Bat Guano Levels of Application Influencing Carrot (*Daucus carota* L.) Growth and Yield Performance

Derby E. Poliquit[1], Eugene S. Calong[2]
Northwest Samar State University-San Jorge Campus
San Jorge, Samar, Philippines
[1]derbypoliquit222@gmail.com

Abstract

Carrot (*Daucus carota* L.) is considered a high value crop in the Philippines. Application of organic fertilizer such as bat guano (BG) is important in carrot root production because of the presence of higher N. But mixture of BG to garden soil (GS) as a medium should be considered to come up with greater efficiency of nutrient release. Thus, this study was conducted to determine the optimum level of BG on the growth performance and root development of carrot, and to evaluate the chemical properties of soil as influenced by BG. The experiment was laid out in randomized complete block design (RCBD) with four treatments which were replicated three times. The treatments tested were composed of T1 - control, T2 - 3 part BG:1 part GS, T3 - 2 part BG:2 part GS, T4 - 1 part BG:3 part GS. Data on plant height, number of leaves, weight, length of roots and shoulder root circumference, fresh and oven-dried of foliage weight, and chemical properties of soil were subjected to analysis of variance in RCBD. The application of BG had significantly influenced the pH, OM, N and available P and K of soil, foliage fresh (FW) and oven dry weight (ODW) of foliage, length and shoulder circumference of root, and yield of carrot. Optimum ratio was observed in 1:3 part of BG to GS (T4) ratio which had heavier foliage mass, longer and broader shoulder circumference of roots, and higher yield as compared to other BG treatments (T2 and T3) and the non-treated (T1). Bat guano application had achieved the lowest percent of sugar conversion relative to the control.

Keywords: *Bat guano, optimum level, protective structure, pot experiment*

I. INTRODUCTION

One of the ten most economically important vegetable crops in the Philippines is carrot (*Daucus carota* L.) (Simon et al., 2008). Carrot is a biennial plant in the Umbelliferae or Apiaceae. It is a popularly demanded perishable crop in the market because of its distinct features as vegetable to be cut into cubes and mixed with pickles, chop suey, and formed into sticks and curls making it as an attractive garnish and appetizer. It usually thrives best in highland areas with Benguet as the main contributor followed by Cebu (Nastor& Reyes, 2011). As a result, market price becomes higher most of the time due to its limited area of production. That is why PCARRD (2010) encourages farmers to engage farming of carrot since it could generate over in a single production process.

The problem of carrot production encountered by most growers is the adaptability of carrot to the climatic conditions. Carrot grows best in temperatures between 16 ºC to 21 ºC. Consequently, temperatures below 10 ˚C will stunt the growth of the foliage while temperatures above the mid-27 ºC will produce undesirable flavors in the carrots (Nunez et al., 2008; Rubatsky et al., 1999). This will depend, however, on the cultivar selected and the manner of cultural practices during the growth of crops.

One of the best alternative ways to improve crop yield is the application of inorganic fertilizer. But continued and too much application of inorganic fertilizers can burn plants and increase the build-up of salt toxicity concentration in the soil, resulting to chemical imbalances of nutrients that might affect growth performance of carrot. In contrast, the build-up of toxicity in organic fertilizer application is unlikely to occur especially when organic material become fully decomposed (Miller, 2008).

One of the organic fertilizers with the fastest rate of decomposition is bat guano (BC) which is beneficial to both soil and plants. It serves as source of nutrients for plants that helps improve soil condition and enhances different microbial action. As a manure, BC is a highly effective fertilizer due to its exceptionally high content of nitrogen phosphate and potassium. It contains 10% nitrogen (promotes green growth), 3% phosphorus (promotes root growth and supports flowering) and 1% potassium (helps plants grow strong stems) (Sridhar et al., 2006). Moreover, Oelhalf (1978) also reported that nitrogen and phosphorus increase root growth, improve the root to shoot ratio and increase dry matter production of crop.

Despite the benefits of organic matter, too much of it can create soil problems such as increased pH level, initiated optimum nutrient level, and direct salt build up. Therefore, this study was carried out to determine the optimum levels of BC on the growth root development or yield of carrot, and evaluate the chemical properties of soil as influenced by application of BC.

II. METHODOLOGY

Experimental Design and Layout

The experiment was laid out in randomized complete block design (RCBD) in single factor with three replicates. Each treatment replicate had 5 sample plants. The treatment includes the following:

T1 – Control
T2 – 3:1 part of bat guano (BG) to garden soil (GS) ratio
T3 – 2:2 part of bat guano (BG) to garden soil (GS) ratio
T4 – 1:3 part of bat guano (BG) to garden soil (GS) ratio

Soil Sample Collection & Processing

Bulk sample of soil from a depth of 0-20 cm was collected randomly from the vegetable production area of the Northwest Samar State University-San Jorge Campus. The bulk soil samples were air dried, pulverized and passed through a 4 mm sieve. Subsamples were subsequently taken and subjected for initial analysis and the rest was utilized for bagging (Figure 1).

Medium Preparation

Sixty bags of medium soil were prepared in a 10×12 inch size of polyethylene bag. Bat guano was air-dried for one (1) week. It was pulverized and thoroughly mixed into the soil following the recommended treatments by using a pail as a basis of measurement. The medium was placed half-filled or approximately two (2) inches from the uppermost side of polyethylene bag (Figure 1).

Seed Sowing

Prior to sowing, the prepared potting medium was moistened. Two to three (2-3) carrot seeds were sown directly on the soil at a depth of 1.5 cm (Figure 1).

Figure 1. Medium Preparation and Seed Sowing

Care and Management

Watering was done every morning or as needed with the use of sprinkler. Weeds were removed throughout the growing stage of the carrots (Figure 2). Pests were controlled by applying insecticide.

Figure 2. Care and Management through Weeding

Harvesting

Carrots were harvested 80 days after planting. The plant from each pot was carefully uprooted and soils adhering to the root were removed.

Soil and Guano Analysis

Initial soil analysis revealed that bat guano has higher N and P with 6% N and 13 mg/kg of P, respectively. It also has higher organic matter of 34%. Likewise, the pH was at an ideal range between 6-6.8 for much better carrot growth and development.

Meanwhile, K was at lower level with only 0.50 mg/kg. The samples were analyzed at the Philippine Root Crop, Regional Training Center (PRC-RTC) Laboratory in Visayas State University (VSU), Baybay City, Leyte, Philippines.

Data Gathering

1. Environmental conditions of carrots.
2. Plant height (cm). Plant height of carrots was measured bi-weekly with a ruler from the base (soil layer surface) to the tip of longer leaves.
3. Number of leaves. This was done by counting the number of fully developed leaves of carrots in bi-weekly collection during the morning.
4. Weight of roots and fresh foliage (gms/plant). This was done by weighing the fully developed roots

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Table 1. Initial Chemical Characteristics of Guano

Sample	pH	(%)		P (mg/kg)	K (mg/kg)
		OM	N		
Guano	6.3	33.78	5.99	13.68	0.50

and foliage after being harvested through weighing balance.

5. Foliage fresh (FW) and oven-dried weight (ODW) (gms/plant). This was first done by weighing the foliage right after harvest for fresh weight. Afterwards, it was dried in the oven for 2 days at 70 ºC.
6. Foliage starch and sugar content. Sample from oven-dried foliage was secured and submitted for plant tissue analysis.
7. Length of roots (cm). This was determined by measuring the root from its proximal end to the distal end of the carrot tuber.
8. Shoulder circumference of the root (cm). This was done by measuring the circumference of root shoulders' broader part by using a tape measure.
9. Carrot yield (ton/ha). This was determined by getting the average weight of samples treatment per plant (gms/plant) and converted to tons/ha.

Statistical Analysis

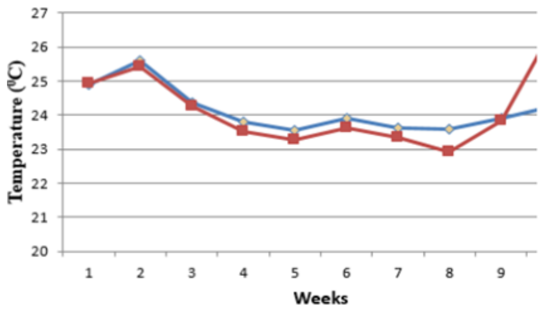
Data analysis was done using the Statistical Tool for Agricultural Research (STAR), Plant Breeding Genetics and Biotechnology Biometrics and Breeding Informatics, version 2.0.1 (2014). Treatment means were compared using Least Significance Difference (LSD) at 5% level of significance.

III. RESULTS AND DISCUSSIONS

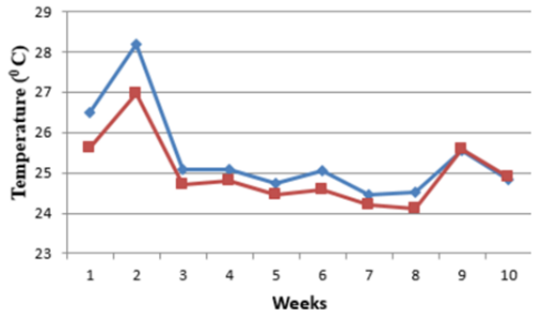
Environmental Conditions

Inside and outside air temperatures (˚C) of the protective structure were recorded at 6:00 am, 2:00 pm, and 6:00 pm (Figure 3). Warmer temperature was recorded both from outside and inside temperature of protective structure at 2:00 p.m.

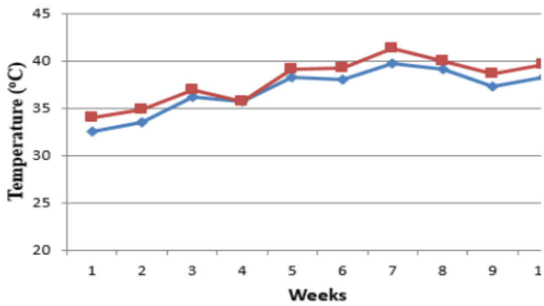
However, slightly warmer temperature was observed from outside temperature as compared to inside protective structure temperature. This could be due to the better air circulation from the inside. Meanwhile, slightly cooler air was observed at 6:00 a.m. and 6:00 p.m. inside. The daily temperature requirements of carrot as mentioned by Rose (2018) is at 16 ºC to 21 ºC did not correspond with the daily inside temperature outcome of the experiments towards the growing period of the carrots which had an average of 28.81 ºC.



a. Inside and Outside Temperature at 6 AM



b. Inside and Outside Temperature at 2 PM



c. Inside and Outside Temperature at 6 PM

Legend: Inside, Outside

Figure 3. Weekly temperature (ºC) inside and outside the protected structure recorded at 6 AM (a), 2 PM (b), and 6 PM (c).

Table 2. Chemical Characteristics of Gano-treated Soil After Harvest

Treatments	pH	Percent (%)		Avail P	Exch K
		OM	N	(mg/kg)	(mg/kg)
T_1 – Control	6.45^a	2.75^c	0.19^c	39^b	1,577^a
T_2 – 3:1 part BG&GS	5.56^{bc}	4.97^a	0.85^b	108^a	1,245^a
T_3 – 2:2 part BG & GS	5.47^c	5.12^a	1.72^a	109^a	1,567^a
T_4 – 1:3 part BG & GS	5.68^b	4.61^b	0.87^b	108^a	394^b
CV (%)	**1.31**	**3.98**	**35.78**	**3.12**	**19.98**

Means with the same letter in a column are not significantly different at 5% of significance using LSD.

Table 3. Bi-weekly Plant Height of Carrot as Influenced by Different Levels of Guano (cm)

Treatments	Bi-weekly Plant Height				
	2	**4**	**6**	**8**	**10**
T_1 – Control	13.94	25.94^{ab}	38.73	40.31	45.16
T_2 – 3:1 part BG&GS	11.65	21.48^{bc}	32.25	43.73	46.33
T_3 – 2:2 part BG & GS	11.41	20.52^c	32.50	39.27	41.77
T_4 – 1:3 part BG & GS	14.28	27.79^a	40.90	46.34	50.48
CV (%)	13.01	10.89	12.41	9.31	8.98

Means with the same letter in a column are not significantly different at 5% of significance using LSD.

Soil Characteristics

The soil analysis after the harvest showed that the chemical properties of soil were significantly influenced by different levels of BG (Table 2). Based on the pH level, the BG-treated soil had significantly (*$p<0.05$*) lower soil pH (5.4 to 5.6) than the control (6.45). It shows that application of BG (T2-T4) had lowered the pH level towards the growth period of carrot compared to non-treated soil (T1). McCauley et al. (2017) explained that this might be due to the buffering capacity of organic matter (OM) to soil pH change due to the presence of many negatively charged sites that decrease pH level.

Correspondingly, in terms of organic matter content, different levels of BG had significantly higher (*$p<0.05$*) OM content than the control. The 2:2 ratio of BG to GS ratio (T3) had significantly (*$p<0.05$*) higher OM content as an optimum level which was comparable with T2. It was indicated that BG as a manure improved the OM content of the soil by almost twice as compared to T1, which was categorized at very high level.

Likewise, the total N was significantly influenced by the different levels of BG. The BG-treated soil had significantly (*$p<0.05$*) higher nitrogen content as compared to the non-BG-treated soil (T0). The BG-treated soil has very high nitrogen content and still enough to support second cropping of production while the non-treated one has medium percent nitrogen level. From among the BG treatments, T3 had the highest total N.

Meanwhile, the BG-treated soil had significantly (*$p<0.05$*) higher accumulated P reserves than the control. The BG-treated carrots had very high extractable P reserves which could also be made available for second cropping.

In terms of K reserves of the soil, T4 had significantly (*$p<0.05$*) lower exchange K from among treatments that indicated a full utilization and translocation of K was achieved more at lower ratio of BG to GS (T4) during the carrots' growth and development.

Horticultural Characteristics

Plant Height

The bi-weekly performance of carrots' plant height generally had no (*$p>0.05$*) significant effect with the application of BG except for the 4th month period (Table 3). The 4th month period shows that T4 had the highest plant height indicating that growth of plant with lower amount of BG to garden soil ratio (1:3) promotes foliage development at the early stage of growth but was comparable with the control. This might be due to the influence of better decomposition and nutrient release with bulky amount of BG manure.

Correspondingly, after the 4th month period, it provided an evidence of the strong stimulation of photosynthetic activity attributed to root development of carrot which was favorably initiated by T4 although no significant (*$p>0.05$*) difference was observed throughout the maturity stage of carrot.

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Table 4. Bi-weekly Number of Leaves of Carrot as Influenced by Different Levels of Guano

Treatments	Bi-weekly Number of Leaves				
	2	4	6	8	10
T_1 – Control	4.00	5.33	7.00	6.33	8.33
T_2 – 3:1 part BG&GS	3.67	5.33	6.67	6.33	8.67
T_3 – 2:2 part BG & GS	4.00	5.00	7.00	6.00	8.67
T_4 – 1:3 part BG & GS	4.33	5.33	8.33	6.67	10.00
CV (%)	9.32	11	12.14	10.85	11.97

Means with the same letter in a column are not significantly different at 5% of significance using LSD.

Table 5. Bi-weekly Number of Leaves of Carrot as Influenced by Different Levels of Guano

Treatments	Fresh Weight (gms)	Oven Dry Weight (gms)
T_1 – Control	72.87^{c}	9.47^{c}
T_2 – 3:1 part BG&GS	155.17^{b}	14.83^{bc}
T_3 – 2:2 part BG & GS	135.20^{b}	12.97^{b}
T_4 – 1:3 part BG & GS	160.60^{a}	16.43^{a}
CV (%)	16.41	12.79

Means with the same letter in a column are not significantly different at 5% of significance using LSD.

Number of Leaves

The number of leaves throughout the growth of carrots had no significant (*$p<0.05$*) difference from among the treatments (Table 4). It was indicated that lower BG manure to garden soil ratio (1:3) (T4) was just enough to promote profuse leaf proliferation on carrots. This coincides with the results of carrot plant height (Table 3) where the lower ratio of BG yielded taller plants than that with greater BG to GS ratios (T2 and T3).

In addition, T_4 had slightly higher number of leaves produce towards the 10th week growing period as compared to the rest of the BG treatments and to the control. It is therefore suggested that lower level of BG ratio to GS (1:3) favorably gave better foliage production with more and lengthy leaves.

Fresh and Oven-dry Weight (grams) of Foliage

Foliage production is one of the determinants of growth as it useful in the process of photosynthesis. Results showed that the biomass of fresh weight of carrot foliage was significantly affected by BG levels of application (Table 5). The 1:3 BG to GS ratio (T4) had significantly (*$p<0.05$*) higher biomass of fresh foliage weight as compared to other treatments (T1, T2 and T3). This indicated that the water as a carrier of nutrients was probably translocate smoothly to the foliage, as a result, enhanced the biomass weight of carrots' fresh foliage.

Likewise, similar results whereas observed in oven-dry weight in which T4 was significantly (*$p<0.05$*) heavier than the rest of the treatments. The results revealed that the lower ratio of BG to GS (1:3) gave a much higher accumulation of organic compounds directly translocated to the foliage. Oelhalf (1978) reported that an increase of dry matter content was attributed to the increase in nitrogen uptake by the plants. Therefore, T4 had better nitrogen release, hence, the accumulated soil component was enhanced with the lower ratio of BG resulting to greater build-up of dry matter component on carrot foliage.

Starch and Sugar Content of Foliage

The starch content of carrots' roots showed that T3 had slightly higher starch content among the treatments, having 1.02% (Table 6). Whereas, T4 has the lowest starch content (0.77%) which suggests that T4 has lower carbohydrates accumulation during the growing period of carrots. On the other hand, based on the sugar content percentage for each treatment, T1 had the highest sugar content accumulation (7.87%) as compared to the BG treatments of T2, T3 and T4.

The data suggests that the application of BG promotes the lowest conversion of sugar from starch during carrot root production. Therefore, it imparts more on the accumulation of non-starch component such as lipids, proteins, minerals, and fiber.

Yield and Yield Components

Length and Circumference of Fresh Root (cm)

The length and shoulder circumference of carrot root were influenced by different BG

Table 6. Bi-weekly Number of Leaves of Carrot as Influenced by Different Levels of Guano

Treatments	Percent Starch	Percent Sugar
T_1 – Control	0.920	7.874
T_2 – 3 part BG&GS	0.856	5.880
T_3 – 2 part BG & GS	1.020	5.921
T_4 – 1 part BG & GS	0.770	5.045

Table 7. Yield of Carrot 77 Days after Harvest

Treatments	Actual Yield (gms/plant)	Computed Yield (tons/ha)
T_1 – Control	43.70[b]	5.89[b]
T_2 – 3 part BG&GS	48.70[b]	7.71[b]
T_3 – 2 part BG & GS	48.10[b]	7.49[b]
T_4 – 1 part BG & GS	73.87[a]	16.54[a]
CV (%)	17.23	17.23

Means with the same letter in a column are not significantly different at 5% of significance using LSD.

levels (Table 7). The lowest BG to GS ratio of 1:3 (T4) had significantly (*p<0.05*) longer and broader shoulder circumference of carrot roots relative to higher ratio of BG to GS (T2 and T3) and to the control. The optimum level of BG application was met in T4. This was probably attributed by better uptake of nutrients generated at lower ratio towards root elongation of carrot. The process of rooting development was reported by Laliberte (2019) that it was stimulated by higher phosphorous level which is dependent on the organism activity present in OM and soil organism.

Hence, P is essential for nucleic acid, phytin and phospholipids (Pankov, 1977). Thus, the results implied that the available nutrients present in BG at lower ratio of 1:3 (BG and GS) (T4) gave a better nutrient balance accumulation process of available nutrients of P and N in the soil and was enough for rooting development of carrot as BG has higher N and P content at 6%and 13 mg/kg, respectively (Table 1). This was confirmed by Westerveld (2002) that OM which respond well to crop growth and development was due to the rapid accumulation of N applied content at an adequate level.

Correspondingly, Robinson (1994) and Hodge (2006) reported that lower level of BG to GS ratio (1:3) has obtained more of localized unleash of N that promotes root growth relative to higher level of BG to GS ratio (T2 and T3) which resulted to a uniform increase of N supply and thereby reducing root growth and development of carrots.

Furthermore, the broader shoulder circumference of carrot roots could be influenced by heavier foliage present in T4 which was directly observed in Table 5. Westerveld et al. (2006) explained that this was due to the faster accumulation and uptake of nitrogen during the early stage of foliage development of carrots. He further explained that the accumulated N in the foliage stimulates faster root growth in carrots. The shoulder circumference of carrot roots was within the range as mentioned by Sanders (2017) that fresh market types of carrot have a circumference range between 5.87 cm to 9.8 cm. However, T4 had significantly broader root shoulder relative to T3, except for T2 as it is comparable to T4.

IV. CONCLUSION

The application of BG had significantly influenced the pH, percent OM, percent N and available P and K of soil, FW and ODW of foliage, length and circumference of root, and carrot yield. However, no significant effects whereas observed on bi-weekly plant height and number of leaves. Optimum ratio was observed in 1:3 part of BG to GS ratio that enormously gave significantly higher effects on the growth performance on carrots foliage and root production. Therefore, the study recommends the BG to GS ratio of 1:3 on carrot production and further experiment should be conducted in the field set-up. In addition, it is suggested that the application of BG to other vegetable crops should also be pursued.

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REFERENCES

Cooperhand, L. (2002). Building soil organic matter with organic amendments. University of Wisconsin-Madison. Center for integrated Agricultural System (CIAS). Accessed from https://www.cias.wisc.edu/wpcontent/uploads/2008/07 /soilorgmtr.pdf.

Dawuda, M., Boateng, P., Hemeng, O. & Nyarko, G. (2011). Growth and yield response of carrot (*Daucus carota* L.) to different rates of soil amendments and spacing. *Journal of Science and Technology, Vol. 31, No. 2*, pp 11-20. Accessed from https://www.ajol.info/index.php/just/article/viewFile/69389/57414

Ertli, T., Marton, A. & Foldenyi, R. (2004). Effect of pH and the role of organic matter in the adsorption of isoproturon on soils. Elsevier Ltd. Vol. 57. Issue 8. pp. 771-779. doi:10.1016/j.chemosphere. 2004.07.009

Hodge, A. (2006). Plastic plants and patchy soils. J. Exp. Bot. 57:407-411.

Lampkin, N.H. (2000). Organic farming. In: S. Padel (ed). Soil sickness and soil fertility. Cab Publisher, Wallingford, USA.

Mccauley, A., Jones, C. & Olson-Rutz, K. (2017). Soil pH and organic matter. Module. MSU Extension. Montana, State Universityhttp://landresources.montana.edu/nm/documents/NM8.pdf

Miller, R. (2008). "Inorganic Fertilizer Vs. Organic Fertilizer." Home Guides | SFGate, Retrieved December 18, 2018, from http://homeguides.sfgate.com/inorganicfertilizer-vs-organic-fertilizer-39528.html

Nastor, J. N. & Reyes, V. (2011). Influence of temperature on yield and quality on carrot (Daucus carota var. sativa). Bpi.da.gov.ph/bpi/images/Production_guide/pdf/CARROT%20.pd

Nunez, J., Hartz, T., Suslow, T., Mcgiffen, M. & Natwick, E. Carrot production in California. Univ. of California. Div. of Agri. And Nat. Resources. Pub. 7226. ISBN-13:978-1-60107-616-8. Retrieved February 2, 2018, from, https://ancrcatalog.ucanr.edu/pdf/7226.pdf

Oelhaf, R.C. (1978). As cited by (Mbatha, N. A.) Influence of organic fertilizer on the yield and quality of cabbage and carrots. Retrieved February 2, 2018, from, http://ideas.repec.org/a/eee/jfpoli/v6y1981i3p207-208.html.

Pankov, V.V. (1977). The effect of phosphorous on the chemical composition and productivity of carrots. Hort. Abstr. 4-7 (6), 484.

PCARRD. (2010). Carrot production guide. Retrieved from, http://region6.dost.gov.ph/pcaarrd-production-guide/.

Robinson, D. (1994). The response of plants to non-uniform supplies of nutrients. New Phytol. 127:635-674.

Rubatsky, V.E., Quiros, C.F., & Siman, P.W. (1999). Carrots and related vegetable umbelliferae. CABI publishing. ISBN978-0-85199-1290.

Sanders, D. (2017). Commercial Carrot production. Horticulture Info. Leaflets. Department of Horticultural Science. North

Simon, P.W., Boiteux, L., Briard, M., Nothnagel, T., Michalik, B., & Kwon, Y. (2008) Carrot. In: Prohens J., Nuez F. (eds) Vegetables II. Handbook of Plant Breeding, Vol 2. Springer, NY.

Sridhar, K.R., Ashwini, K.M., Seena, S., & Sreepada, K.S. (2006). Manure qualities of guano of insectivorous bat Hippo siderosspeoris. Tropical and Subtropical Agroecosystems, 2006; 6:103-110.

Waalewijn-Kool, P., Rupp, S., Lofts, S., Svendsen, C. & Van Gestel. C. (2014). Effects of soil organic matter content and pH on the toxicity of ZnO nanoparticles to Folsomia candida. Elsevier Ltd. Vol. 108, pp.15.Doi:10.1016/j.ecoenv.2014.06.031

Westerveld, S. M. (2002). Nitrogen management of cabbage, onions, and carrots as part of an integrated crop management program in Ontario. M. Sc. Thesis, University of Guelph, Guelph, ON.

Westerveld, S. M., Mckeown, A. W., & Mcdonald, M.R. (2006). Carrot yield, quality, and storability in relation to preplant and residual N on mineral and organic soils, Hort. Technology 16: 286-293.