

Dry Matter Yield and Growth of Mixed Forage in Corn-Soybean Intercropping Systems Affected by Different Fertiliser Types

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ABSTRACT

Fertilisation plays a major role in growth and dry matter yield of forage. A field experiment was conducted over two planting seasons on the same site to determine the effect of different fertilisers on growth of corn and soybean and dry matter yield of mixed forage. Six fertiliser treatments with three replications were arranged in randomised complete block design. The treatments were 100% chemical fertiliser (NPK), 100% poultry manure (PM), 50% PM, combined application of 50% PM with biofertiliser, sole biofertiliser and untreated (control). The results in the first season showed that 100% NPK produced the highest dry matter yield (13.83 t ha⁻¹) but in the second season, 100% PM produced a similar dry matter yield (9.91 t ha⁻¹) with 100% NPK (9.84 t ha⁻¹). Sole biofertiliser produced the same yield as 50% PM. The results indicate that 100% PM at the rate of 6.3 t ha⁻¹ significantly increased dry matter yield of mixed forage.

Key words: Poultry manure, biofertiliser, chemical fertiliser, dry matter yield, mixed forage.

INTRODUCTION

Chemical fertilisers have been a major nutrient source to promote and sustain crop production. However, continuous use of chemical fertilisers has contributed to environmental problems. Poultry manure and biofertilisers are nutrient sources that can substitute the use of chemical fertilisers. Nutrients from poultry manure are gradually released into the soil as decomposition of the manure progresses. The slow process of decomposition improves soil fertility and extends nitrogen availability for plant uptake as well as minimises nutrient losses through leaching or runoff after rainfall (Zublena *et al.* 1997). Biofertilisers are now of interest as they contain live microorganisms that can help to increase availability and uptake of mineral nutrients for plants through nitrogen fixation, solubilisation of soil minerals, organic matter decomposition, and organic waste degradation.

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Biofertilisers promote root growth and morphology and build up long term soil productivity and crop health. Integration of poultry manure and biofertilisers has been suggested as a soil fertiliser management strategy especially to increase productivity and long-term maintenance of soil health (Wu *et al.* 2015; Adesemoye and Kloepper 2009). The potential of poultry manure and biofertilisers has not been fully utilised due to lack of knowledge in handling manure systems and appropriate application rates for biofertilisers under field conditions. Therefore, the objective of the experiment was to determine the effect of poultry manure and biofertilisers on growth of corn and soybean and dry matter yield of mixed forage (corn-soybean) in comparison with chemical fertilisers.

MATERIALS AND METHODS

Study Site

This study was conducted at Field 2, Faculty of Agriculture, Universiti Putra Malaysia (UPM), Malaysia at a latitude of 3°0'29.53"N and a longitude of 101°42'14.54"E. The experiments were carried out from March to May 2014 and repeated from November 2014 to January 2015. The area experiences a hot and humid climate with an annual rainfall of 2911 mm. Figure 1 shows the distribution of rainfall from January 2014 to January 2015. The temperature ranges from 24.3°C to 35.1°C and relative humidity from 91.5% to 94.7% (Figure 2). The samples for soil analysis were taken from the top soil layer (0 to 30 cm) at random by walking in a zig-zag pattern in the entire plot before the experiment. All the soil samples were mixed thoroughly for a composite lab sample. The soil texture of the experimental site was sandy loam. The details of soil chemical characteristics for both seasons are shown in Table 1

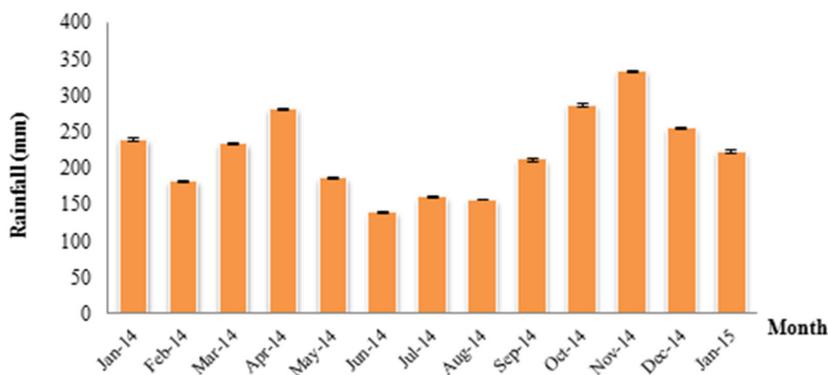


Figure 1. Distribution of rainfall in Serdang, Malaysia

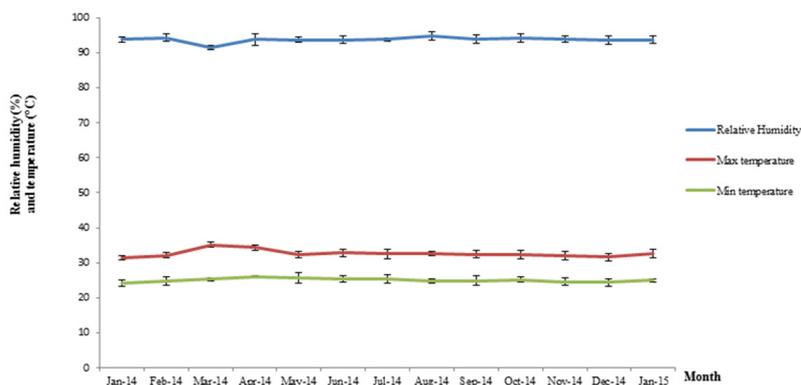


Figure 2. Temperature and relative humidity in Serdang, Malaysia.

TABLE 1
Two-season analysis of chemical characteristics of soil at experimental sites

Soil characteristics	Season 1	Season 2
Organic carbon (%)	2.03 ± 0.07	3.02 ± 0.09
pH	6.43 ± 0.39	6.03 ± 0.16
EC (ds m ⁻¹)	3.01 ± 0.14	2.75 ± 0.23
K (ppm)	13.04 ± 0.14	14.55 ± 0.53
N (%)	0.17 ± 0.03	2.05 ± 0.21
P (ppm)	22.12 ± 0.68	24.87 ± 0.64

Fertiliser treatments consisted of chemical fertiliser, organic fertiliser, biofertiliser and untreated plot as control (Table 2). The required levels of N, P and K to support the yield goals for mixed forage production were 140 kg N ha⁻¹, 130 kg P ha⁻¹ and 80 kg K ha⁻¹. The first treatment (T1) was chemical fertiliser that supplied N, P and K in the form of urea, triple super phosphate (TSP) and muriate of potash (MOP), respectively. The whole of P and K and half dosage of N fertiliser were applied at planting time. Another half of N fertiliser was given at the eighth leaf stage of corn. The second and third treatments were based on organic fertiliser application. The organic fertiliser used in this study was processed poultry manure. Poultry manure in powder form was applied 10 days before planting. Based on the chemical analysis, every 40 kg of the manure contained 4.5% N, 2.5% P, 2% K₂O, 2% CaO and 1% MgO. The second treatment (T2) was poultry manure at the rate of 6.3 t ha⁻¹ which supplied 140 N kg ha⁻¹. The third treatment (T3) was poultry manure at the rate of 3.15 t ha⁻¹ where the N rate was reduced by half of T2. This treatment was included to determine whether the use of biofertiliser (T4) can supplement nutrients when poultry manure is reduced by half the rate. The half rate of poultry manure was applied 10 days before the planting time. The biofertiliser consisted of a mixture of six bacterial strains without additional nutrients. These z bacterial strains were nitrogen-fixing bacteria and a phosphorus

solubilising bacteria. The biofertiliser mixture in solution form was prepared in the Soil Microbiological Laboratory, Department of Land Management, UPM and applied twice. The first application was prior to planting where corn and soybean seeds were inoculated with the biofertiliser mixture as seed treatment. The washed seeds were immersed in a biofertiliser solution for 60 min after which they were sown in the field. The second biofertiliser application was on soil surface at 7 days after seed emergence. The biofertiliser was sprayed at a rate of 10 ml plant⁻¹. The fifth treatment (T5) comprised of solely biofertiliser without chemical fertiliser or poultry manure. The sixth treatment (T6) was an untreated plot that served as the control.

Statistical Data Analysis

All data were analysed with analysis of variance (ANOVA). SAS Software Package (Version 9.4) was used to perform an analysis of variance appropriate for randomised complete block design with three replications. The Tukey Honest Significant Differences (HSD) test was used to compare treatment means at 0.05 probability levels.

RESULTS AND DISCUSSION

Dry Matter Yield

There were significant effects of season, fertiliser and interaction between seasons and fertilisers on dry matter yield of corn, soybean and the mixture of corn and soybean (mixed forage) (Table 2).

TABLE 2
Mean square of fertiliser effects and season effects on dry matter yield of corn, soybean and mixed forage

Source of variance	df	DM yield corn	DM yield soybean	DM yield mixed forage
Season	1	1.36*	1.31*	21.76*
Block	2	0.07	0.12	0.21
Season*block	2	0.07	0.06	0.16
Fertilizer	5	11.77*	8.13*	46.09*
Season*fertiliser	5	1.24*	0.74*	2.73*
Error	20	0.04	0.03	0.05
cv (%)		0.32	0.34	0.37

Notes: *significant at $P \leq 0.05$. DM- Dry matter

TABLE 3
Effects of different fertilisers on dry matter yield of corn, soybean and mixed forage for both seasons

Treatment	Corn (t ha ⁻¹)		Soybean (t ha ⁻¹)		Mixed forage (t ha ⁻¹)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
100% NPK	7.70 ± 0.14a	5.52 ± 0.06a	6.14 ± 0.14a	4.36 ± 0.08a	13.83 ± 0.07a	9.84 ± 0.06a
100% PM	5.59 ± 0.04b	5.70 ± 0.21a	4.23 ± 0.13b	4.44 ± 0.24a	9.82 ± 0.16b	9.91 ± 0.08a
50% PM	3.85 ± 0.02c	3.70 ± 0.17b	2.90 ± 0.09d	2.81 ± 0.11b	6.75 ± 0.07c	5.13 ± 0.22b
50% PM + BIO	3.61 ± 0.15cd	3.98 ± 0.15b	3.22 ± 0.11c	3.07 ± 0.02b	6.83 ± 0.24c	5.37 ± 0.14b
BIO	3.85 ± 0.18c	3.53 ± 0.06b	2.87 ± 0.08d	2.56 ± 0.07bc	6.71 ± 0.25c	5.24 ± 0.16b
Control	3.03 ± 0.08d	2.86 ± 0.05c	2.20 ± 0.10e	2.03 ± 0.06c	5.23 ± 0.17d	4.35 ± 0.07c
<i>P Value</i>	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Notes: Means values ± S. E. followed by the same letter in the same column are not significantly different based on Tukey HSD test at 5% level. NPK - Chemical fertiliser; PM - Poultry manure; BIO - Biofertiliser

Dry matter yield of corn was significantly affected by fertiliser applications and seasons. In season 1, the highest DM yield of corn was found from 100% NPK treatment compared to other treatments. This was followed by application of poultry manure at the rate of 6.3 t ha⁻¹. Reducing poultry manure to half reduced the DM of corn. Applications of biofertiliser individually or in combination with poultry manure were not able to improve the plant biomass. In season 2, greater dry matter of corn was found in 100% NPK and 100% PM treatments compared to other treatments. No differences in DM were observed in treatments 50% PM, 50% PM + BIO and sole BIO. The DM yield of corn from control plot was significantly lower than other fertiliser applications. Dry matter yield of soybean was significantly affected by fertiliser applications and season. In season 1, the highest yield was obtained from NPK fertiliser followed by 100% PM. Combination of 50% PM with BIO produced greater DM yield than 50% PM and sole BIO. In season 2, greater dry matter of soybean was found in 100% NPK and 100% PM treatments compared to other treatments. The DM yields of soybean were not significantly different among 50% PM, 50% PM with BIO and sole BIO. The lowest DM yield of soybean was obtained from control plots.

Dry matter yield of mixed forage was significantly affected by fertiliser applications and season. In season 1, DM yield of mixed forage followed the trend of 100% NPK > 100% PM > 50% + BIO, sole BIO and 50% PM > control. In season 2, the highest plant biomass was found in 100% PM followed by 100% NPK treatments compared to other treatments. Applications of biofertiliser individually or in combination with poultry manure were not able to improve the plant biomass. The DM yield of mixed forage from control plot was significantly lower than other fertiliser applications.

These results demonstrate the effect of fertilisers and interaction between fertilisation and season. In season 1, NPK gave the highest DM yields for corn, soybean and mixed forage. NPK application was expected to show excellent results

over PM and BIO because it is a fast-release fertiliser and a highly water-soluble macronutrient that immediately meets the plant nutrient requirements compared to PM and BIO. Decomposition of organic matter from PM usually needs a longer time to fulfil the nutrient requirement for plant growth. Although PM used was based on nitrogen crop requirement, the proportion of other major nutrients in PM was not ready to be taken by plant and still waited for the decomposition process to be accomplished. However, application of 100% PM showed improvements in DM yield of corn, soybean and mixed forage in season 2 which were not significantly different from 100% NPK. The previous application of PM from season 1 is believed to have created residual effects in the experimental site. This was due to the content of N, P and K of the experimental site prior to season 2 being greater than in season 1 (Table 1). Higher availability of nutrients for plant uptake in the following season was associated with mineralisation of manure and the consequent release of nutrient elements during microbial decomposition (Witkamp 1971). Savithri *et al.* (1991) reported that 6.25 t ha⁻¹ of poultry manure was used in the first season of sorghum. They found a significant residual effect on succeeding crop yields with increasing content of soil nutrients. Another study by Liu *et al.* (2011) reported that organic manure cumulatively increased the content of organic matter in the soil when fully decomposed. They found the highest DM of stevia during seedling stage to be influenced by chemical fertilisers but noted that organic manure was capable of producing higher DM yield than chemical fertilisers at the harvest stage. Moreover, Nsa *et al.* (2013) found that poultry manure application gave a similar yield for sweet potato as chemical fertiliser application. In this case, sweet potato is a perennial shrub and the process of organic matter decomposition may have enough time to enhance soil fertility and result in increased crop yield. In addition, other researchers have reported the benefit of poultry manure on rice production. Nitrogen uptake in rice was increased under poultry manure application thus producing an equal yield as chemical fertilisers (Xu *et al.* 2008).

In both seasons, application of BIO was found to be inadequate to meet the nutritional needs of crops. BIO did not directly supply any nutrients to the plant but enhanced nutrient availability by fixing the atmospheric nitrogen, solubilising soil minerals and decomposing the organic matter in the soil. These natural processes take time to release the nutrients and might be too slow to meet crop requirements within a short time, hence some nutrient deficiency may occur. Our results revealed that sole BIO application produced DM yields of corn, soybean and mixed forage below that of NPK and 100% PM applications, but produced similar DM yields with 50% PM application in both seasons. This showed that bacterial inoculants in BIO application were capable of supporting plant growth nutrients, similar to the half rate application of PM. However, no further increase in DM yield was observed when BIO was combined with 50% PM (50% PM + BIO). This finding is associated with the ability of bacterial inoculants to be active when combined with PM application. Competition for available substrate resources between bacterial inoculants with indigenous microorganisms

originating from PM may possibly affect bacterial activity. According to Ho and Ko (1985), the ability of biofertilisers to improve the yield is dependent on the activity of bacteria in fixing atmospheric nitrogen, decomposing organic matter, mineralising and solubilising minerals in the soil for plant uptake. This is in line with Veen *et al.* (1997) who noted that bacteria activity increased when they have the capability to compete with other microorganisms for limited resources such as organic carbon, inorganic nitrogen and phosphorus as well as biological space for microbial growth. Araujo *et al.* (2015) reported that the performance of inoculant bacteria in biofertilisers differ depending on the condition of the cultivation area. Their activity will be slow if the soil contains too much competition due to limited resources and space for microbial growth in the plant rhizosphere (Baghdadi 2015).

Growth

Significant effects were found for fertilisers, season and their interactions on plant height and leaf area index (LAI) of corn and soybean (Table 4).

TABLE 4
Mean square from ANOVA of plant height and LAI of corn and soybean

Source of variance	df	Plant height corn	Plant height soybean	LAI corn	LAI soybean
Season	1	1871.57*	96.86*	0.13*	0.16*
Block	2	3.60	0.60	0.00	0.00
Season*block	2	1.60	0.73	0.00	0.00
Fertilizer	5	3356.23*	1191.17*	0.37*	0.19*
Season*fertiliser	5	184.07*	55.00*	0.02*	0.04*
Error	20	3.74	1.87	0.00	0.00
cv (%)		0.15	0.16	0.12	0.07

*significant at P<0.05

TABLE 5
Plant height of corn and soybean as affected by different fertiliser treatments

Treatment	Season 1		Season 2	
	Corn (cm)	Soybean (cm)	Corn (cm)	Soybean (cm)
100% NPK	197.0 ± 0.58a	109.0 ± 1.00a	170.6 ± 0.22a	94.5 ± 1.04a
100% PM	184.0 ± 0.58b	98.7 ± 0.33b	174.0 ± 1.15a	96.8 ± 0.44a
50% PM	153.0 ± 1.15c	78.0 ± 0.58c	147.2 ± 0.44b	75.6 ± 0.71b
50% PM+ BIO	152.3 ± 0.33c	78.3 ± 0.67c	146.6 ± 2.34b	76.2 ± 0.22b
BIO	152.3 ± 1.76c	76.3 ± 0.88c	121.8 ± 0.42c	73.5 ± 0.76b
Control	127.0 ± 1.15d	64.0 ± 1.15d	119.0 ± 0.63c	68.0 ± 0.50c
<i>P Value</i>	<.0001	<.0001	<.0001	<.0001

Notes: Means values ± S. E. followed by the same letter in the same column are not significantly different based on Tukey HSD test at 5% level. NPK- Chemical fertiliser; PM- Poultry manure; BIO- Biofertiliser

TABLE 6
LAI of corn and soybean as affected by different fertiliser treatments

Treatment	Season 1		Season 2	
	Corn	Soybean	Corn	Soybean
100% NPK	2.6 ± 0.03a	3.2 ± 0.01a	2.4 ± 0.02a	2.8 ± 0.01a
100% PM	2.4 ± 0.02b	3.1 ± 0.04b	2.4 ± 0.02a	2.8 ± 0.01a
50% PM	2.1 ± 0.01c	2.8 ± 0.01c	2.0 ± 0.01b	2.8 ± 0.02a
50% PM+ BIO	2.1 ± 0.01c	2.8 ± 0.01c	2.1 ± 0.01b	2.8 ± 0.02a
BIO	2.2 ± 0.01c	2.8 ± 0.02c	1.9 ± 0.01c	2.8 ± 0.02a
Control	1.8 ± 0.01d	2.5 ± 0.001d	1.7 ± 0.02d	2.4 ± 0.02b
<i>P Value</i>	<.0001	<.0001	<.0001	<.0001

Notes: Mean values ± S. E. followed by the same letter in the same column are not significantly different based on Tukey HSD test at 5% level. NPK- Chemical fertiliser; PM- Poultry manure; BIO- Biofertiliser

The study results showed that the highest plant heights of corn and soybean were obtained from NPK followed by 100% PM in season 1. Reducing the application of PM by half resulted in decreased plant height of corn and soybean compared to 100% PM. Application of BIO individually or in combination with PM did not result in increased plant height. In season 2, the highest plant heights of corn and soybean were found from the application of 100% NPK and 100% PM. No differences in plant height were observed in 50% PM, 50% PM + BIO and sole BIO treatments. The plant height of both crops from the control plot was significantly lower than other fertiliser applications. The results for LAI also showed that NPK produced superior mean values compared to other fertilisers for both crops in season 1. This was followed by the application of 100% PM. However, LAI of corn from 100% NPK and 100% PM was greater compared to other treatments in season 2. No differences in LAI were observed in 50% PM, 50% PM + BIO treatments. The control plot produced the lowest LAI compared to all treatments. For soybean, no significant difference among fertiliser treatments was observed with all treatments significantly producing higher LAI than control.

The trend of plant height was similar with DM yield where the highest plant heights were produced by NPK in season 1. Application of NPK was better than 100% PM because NPK provided all three major nutrients in water soluble form and was readily available for plant uptake. According to Bilal *et al.* (2015), plant height was most responsive to nutrients especially nitrogen and each successive increase in nitrogen dose significantly produced taller plants. In season 2, there was no difference in plant height between 100% PM and NPK. PM worked quite differently from NPK. Nutrients from PM are derived from the natural process of organic matter decomposition which takes time to release the nutrients for growth of corn and soybean. By the time these nutrients change to water soluble forms, plant roots are ready to absorb all the soluble nutrients (Adeola *et al.* 2011). The current study showed that the macronutrient content in the soil prior to season 2 was greater than in season 1. The contents of N, P and K were increased from 0.17%, 0.0022% and 0.0013% to 2.05%, 0.0025% and

0.0015% respectively. PM ensured a long supply season of nutrients compared to NPK. Application of NPK and 100% PM did not only enhance plant height but also produced a similar trend for LAI. This finding is in agreement with earlier studies conducted on various crops (Bondada *et al.* 1996; Gardner and Tucker 1967; Muharam *et al.* 2014; Shahin *et al.* 2013). Nitrogen is a nutrient essential to meristematic and photosynthetic activity by regulating cell division, stem elongation and leaf expansion (Bakry *et al.* 2009; Bilal *et al.* 2015). An increasing rate of nitrogen tends to produce more leaves, therefore generating a high value of LAI (Bilal *et al.* 2015). Treatments receiving BIO (either alone or in combination with PM) produced significantly shorter plants and lower LAI compared to NPK and 100% PM. This could be attributed to BIO being a slow-release fertiliser across growth stages (Chen 2006). The major nutrients may not exist in BIO to sustain optimum crop growth in the field, but the bacterial inoculants in BIO are still able to enhance the availability of nutrients in the soil of the control plot, resulting in a similar crop performance to the plot treated with half rate of PM.

CONCLUSIONS

Application of 100% PM showed almost a similar effect to conventional fertiliser (100% NPK) which significantly increased DM yield of mixed forage and enhanced growth characteristics in corn and soybean. PM at the rate of 6.3 t ha⁻¹ supplying 140 N kg ha⁻¹ has the potential to support good growth of both crops; it is available in the local market and is affordable compared to chemical fertilisers. Thus, application of PM is recommended for a corn-soybean intercropping system. Applications of BIO individually or in combination with half rate of PM did not improve DM yield of mixed forage, compared to 6.3 t ha⁻¹ of PM.

ACKNOWLEDGEMENTS

The authors gratefully extend their appreciation to the staff of the Department of Land Management and Crop Science, Faculty of Agriculture, Universiti Putra Malaysia for their support throughout this research.

REFERENCES

- Adeola, R. G., H. Tijani-Eniola and E.A. Makinde. 2011. Ameliorate the effects of poultry manure and NPK fertilizer on the performance of pepper relay cropped with two cassava varieties. *Global Journal of Science Frontier Research* 11(9): 6–9.
- Adesemoye, A. O. and J.W Kloepper. 2009. Plant-microbes interactions in enhanced fertilizer-use efficiency. *Applied Microbiology and Biotechnology* 85(1): 1–12.
- Araujo, J., C.A. Díaz-Alcántara, E.Velázquez, B.Urbano and F. González-Andrés. 2015. *Bradyrhizobium yuanmingense* related strains form nitrogen-fixing symbiosis with *Cajanus cajan* L. in Dominican Republic and are efficient biofertilizers to replace N fertilization. *Scientia Horticulturae* 192: 421–428.

- Baghdadi, A. 2015. Intercropping of corn and legume with application of chicken manure and crop combination ratios to increase yield and quality of corn-legume forage (Doctoral dissertation). Universiti Putra Malaysia.
- Bakry, M. A. A., Y.R.A. Soliman and S.A.M. Moussa. 2009. Importance of micronutrients, organic manure and biofertilizer for improving maize yield and its components grown in desert sandy soil. *Research Journal of Agriculture and Biological Sciences* 5(1): 16–23.
- Bilal, M., M. Ayub, M. Tariq, M. Tahir and M.A.Nadeem. 2015. Dry matter yield and forage quality traits of oat (*Avena sativa* L.) under integrative use of microbial and synthetic source of nitrogen. *Journal of the Saudi Society of Agricultural Sciences* 16(3) : 1–6.
- Bondada, B. R., D.M. Oosterhuis, R.J. Norman and W.H. Baker. 1996. Canopy photosynthesis, growth, yield, and boll 15N accumulation under nitrogen stress in cotton. *Crop Science* 36: 127–133.
- Chen, J. 2006. The combined use of chemical fertilizers and organic fertilizers and/or biofertilizer for crop growth and soil fertility. In: *International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use*, Vol. 16, p. 20. Bangkok Thailand: Land Development Department.
- Gardner, B. R. and T.L. Tucker. 1967. Nitrogen effects on cotton: I. Vegetative and fruiting characteristics. *Soil Science Society of America Journal* 31(6): 780-785.
- Ho, W. C. and W.H. Ko. 1985. Soil microbiostasis: effects of environmental and edaphic factors. *Soil Biology and Biochemistry* 17(2): 167–170.
- Liu, X., G. Ren and Y.Shi. 2011. The effect of organic manure and chemical fertilizer on growth and development of *Stevia rebaudiana* Bertoni. *Energy Procedia* 5: 1200–1204.
- Muharam, F. M., K.F. Bronson, S.J. Maas and G.L. Ritchie. 2014. Inter-relationships of cotton plant height, canopy width, ground cover and plant nitrogen status indicators. *Field Crops Research* 169(3): 58–69.
- Nsa, O. S., D.P. Okon and S.P. Roberts. 2013. Comparative effects of chicken manure and NPK on the yield of *Ipomoea batatas*. *Journal of Agricultural and Crop Research* 1(6): 90–93.
- Savithri, P. S. Subbiah, P. Malarvili and A. Gopalsamy. 1991. Effect of coir pith based poultry litter on yield and nutrient uptake by sorghum cowpea cropping

- system. In: *Proceedings of Seminar on Utilization of Coirpith in Agriculture*, 20th November, TNAU, Coimbatore, pp. 1-11.
- Shahin, M. G., R.T. Abdrabou, W.R. Abdelmoemn and M.M. Hamada. 2013. Response of growth and forage yield of pearl millet (*Pennisetum galucum*) to nitrogen fertilization rates and cutting height. *Annals of Agricultural Sciences* 58(2): 153–162.
- Veen, J. A. V., L.S.V. Overbeek and J.D.V. Elsas. 1997. Fate and activity of microorganisms introduced into soil. *Microbiology and Molecular Biology Reviews* 61(2): 121–135.
- Witkamp, M. 1971. Productivity of forest ecosystems. In: *Forest Soil Microflora and Mineral Cycling*. Paris, pp. 413–424.
- Wu, Y., C. Zhao, J. Farmer and J. Sun. 2015. Effects of bio-organic fertilizer on pepper growth and Fusarium wilt biocontrol. *Scientia Horticulturae* 193: 114–120.
- Xu, M., D. Li, J. Li, D. Qin, Y. Kazuyuki and Y. Hosen. 2008. Effects of organic manure application with chemical fertilizers on nutrient absorption and yield of rice in Hunan of Southern China. *Agricultural Sciences in China* 7(10): 1245–1252.
- Zublena, J. P., J. C. Barker and T.A. Carter. 1997. Poultry manure as a fertilizer source. North Carolina Cooperative Extension Service. Retrieved 23 January 2017 from <http://www.soil.ncsu.edu/publications/Soilfacts/AG-439-05/>

