becoming a global one and researchers are working all over the world to find a solution to this problem. The excessive use of chemical fertilizer in agriculture causes environmental problems including soil, physical destruction and nutrient imbalance.

The main advantage of bio-fertilizer is that it does not pollute the soil and also does not show any negative effect to environment and human health. This can be overcome either by adding chemical fertilizers containing nitrogen only for plants which are chemical treated or add other nutrients such as potassium and phosphorus to plant inoculated with bacteria. Finally obtaining fewer amounts of healthy products with less environmental disturbances is preferred over obtaining higher amount of non-healthy products with more environmental disturbances.

CONCLUSION

According to this study using biofertilizers has increased yield and yield component of cucumber significantly. In other words, presences of these bacteria have increased cucumber growth factors. The result from the present study indicated that yield and growth of cucumber, have been affected by the inoculation with *Azotobacter chroococcum*, because these biofertilizers can fix the atmospheric nitrogen in soil. The seeds inoclutated with *Azotobacter chroococcum* had beneficiary response on growth and yield of cucumber by 5- 30%. As a result, biological fertilizers can be recommended for the sake of achieving the higher quality production. The traits fruit weight and fruit size could be used for the selection of batter yielding lines under Kurdistan region. The results of compare means indicated that combination of bio-fertilizer and 1/2 chemical fertilizer treatments maximum fruit yield was recorded.

REFERENCES

Anandaraj, B. and L.R.A. Delapierre, 2010. Studies on influence of bioinoculants (*Pseudomonas fluorescens*, *Rhizobium* sp., *Bacillus megaterium*) in green gram. J. Biosci. Technol., 1: 95-99.

Astarai, A.R. and A. Kochaki, 1996. Application of permanent biological fertilizers. Ferdosi Mashhad University, Mashhad, Iran.

Banerjee, M., R.L. Yesmin and J.K. Vessey, 2006. Plant-Growth Promoting Rhizobacteria as Biofertilizers and Biopesticides. In: Handbook of Microbial Biofertilizers, Rai, M.K. (Ed.). Taylor and Francis, USA., ISBN: 9781560222705, pp: 137-181.

Bremner, J.M., 1996. Nitrogen Total. In: Methods of Soil Analysis: Part 3. Chemical Methods, Sparks, D.L. (Ed.). American Society of Agronomy-Soil Science Society of America, Madison, WI., USA., ISBN-13: 978-0891188254, pp: 1085-1121.

Cramer, C.S. and T.C. Wehner, 1998. Fruit yield and yield component means and correlations of four slicing cucumber populations improved through six to ten cycles of recurrent selection. J. Am. Soc. Hortic. Sci., 123: 388-395.

Gholami, A., S. Shahsavani and S. Nezarat, 2009. The effect of Plant Growth Promoting Rhizobacteria (PGPR) on germination, seedling growth and yield of maize. World Acad. Sci. Eng. Technol., 49: 19-24.

Hayat, R., S. Ali, U. Amara, R. Khalid and I. Ahmed, 2010. Soil beneficial bacteria and their role in plant growth promotion: A review. Annal. Microbiol., 60: 579-598.

Jones, J.B. and V.W. Case, 1990. Sampling, Handling and Analyzing Plant Tissue Samples. In: Soil Testing and Plant Analysis, Westerman, R.L., J.V. Baird, N.W. Christensen, P.E. Fixen and D.A. Whitney (Eds.). 3rd Edn., Soil Science Society of America, Madison, Wisconsin, ISBN: 9780891187936, pp: 389-427.

Khan, A.A., G. Jilani, M.S.Akhtar, S.S. Naqvi and M. Rasheed, 2009. Phosphorus solubilizing bacteria: Occurrence, mechanisms and their role in crop production. J. Agric. Biol. Sci., 1: 48-58.

Kuo, S., 1996. Phosphorus. In: Methods of Soil Analysis Part 3: Chemical Methods. Sparks, D.L. (Ed.). Soil Science Society of America, USA., ISBN-13: 978-0891188254, pp: 869-920.

Mahato, P., A. Badoni and J.S. Chauhan, 2009. Effect of azotobacter and nitrogen on seed germination and early seedling growth in tomato. Researcher, 1: 62-66.

Mahfouz, S.A. and M.A. Sharaf-Eldin, 2007. Effect of mineral vs. biofertilizer on growth, yield and essential oil content of fennel (*Foeniculum vulgare* Mill.). Int. Agrophys., 21: 361-366.

Matlob, A.N., E. Sultan and K.S. Abdul, 1989. Vegetable Production Part one and Two. Dar Al-Kutub Publication, Iraq, (In Arabic).

Peyvast, G.A., 2009. Vegetable Production. Danesh Pazir Publication, Rasht, Iran.

Serquen, F.C., J. Bacher and J.E. Staub, 1997. Mapping and QTL analysis of horticultural traits in a narrow cross in cucumber (*Cucumis sativus* L.) using random-amplified polymorphic DNA markers. Mol. Breed., 3: 257-268.

Shahdi Komalah, A., 2010. The investigation of effects of there promoting biological organic products and plant growth regulator on the qualitative and quantitative yield of rice (*Oriza sativa*). Research Report of Special Project in Years 2008, 2009, Rice Research Institute, Iran.

Turan, M., N. Ataoglu and F. Sahin, 2006. Evaluation of the capacity of phosphate solubilizing bacteria and fungi on different forms of phosphorus in liquid culture. J. Sustainable Agric., 28: 99-108.

Vessey, J.K., 2003. Plant growth promoting rhizobacteria as biofertilizers. Plant Soil, 255: 571-586.

Wehner, T.C., N.V. Shetty and R.L. Clark, 2000. Screening the cucumber germplasm collection for combining ability for yield. HortScience, 35: 1141-1150.

Wehner, T.C. and N. Guner, 2004. Growth stage, flowering pattern, yield and harvest date prediction of four types of cucumber tested at 10 planting dates. Acta Horticulturae, 637: 223-230.

Wu, S.C., Z.H. Cao, Z.G. Li, K.C. Cheung and M.H. Wong, 2005. Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: A greenhouse trial. Geoderma, 125: 155-166.

Zahir, Z.A., M. Arshad and W.T. Frankenberger Jr., 2004. Plant growth promoting rhizobacteria: Applications and perspectives in agriculture. Adv. Agron., 81: 97-168.

Zakaria, A.A.B., 2009. Growth optimization of potassium solubilizing bacteria isolated from biofertilizer. Engineering Thesis, Faculty of Chemical and Natural Resourses Engineering, University Malaysia, Pahang, Malaysia.