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Enhancing the Yield and Profitability of Peanut (*Arachis hypogaea* L.) to Application of Different Organic Foliar Fertilizers

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Abstract

One strategy to produce enough, healthy, and safer products is to apply the best practices by using locally produced organic bio-fertilizer as nutrients for the crops. This study aimed to evaluate the effects, determine the appropriate, and assess the profitability of using locally produced organic foliar fertilizers on peanut production. The treatments designated as follows: T_1 - Control (no application), T_2- Power grow 100 ml/16li H_2O, T_3 - Vermi tea 100 ml/16li H_2O, T_4 - Poultry litter tea100 ml/16li H_2O, and T_5 - Wood vinegar 100 ml/16li H_2O. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each replication was divided into five (5) treatment plots measuring twelve (12) m^2 separated by 1 m alleyways between replications and treatment plots to facilitate farm operations and data gathering. The treatment plants were sprayed with foliar fertilizer six times at weekly intervals, starting two weeks up to the pick of the peanut plants' last flowering. Results showed that peanut plants flowered early when applied with poultry litter tea. Likewise, highest leaf area index (LAI) and weight of 1,000 seeds (g) when applied with Power grow foliar fertilizer. Application of poultry litter tea, power grow and wood vinegar obtained the highest seed yield of 1.31-1.470 t ha^{-1} and achieved the highest grain yield tha^{-1}. Thus, gave the high gross margin of PhP36,723-48,965.00 ha^{-1} among the treatments. In terms of pest incidence, no serious presence of insects and diseases were noted; thus, a high to moderate resistance rating was obtained in all treatment plants.

Keywords: Best practices, local organic produced, sustainable, productivity and income

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INTRODUCTION

Peanut (*Arachis hypogaea* L.) is also named groundnut, which belongs to the family Leguminosae that produces underground fruits called pods (Aboelill et al., 2012). The Philippines is consumed as boiled peanut, peanut oil, peanut butter, roasted peanuts, peanut bars, and candies. Groundnuts are considered a vital source of nutrients, calories, minerals, and antioxidants, vitamins essential for optimum health. It is one of the legumes considered as an excellent intercrop to corn, sorghum, sugarcane. Planting peanut help enrich the soil nutrients due to its ability to fix atmospheric nitrogen. Peanut, as a legume, needs only a small amount of N because of its ability to fix nitrogen from the atmosphere (Jordan et al., 2017). Organic substances can be used as fertilizer because it contains essential nutrients like nitrogen, phosphorus, potassium, calcium, iron, manganese, zinc, copper, magnesium, and protein substances that stimulate plant metabolism. Organic fertilizers are an excellent substitute for inorganic fertilizer in crops that require less nutrients for their growth and development. The use of organic foliar fertilizer is beneficial. It contains microorganisms such as bacteria that hastens organic materials' mineralization and makes it available to plants through the foliar spray (Yansong et al., 2009).

Foliar application of nutrients is a feasible, economically viable, and environmentally friendly approach to nutrient management. It is often the most effective and economical way to correct plant nutrient deficiencies at critical growth stages. Reports indicated that foliar application promoted root absorption of the same nutrient or other nutrients by improving root growth and increasing nutrients' uptake (Meena et al., 2007). The foliar application also overcomes the physiological disturbances caused by adverse soil conditions that hamper mobility and nutrient absorption. Foliar spraying of N, Mn, Cu, and B on several crops indicated beneficial effects.

Kalinova, et al. (2014) indicated that foliar application of 1% KCl obtained the best results in groundnuts. Manure tea as foliar fertilizer corrects the plant's deficiencies because the nutrients enter the plant through the stomata and cuticle. Foliar application of fertilizer is an effective way of correcting soil nutrient deficiency when plants cannot absorb directly from the soil (Jordan et al., 2017). The foliar application provides a quicker response and more effective for some nutrients like NPK than soil-applied fertilizer (Brandenburg, et al., 2019). Foliar feeding is often the most effective and economical way to correct plant nutrient deficiencies. It has become an established procedure in crop production to increase yield and improve the product's quality. Since there is a need to look for cheap and ecologically safe plant growth enhancers as a supplement to inorganic fertilizer for peanut production, Power grows, vermi tea, poultry litter tea, and wood vinegar can be used for this purpose. Hence, this study was conducted to evaluate the effects of different organic foliar fertilizers on peanut growth and yield.

MATERIALS and METHODS

Experimental Area, Design, and Soil Sampling

An area of 226.0 m^2 Umingan clay loam soil (FAO, 2016) is located at the Agronomy Experimental Area College of Agriculture and Food Science, Visayas State University, Baybay City, Leyte. The experimental area has a GPS coordinates of 10^o44' 59.8668" N, 124^o47' 38.1264" E. This was plowed and harrowed twice using a tractor-drawn implement at weekly intervals.

These were done to allow the weeds to decompose, pulverize the soil, level the field, and provide time for weed seeds to germinate and incorporate them into the soil. Furrows were constructed at a distance of 0.5 m apart.

Soil samples were collected randomly from the experimental area before plowing. These were composited, air-dried, pulverized, sieved (2 mm wire mesh) and submitted to the Central Analytical Service Laboratory (CASL), PhilRootcrops, Visayas State University, Visca, Baybay City, Leyte. The soil samples were analyzed to determine the soil pH Potentiometric method (1:2.5 soil water ratio), % organic matter (Modified Walkley-Black method), total N by (micro Kjeldal method), extractable P, and exchangeable K (ammonium acetate extraction method). For the final soil analysis, three samples were collected from each treatment plot after peanut harvest. Collected soil samples were air-dried, composited, and processed to determine the same soil parameters mentioned above. The experiment was laid out in an RCBD (Randomized Complete Block Design) with three replications. Each replication was divided into five treatment plots, measuring 3 m × 4 m with 1 m alleyways between replications and 0.50 m between treatment plots to facilitate farm operations and data gathering. The different treatments are as follows: T_1- Control (no application), T_2 -100ml/16li H_2O Power Grow, T_3 - 100ml/16li H_2O Vermi tea, T_4 -100ml/16li H_2O Poultry litter tea, T_5 -100ml/16li H_2O Wood vinegar.

Organic Foliar Fertilizer Preparation

Vermicast was purchased at the Eco FARMI, and Poultry litter at the Department of Animal Science, both from Visayas State University, Baybay City, Leyte. While Wood vinegar was procured at Balinsasayao Research Station, Balinsasayao, Abuyog, Leyte. Vermitea, and Poultry litter tea were prepared through fermentation for three (3) weeks. The mixture of 1:1 ratio was prepared by mixing 1 liter of unchlorinated water and 1 kg of Vermicast in a clean bucket, covered with cheesecloth to prevent insects and other organisms' entry while allowing air circulation inside of the bucket and was mixed thoroughly and was fermented for 3 weeks. The mixture was then filtered, and the filtrates were placed in clean containers and stored under ambient conditions. (Krawczyk, 2018). All organic foliar fertilizer samples were collected and brought to the Central Analytical Service Laboratory (CASL), PhilRootcrops, Visayas State University, Visca, Baybay City, Leyte for the analysis of NPK contents.

Organic Foliar Fertilizer Application

Spraying of foliar fertilizers (100 ml of fermented organic foliar fertilizers per 16 liters of water) was done six (6) times at weekly intervals starting two (2) weeks after sowing (DAS) up to the peak of the last flowering of peanut plants.

Spraying of organic foliar fertilizers was done when the wind is expected, and an enclosure was provided around the treatment plants to avoid contamination of other treatments.

Harvesting was done when 90% of the plants reached maturity. The pods became firm at this stage, and the crop exhibited yellowing to brown of matured leaves. One row on each side and two end hills served as border plants leaving two border rows in each treatment plot. Extra care was observed to minimize the damage of pods. After this, peanut pods were handpicked, washed, and sundried to attain a moisture content of 14% using a moisture meter.

Data Gath

For agronomic characteristics: days from sowing to flowering, days from sowing to maturity, plant height (cm) Leaf area index (LAI). LAI was computed using the formula:

$$\text{LAI} = \frac{\text{Total leaf area (TLA)}}{\text{Ground area (2,500 cm}^2\text{)}}$$

Whose: $\text{TLA} = \sum (L \times W \times 0.552)$

Fresh herbage weight (t ha-¹) was gathered and converted to tons per hectare using the formula:

$$\text{Herbage yield (t ha}^{-1}\text{)} = \frac{\text{Plot herbage yield (kg)}}{\text{Harvestable area (7.2 m}^2\text{)}} \text{ x } \frac{\text{10,000 m}^2\text{ ha}^{-1}}{\text{1,000 kg t}^{-1}}$$

For yield and yield components: number of pods per plant, number of seeds per pod, weight (g) of 1,000 seeds, dry pod yield (t ha^{-1}), total seed yield (t ha^{-1}), and harvest index (H.I.).

$$\text{Harvest Index (H.I.)} = \frac{\text{Dry weight of seeds (g) 3 sample plants}}{\text{Dry herbage yield (g)+Dry weight of seeds (g)}}$$

Cost and return analysis: Gross Income = Pod Yield (kg ha^{-1}) x Current Market Price kg^{-1} of Peanut

Gross Margin = Gross Income – Total Variable Cost

Climatic data such as total monthly rainfall (mm), average daily minimum and maximum temperatures (°C), and relative humidity (%) throughout the conduct of the experiment were obtained from the records of the Philippine Atmospheric, Geographical and Astronomical Service Administration (PAGASA) Station, Visayas State University, Visca, Baybay City, Leyte. Data were computed, and analysis of variance (ANOVA) was done using the Statistical Tool for Agricultural Research (STAR). A comparison of means was made using Tukey's Test.

RESULTS and DISCUSSION

Table 1 shows the total monthly rainfall (mm), average daily minimum and maximum temperatures (˚C) and relative humidity (%) throughout the study obtained from the Philippine Geophysical, Astronomical, Services, Administration (PAGASA) Station, Visayas State, University, Visca, Baybay City, Leyte, the Philippines from May to August 2019.

The total weekly rainfall (mm) recorded throughout the study ranges from 80-116 mm with a total rainfall of 410.22 mm. AVRDC, (2006) mentioned that the water requirement of the peanut plant for its normal growth and development is about 500-600 mm per cropping season.

In this study, the amount of rainfall is insufficient; hence, the plants were watered every morning and late afternoon during the early stage of the crop to meet the water requirement needed by the peanut plants. The average daily minimum and maximum temperature, and the % R.H. recorded ranged from 25.49-32.83 ˚C and 77%, respectively. The temperature requirement ranges from 25 to 33ºC, and % R.H. is 75-85% (AVRDC, 2006). Thus, the temperature (^{0}C) and % R.H. were at an optimum level; thus, flowering and pod filling processes of crops were favorable resulted in high total grain yield (tha^{-1}) except on the plant not applied with any fertilizer as the control plants.

Table 1. Climatic data obtained from the PAGASA Station of VSU, Visca, Baybay City, Leyte

Period (Monthly)	Total Rainfall (mm)	Temperature (°C)		Relative Humidity (%)
		Minimum	Maximum	
May	80.95	25.52	34.23	78.00
June	116.21	26.43	32.76	80.00
July	115.46	25.43	31.57	75.00
August	97.60	24.60	32.76	76.00
Total	410.22	-	-	-
Mean	-	25.49	32.83	77.00

Organic Foliar Fertilizer analysis

The nutrient content analysis of the organic foliar fertilizer used in the study is presented in Table 2. These locally and commercially produced organic foliar fertilizer varies on the macronutrient contents. Hence, the result's efficiency was also varied as observed and discussed in the agronomic and yield components parameters (Table 4 and 5).

Table 2. Analysis result of the nutrient content of the different locally and commercially produced organic foliar fertilizers

Foliar Fertilizer	Total N	Available P ($mgkg^{-1}$)	Exchangeable K ($me100g^{-1}$)
Power grows	2.35	1.44	1.75
Vermi tea	0.90	0.72	1.47
Poultry litter tea	1.26	0.83	0.99
Wood vinegar	0.80	0.71	0.98

Soil Properties

Initial soil analysis taken from the experimental area showed that the soil had a pH of 6.20 with 1.351 % organic matter (O.M.), 0.081 % total N, 1.694 mg kg^{-1} available P and 0.641 me 100 g^{-1} exchangeable K (Table 3). The result indicated that the soil was slightly acidic, with a meager amount of organic matter, very low in total nitrogen, low in available phosphorus, and a high amount of exchangeable K (Landon, 1991).

The results showed that the soil's pH, organic matter, and total N were increased while available P, and exchangeable K decreased for the final soil analysis. The increase in soil pH relative to the initial soil analysis could be due to the release of organic substance and basic cations upon decomposition of some plant herbage and residues from the previous cropping. The decrease in available P and exchangeable K at final soil analysis is due to the consumption of the crop for pod and seed development as well as the losses due to leaching thereby, decreasing the nutrients described above, (Marschner, 1997).

Table 3. Soil test results before planting and after harvest of peanut using different organic foliar fertilizers

Treatment	Soil pH (1:2:5)	O.M. (%)	Total N	Available P ($mgkg^{-1}$)	Exchangeable K ($me100g^{-1}$)
Initial	6.00	1.34	0.081	1.694	0.641
Final					
T_1- Control	6.45	1.455	0.077	1.649	0.550
T_2- Power grow	6.68	1.383	0.099	1.526	0.512
T_3- Vermi tea	6.58	1.420	0.083	1.649	0.538
T_4- Poultry litter tea	6.31	1.416	0.086	1.597	0.623
T_5-Wood vinegar	6.42	1.643	0.108	1.289	0.635
Mean	6.49	1.443	0.091	1.850	0.618

Agronomic Characteristics

Table 4 shows the agronomic characteristics of peanut as influenced by the application of different organic foliar fertilizers. Analysis of variance revealed that the only number of days from planting to flowering and leaf area index (LAI) differed significantly and not on the other growth parameters. Peanut treated with poultry litter tea flowered significantly early than plants applied with Power grow, Vermi tea, Wood vinegar and the control. According (Jordan et al. (2017), poultry tea provides a higher amount of N nutrients (2.35-1.44-1.75 N, P_2O_5, K_2O kg ha^{-1}, Table 2), which enhanced the early flowering of the peanut plants. Moreover, plants treated with Power grow had a broader leaf area index of (1.14) than other treatment plants. Power grow to have higher N content (Table 2) than the other foliar fertilizers, which stimulates root development and improves leaf development. Lalog, (2011) mentioned that Power grow a certified organic foliar fertilizer that rich in macronutrients, micronutrients, and humic acid. It is environment friendly, helps the growth of various crops and vegetables while improving the quality of soil, and increases crop growth and yield.

Table 4. Agronomic characteristics of different organic foliar fertilizers on the growth and yield of peanut

Treatment	Number of days from Sowing to		Plant Height (cm)	Leaf Area Index	Fresh Herbage Yield (tha^{-1})
	Flowering	Maturity			
T_1- Control	31.00c	99.00	115.47	0.40c	13.46
T_2- Power grow	28.00b	98.00	122.57	1.34a	14.76
T_3- Vermi tea	28.67b	98.00	114.47	0.56d	15.28
T_4- Poultry litter tea	27.00a	99.00	110.43	1.04b	14.00
T_5-Wood vinegar	29.33bc	99.00	114.50	0.52c	12.07
Mean	28.80	98.62	115.49	0.70	13.91
C. V. %	2. 61	0.34	6.33	9.39	9.17

Means within the same column followed by common letters and without letter designations are not significantly different at the 5% level, HSD test

Yield and Yield Components and Harvest Index

Yield, yield components, and harvest index of peanut as influenced by applying different organic foliar fertilizer are presented in Table 5. Analysis of variance revealed that weight (g) of 1,000 seeds, the weight of dry pods and seed yields (tha-^{1}) differ significantly among treatment plants. Plants applied with Power grow obtained significantly heavier weights of 1,000 seeds of 590.47g, dry pod (2.07 t ha^{-1}), and seed yield (1.35 t ha^{-1}) comparable to plants sprayed with poultry litter tea and wood vinegar as foliar fertilizers. On the other hand, plants with Vermi tea got the lowest 1,000 seed weight with 495.93g, comparable to the plants not sprayed with any foliar fertilizer as control plants of 471.23g. This result can be attributed to the positive effect of Power grow to stimulate fruiting and produce larger with quality of harvested fruits. It also enhanced the quality and quantity of fruits, thus, increases the harvest yield. Studies show that using Power grow foliar fertilizer is the quick absorption of nutrients, thus, addressing nutrient deficiency very quickly. Likewise, Lalog (2011) explained further that Power grows by increasing photosynthetic activity in the leaves, stimulating the need for water by the leaves. Thus, there is an increase in water uptake by the plants' vascular system, which increases the quantity and quality of crop yield. On the other hand, the application of diluted chicken manure tea as soil drenched combined with beneficial and effective microorganisms could be used as a substitute with inorganic fertilizers. Likewise, Wood vinegar also improves plant metabolism and contributes to higher fruit production. It also Strengthen the process of photosynthesis and increases the content of chlorophyll of the plants. Hence, it increases yield production of the crops (Mungkunkamchao, et al., 2013).

Table 5. Yield, yield components, and harvest index of peanut using different organic foliar fertilizers

Treatment	No. of Pods^{-1}	No. of Seeds^{-1}	Weight of 1000 seeds (g)	Dry Pod Yield (tha^{-1})	Seed Yield (tha^{-1})	Shelling Percentage (%)	Harvest Index (H.I.)
T_1- Control	12.23	2.12	471.23c	1.49b	0.87c	59.65	0.67
T_2- Power grow	12.80	2.29	590.47a	2.07a	1.35a	65.05	0.56
T_3- Vermi tea	12.47	2.24	495.93bc	1.64b	1.18b	72.27	0.59
T_4- Poultry litter tea	13.00	2.17	574.37a	2.10a	1.47a	69.77	0.74
T_5- Wood vinegar	12.57	2.07	547.73ab	2.01a	1.31a	64.78	0.65
Mean	12.61	2.18	515.95	1.86	1.38	60.30	0.64
C.V. %	8.37	7.80	6.60	16.37	18.23	12.61	18.44

The same column, followed by a common letter and without letter designations, is not significantly different at 5% level, HSD.

Incidence of Insect Pest and Diseases to Peanut

The incidence of insect pests and diseases to peanut plants is presented in Table 6. Treatment plants showed high resistance to insect pests and moderately resistant to *cercospora* leaf spot diseases. They produce a reasonable higher yield in all treatment plots. Moreover, based on peanut plants' reaction (variety NSIC Pn_{18}) to insect pests and diseases, this variety is recommended to the farmers because it is high to moderately resistant to pests.

In effect, they can minimize the cost of pesticides. These results confirm the statement of Brandenburg, et al. (2019), it is important to test the resistance of the crop to pests and diseases before recommending it to the farmers and other interested clientele.

Table 6. Incidence of insect pests and diseases of peanut (NSIC Pn_{18}) variety applied with organic foliar fertilizers

Treatment	Insect Pests Damage	Reaction	Disease (CLS)	Reaction
T_1- Control	1.40	highly resistant	2.33	moderately resistant
T_2- Power grow	1.70	highly resistant	1.67	moderately resistant
T_3- Vermi tea	2.30	moderately resistant	1.23	moderately resistant
T_4- Poultry litter tea	2.20	moderately resistant	2.07	moderately resistant
T_5-Wood vinegar	2.30	moderately resistant	2.20	moderately resistant

Rating Scale for insect pest and diseases (NCT, 2017)

Damage Index	**Insects Leaf Damage (%)**	**Reaction**	**Damage Index**	**Range of Average Scale for Diseases**	**Description**
1	1-20	Highly resistant			
2	21-40	Moderately resistant	1	1.00	Highly resistant
3	1-60	Moderately susceptible	2	1.01-2.49	Moderately resistant
4	61-80	Susceptible	3	2.50-3.49	Intermediate resistant
5	80-100	Highly susceptible	4	3.50-4.49	Moderately susceptible
			5	4.50-5.00	Highly susceptible

Cost and Return Analysis

Cost and return analysis of peanut production as influenced by different organic foliar fertilizers is presented in Table 7. Plants applied with poultry litter tea obtained the highest gross margin of PhP 48,695.00 ha^{-1}, followed by plants applied with Power grow at PhP37,910.00 ha^{-1}, Wood vinegar at PhP36,723.00 ha^{-1}, and Vermi tea at PhP34,206.00 ha^{-1}. While control plants gave the lowest gross margin of PhP18,750.00 ha^{-1}. Variation in the treatments' gross margin was due to the differences in seed yield and cost of production, specifically on the cost of organic foliar fertilizers.

Table 7. Cost and return analysis ha^{-1} of different organic foliar fertilizers on the growth and yield of peanut

Treatment	Seed Yield (kg ha^{-1})	Gross Income (PhP)	Total Variable Cost (PhP)	Gross margin (PhP)
T_1- Control	0870c	43,500.00	24,750.00	18,750.00
T_2- Power Grow	1,350a	67,500.00	29,590.00	37,910.00
T_3- Vermitea	1,180b	59,000.00	24,794.00	34,206.00
T_4- Poultry tea	1,470a	73,500.00	24,805.00	48,695.00
T_5-Wood Vinegar	1,310a	65,500.00	28,777.00	36,723.00

*Calculation of gross income is based on the current price of dried peanut @Php50 kg

CONCLUSION

1. Plants with commercially produced (Power grow) foliar fertilizers achieved the highest LAI value and weight (g) of 1,000 seeds. While plants applied with Poultry litter, tea flowered the peanut plants early. Likewise, locally available organic foliar fertilizers (Poultry litter tea and Wood vinegar) can compete with commercial organic foliar fertilizers (Power grow) in enhancing the total pod and seed yields (t ha^{-1}).
2. In terms of total seed yield (tha^{-1}), poultry litter tea and Wood vinegar tea obtained higher yields comparable to commercially produced organic foliar fertilizer (Power grow).
3. Poultry litter tea obtained the highest gross margin of PhP48,695.00 ha^{-1} followed by Power grow of PhP37,910.00 ha^{-1}, Wood vinegar PhP36,723.00 ha^{-1} and Vermi tea with PhP34,206.00 ha^{-1}. The lowest was observed in the control plants with a gross margin of PhP 18,750.00 ha^{-1} only.

RECOMMENDATION

1. Poultry litter tea at the rate of 100ml per 16li of water can be recommended for peanut production as an organic foliar fertilizer.
2. It is also recommended that the results obtained from this study be tested in other locations of different soil types and agro-climatic conditions with the inclusion of the recommended rate of inorganic fertilizer of 30-30-30 kg ha^{-1} N, P_2O, and K_2O.

Conflict of Interest

The authors would like to declare that there is no conflict of interest regarding this paper's publication. Hence, all authors are informed by the corresponding author before submission of this article for publication.

Authors' Contribution

This work was carried out in collaboration between the senior and junior authors. Both authors contributed to the conduct of the study up the final editing of the article before submission for publication.

REFERENCES

Aboelill A.A., Mehanna H.M., Kassab OM., & Abdallah EF. 2012. The Response of Peanut to Foliar Spraying with Potassium Under Water Stress Conditions. *Australian Journal of Basic and Applied Sciences,* 6(8): 626-634.

AVRDC, 2006. Association of International Research and Development Centers for Agriculture Conference. ACIAR; Australia. 7:27-46pp.

Brandenburg R.L., Jordan D.L., Royals B.R., Mahoney D.J. & Johnson P.D. 2019. Utilization of Imidacloprid to Control Pests in Peanut in North Carolina. *Peanut Science* 46:1, 8-13. Online publication date: 24-Apr-2019.

FAO, 2016. Food and Agriculture Organization of the United Nations, Rome, Italy.

Jordan D.L., Brandenburg R., Brown B., Bullen G., Roberson G. & Shew B., 2017. Peanut Information. *North Carolina Cooperative Extension Service Pub.* AG-331. 172 pages.

Kalinova S., Kostadinova S. & Hristoskov A. 2014. Nitrogen use efficiency and maize yield response to nitrogen rate and foliar fertilizing. *Bulgarian Journal of Agricultural Science*, No. 20, pp.

Krawczyk M. L., 2018. Make Your Own Liquid Garden Fertilizer, URL: http://goo.gl/k80xwW,Date Retrieved: May 16, 2018

Lalog J.T. 2011. Dynapharm Company Incorporation, Quezon City, Philippines

Landon J.R. 1991. Booker Tropical Soil Manual. *Longman Scientific and Technical/Ezzex*, England p.474

Marschner H.I. 1997. Mineral nutrition of higher plants. *2nd ed. San Diego: Academic Press*, 889p.

Meena S., Malarkodi M. & Senthilvalavan P. 2007. Secondary and micronutrients for groundnut. A review. *Agric. Rev.*, 28(4):295- 300

Mungkunkamchao T., Kesmala T., Pimratch S., Toomsan B. & Jothityangkoon D. 2013. Wood vinegar and fermented bioextracts: Natural products to enhance growth and yield of tomato. *Sci. Hortic*-Amsterdam. 154, 66-72.

NCT Manual for Legumes. Revised. 2017. Guidelines in conducting National Cooperative Testing in Field Legumes. Field legumes Technical Working Group. Bureau of Plant Industry. Diliman, Quezon City. Revised 2017.

Travero J.T. & Mihara M. 2016. Effects of pyroligneous acid to growth and yield of soybean (glycine max L.). *International Journal of Environmental and Rural Development.*7,50-54.