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Understanding the Management Practices of Animal Manure Adopted by Livestock Breeders and Crop Growers of Mauritius

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Abstract

Manure is being increasingly used in agricultural production in Mauritius. This study focuses on understanding the manure management (collection, piling, storage, distribution and usage) practices adopted by cattle and poultry farmers (manure producers) and carrot and lettuce growers (manure end users) in Mauritius.Information on the management practices was primarily gathered through a survey using a questionnaire on the most important aspects of manure management. Briefly, in-depth interviews with 15 livestock breeders and 30 crop growers located in different parts of the island were carried out to gather information on their daily activities, with particular emphasis on management of manure. In addition, informant responses were also collected on their perception of the health risks and safety of manure use.Manure accumulated from the farm was piednear the barn itself, until picked up by a middleman ('collector')or growers.Vegetable growers manually applied the untreated manure to soil and mixed it by ploughing prior to sowing of seeds. Addition of chemical fertilizers during manure applicationwas also occasionally noted. Cattle and poultry manure tended to be used more often by lettuce and carrot growers respectively. Crop farmers admitted receiving manure from several manure producers, and indicated being unaware of the original source of manure. After harvest, vegetables were washed with water only and then sold to the local market or to vegetable mongers. Growers and 'collectors' had no negative perception of the use of untreated manure for vegetable cultivation and were generally unaware of any health risks.

Keywords: Manure; Management crop; Farmers; livestock

Introduction

Manure is any material that fertilizes land, especially refuse of stables and barnyards consisting of livestock excreta with or without litter. Broadly defined, manure includes feces, urine and bedding from livestock and other animals (animal manure), residue or biomass from plants (plant manure), as well as decomposed forms of either animal or plant manure (compost). Manure is being immensely used in agriculture as it provides valuable nutrients for crops and helps improve crop yields [1]. However, improper manure management can have several drawbacks such as odour problems, pollution of water and air and several risks of diseases [2]. Some of the well-known disease-causing microorganisms found in animal wastes include *Escherichia coli, Salmonella, Campylobacter* and *Yersinia* [3].

Good animal husbandry practices including vaccination, adequate access of animals to water and feed, appropriate space, temperature and ventilation control, sanitation, bio security measures, careful choice of housing types and diet selection can all help reduce the load of pathogens in manure which may range from 100 to 1,000,000 bacteria per gram of manure. Proper diet selection can also reduce pathogens in faecal discharge. Examples include organic acids used in poultry diets to reduce *Campylobacter* and *Salmonella*. However, Hovde et al. [4] showed that changing of diet from grain to hay in cattle may increase *E. coli* shedding. In addition, proper manure handling and storage practices can alleviate or reduce the risks of pathogen survival. Temperature control plays a very major role in reducing pathogen counts in animal wastes. Nicholson et al. [5] showed that pathogens such as *E.coli, Salmonella* and *Campylobacter* lived less than one month in solid manure where the temperature is greater than 55°C. When manure is applied directly to the soil without any treatment, the time for the bacteria to become less viable is more.

Thus, manure has to undergo several physical, chemical and biological processes so as to prevent the multiplication of these pathogens [6]. Physical processes include 'use of vegetative filter strips, control of runoff, and installation of clean water diversion. Biological processes are anaerobic storage, composting, aeration and anaerobic digestion and chemical processes include use of chlorine, lime, ozone, UV irradiation and pasteurisation [3]. The objectives of this study are as to understand the animal manure management practices of animal farmers and vegetable growers in Mauritius as well as shed light on the risks of pre-harvest contamination of vegetables by manure-borne pathogens.

Materials and Methods

Sample Collection

The targeted population for the survey comprised of livestock - cattle and poultry- breeders (manure producers) and vegetable - carrot and lettuce-growers (manure end-users). Many of the crop growers were registered with the Food and Agricultural Research and Extension Institute (FAREI) and their contact details were made available. However, to obtain contact details of animal farmers, we used a snowball approach, where farmers participating in the survey were requested to identify other survey participants for the study. Manure producers were categorized as cattle manure or poultry manure producers. A total of 16 producer's and 36 manure end-users were interviewed.

Data Collection

Data was collected through questionnaires tailored for either manure producers or end-users. Bearing in mind the characteristics of the target population, the questionnaires were translated to 'Creole' so that it was easier to communicate with the participants and to avoid bias of the survey. This also avoided on-the-spot translation from English to Creole and inconsistencies in phrasing questions by the enumerators during interviews. At the same time, this ensured good quality and consistency in the responses obtained.

Pre-testing

A pre-testing of the questionnaire was carried out with two carrot growers, two lettuce growers and two manure producers. Pilot testing is necessary for improving both the quality and clarity of the questionnaire. After the pre-testing, several questions were rephrased/removed and some important ones were inserted.

Interview

All the participants were first contacted by phone to explain the purpose of the survey and to schedule the interviews. In very few cases where the participants were not available, the survey was done by telephone. The survey was conducted over the period of November 2014 to January 2015 and one questionnaire took approximately 45 minutes to be completed.

Data analysis

Prior to data processing, there was a verification of the completed questionnaires for errors, incompleteness and gaps in the information collected. The data collected was read into SPSS version 19 for the analysis. Appropriate tabulations and statistical analyses were then performed using the statistical software and Microsoft Excel.

Results and Discussion

Livestock and poultry breeders were scattered over the island rather than concentrated in certain regions. A total of 7 cattle and 9 poultry breeders were approached in this study. The majority (94%) of animal farmers (manure producers) were of the male gender; approximately two-third of them worked full-time while the rest worked on a part-time basis. FAO [7] on the other hand reported a higher involvement of women in farming and approximately23% of household farmers was females in Mauritius. The years of experience of the farmers in the livestock sectornoted in our study varied from 1 and up to 50 years of experience in the field.

Of all animal farmers who were interviewed, we noted that approximately 44% were cattle breeders compared with 56% of poultry farmers, however they represented only 13 and 17% respectively of farmers in general. The rest (69%) of farmers interviewed were involved in crop cultivation. According to the 2014 Census of Agriculture [8] carried out from July to December 2014 in the Republic of Mauritius, 55% of agricultural activities were focused on crop cultivation and 45% on mixed farming (i.e. growing of crops and raising of livestock and poultry).

Our findings thus indicate an overall increase in the proportion of crop growers and decrease in the proportion of animal farmers in Mauritius since 2014. FAO [7] reported that 29% and 25% of the animal farmers were centered on rearing of cattle and poultry respectively, thus showing the relatively equal tendency for farmers to rear these live stock animals. Although FAO [7] has noted an increase in the importance of the livestock sector of Mauritius from 8% in 1990 to 13% in 1999, cattler earing has been on a general decline since. Indeed, the beef sector has declined drastically due to shrinkage of land available for cattle rearing through increased pressure for residential areas and other developments, work opportunities in other economic sectors and also due to the liberalization of imports of slaughter animals in 1996 [7]. Some farmers have reportedly abandoned cattle rearing because it is more demanding in terms of efforts and adds more pressure on the environment [8]. Production of beef from the local cattle livestock industry has decreased from 450 to 279 tonnes. In contrast, production of poultry has increased from 12, 500 to 20, 900 tonnes due to an increase in purchasing power [8].

Cattle breeders were all small-scale backyard farmers who owned < 15 animals. Indeed, cattle-rearing in Mauritius is mostly a sideline activity [7]. The cattle breed smost frequently encountered on the farms were Friesian (58%), followed by cross breeds of Creole and Friesian (14%), Creole (14%) and Camaron (14%) breeds. Lam Sheung Yen [9] also pointed that the three most common cattle breeds in Mauritius wereFriesian, Creole and Cross (Creole and Friesian) breeds. Cattle were kept in units

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of 1-4 animals. One goat breeder was found to keep 12 animals within one unit, which is in agreement with the stocking density reported by FAO [7]. Hence, the livestock housing systems encountered in this study were usually small with a fairly low stocking ratio.

The housing systems comprised of barns with roofs made of corrugated iron sheets, concrete flooring and stanchions for the cows. These housing systems were however different from those commonly encountered in the literature comprising of slatted barns, straws, crates or outdoor types. In developed countries, the choice of housing systems has largely been influenced by animal welfare and environmental protection legislations that influence the choice of the system [10]. For example, welfare guidelines account for the larger number of sows in the UK that are housed in groups and have access to straw (60%), whereas most other sows in Europe are kept individually and without access to straw.

Poultry production in Mauritius is usually semi-industrial (medium and small sized producers) to industrial (private industrial firms) [7]. Poultry farms approached in the study were small or medium-sized with generally 1200-1500 birds. The poultry farming systems observed in this study were all indoor types (100%) and the housing type comprised of medium to large buildings where the birds were reared on the deep-litter system. Deep litter systems are in fact quite common in many African countries [11]. Free-range poultry farming, on the other hand, is relatively less common because it restricts the scope for manure management compared to other systems [11]. In deep litter systems, poultry birds (broilers) were kept in large pens on the floor, which was itself covered with litters, such as straw, saw dust or eaves up to a depth of 2-3 inches. Advantages of the deep litter system include easy access for feed, water and egg collection and good protection for the birds [11]. We can thus infer that the small-scale poultry farms of Mauritius are of an intensive or smallholder nature since animals are kept at a relatively high stocking density with a low level of management and inputs.

Farmers approached in our study kept animals at varying stocking rates depending on the housing system and animal type. For cattle, the area occupied per animal varied between 4 to 27m^2 while for poultry the mean area occupied per animal was ca. 0.4m^2. Livestock stocking of cattle can also be expressed in terms of animal numbers or livestock units (LU) and provides an estimate of the density of animal production [2]. Moreover, LU can easily give an estimate of the total quantity of organic waste accumulated in the farms.

All the chicken farmers interviewed (100%) were reliant on purchased inputs such as factory-processed or ready-made feeds. Farmers mentioned using them because of their excellent quality, containing all the relevant nutrients in the correct proportions required for healthy growth and development of the chickens. They also mentioned benefitting from the veterinary services provided by the Division of Veterinary Services of the Ministry of Agriculture. In addition to services provided by the governmental institutions, farmers also purchased drugs such as antibiotics and vaccines from private firms. For cattle, the animals were generally tied in stalls and fed fresh grass using a "cut and carry method". For both cattle and poultry farming, production was usually meant for family consumption in the first instance with the remainder being sold on the local market with virtually no exports.

Most of the cattle farms visited (88%) stored collected manure in an uncovered stockpile on the ground, near or outside the barns. Manure is similarly often heaped outside of the "Cattle boma" in various East African countries [11]. Stacks and bunk silos are in fact the two most common means of storage of solid manure [12]. Moore et al. [11] also reported that there was a significant variation in the manure storage practices adopted by farmers in different countries. For instance, manure is often kept below the slatted floor of animal houses, in concrete stores, in lagoons or in lined ponds [2]. Moreover, the practice of covering or leaving stored manure uncovered also tends to vary. In fact, manure stores are mostly uncovered except for a few countries [2]. In Denmark, formation of a natural crust is mandatory. Moreover, in several countries, solid manure is typically kept in heaps on a contained concrete pad, which usually includes a provision for collecting the effluent that drains out. This is considered an important feature, as this effluent can be very polluting to the local area [2]. However, it has also been reported that storing manure in heaps are permitted in some countries without prior condition for effluent containment [2]. In our study, we did not observe any set-up for effluent discharge during cattle manure storage.

Farms involved in poultry production normally generate three types of manure; these are (i) litter associated with broiler production, (ii) manure generated from laying operations (hens and pullets) and (iii) dead birds [13]. For poultry farms visited in this study, litter of broilers and layers were the main source of manure and the waste material comprised of a dry mixture of chicken droppings and bedding. Indeed, as Bolan et al. [14] mentioned, deep-litter poultry systems are often ventilated thus producing a very dry manure material. Moreover, the addition of bedding further keeps moisture levels down In other countries however, different poultry manure collection methods have been reported namely (i) manure pit collection systems, which produce dry, wet or even liquid manure depending on whether air is ventilated or not, (ii) liquid manure systems used for laying hens or (iii) cage housing systems too [3]. Although popular, deep litter systems have a higher propensity to transmit litter-borne diseases [15]. All poultry farmers in our study indicated that they stored deep-litter poultry manure on concrete surfaces in the animal house itself, until picked up by a "middleman", also referred to as the "collector". For transportation of manure, collectors typically transferred the solid poultry manure to other farms by dump trucks. Other vehicles generally used in transfer operations include manure wagons, open tank spreaders and earth moving equipment [2]. Storage practices of poultry litter

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tend to vary across countries; the type of storage facility used for poultry litter can range from an open pile on a well-drained site to a covered storage facility [16]. Bird [16] recommended storing dry litter in a covered area to keep the material relatively odour-free [16].

Regarding length of storage, it generally varies from 2 to 12 months for solid manure [17]. In fact, storage is considered as a mode of treatment, because it enhances the timeliness and convenience of disposal [14]. In other words, solid manure must be stored for an appropriate period, in order to wait for the most suitable spreading time. This is very important when considering the correct utilization of nutrients and their impact on the environment. In our study, most farmers did not store manure for any defined period and used them as and when needed thus underscoring the risks when using or handling untreated or inadequately treated manure. Generally, three main hygienic risks exist in the handling of biological wastes: occupational health risks, environmental risks and risks concerning product safety [18].

In agriculture, a financial value can be ascribed to the use of manure through (i) energy savings from the use of generated biogas, (ii) sales of organic by-products or (iii) reduced purchases of inorganic fertilizer. Most animal farmers interviewed (75%) mentioned that they became involved in the sales of manure mainly to obtain an additional source of income. Lazarus & Koehler [19] indicated that manure trade is particularly profitable in farms having manure with a high concentration of nutrient. By delivering or selling manure, farmers and 'collectors' indicated obtaining a financial reward through a net earning of money. There is no doubt therefore that there can be tangible benefits from the good management of livestock manure. In the absence of any pressure from environmental or food safety regulations, Mauritian farmers avoid applying any treatment to manure, which would otherwise represent an expense.

38% of the animal farmers mentioned not treating the manure collected, thus incurring zero cost. The remaining 62% did not apply any formal treatment other than leaving the manure to decay naturally. In fact, Burton & Turner [2] have indicated that any major treatment package brings an overall financial charge to the farmer due to considerable manpower requirements. This can be expressed as a charge per animal produced, or more specifically, a percentage of the earnings per animal. Based on our findings, manure does not appear to go through any treatment process, thus bringing the net charge down almost to nil hence making the manure handling and storage business more economically viable for farmers. The use of manure in lieu of or in conjunction with chemical fertilizers is also widely practiced by growers interviewed in this study. Since farmers in general are known to face uncertain markets and narrow margins [19], this situation motivates them to optimize production methods, utilizing all resources including manure. In addition, increases in the price of commercial fertilizer experienced since 2009, has heightened interest in the use of livestock manure for supplying crop nutrients and has significantly increased the value of manure as a nutrient source [19].

According to Burton & Turner [2], the accumulation of livestock slurries constitutes a nuisance due to the very unpleasant odour. In addition to providing a source of income, manure trade also provided Mauritian farmers with a solution to odour problems caused by manure. Lazarus [20] also recognized odour problems arising during storage of manure as an important driver encouraging farmers to sell manure. Most farmers (74%) regularly disposed, transported or sold manure to crop growers to curtail that specific problem.

Raw bovine manure was initially accumulated in a semi-liquid form although the organic material acquired a more solid-like texture after extended storage. Manure of livestock animals, as observed in this study, was typically collected in solid/dry forms, although it is known to exist in other forms including wet/liquid (raw) as well as intermediate (solid/liquid mix) forms [2]. Irrespective of their states, the different forms of animal manure are equally valuable source of crop nutrients and are intended for fertilization of soil [2]. Since animals were kept on a bedding material, this together with all excreta was periodically collected as solid farmyard manure (FYM). Manure collected by different farmers may not always be similar in composition. As indicated by Burton & Turner [2], solid manure may contain variable proportions of faeces, urine and bedding material depending on the housing systems and management. The predominant collection of solid manure over other forms in Mauritius is comparable to farms in various European countries where cattle manure represents 40-70% of total animal manure production and cattle contribute over 80% of solid manure production [2]. In addition, the heavy reliance on solid cattle manure by crop growers in Mauritius is also comparable to Europe [2].

60% of manure producers interviewed in the study claimed to treat the manure before selling whereas the rest (40%) did not apply any treatment. None of the livestock breeders had received training from any institution on the management of manure, which they produce. The most popular form of "treatment" involved (i) mixing manure with straws, (ii) leaving the manure mix in open air and (iii)waiting for it to dry up and decompose. As soon as the manure was deemed sufficiently dried up, they were collected and sold to vegetable growers. Composting was not commonly practiced in Mauritius unlike other countries where it is used widely to treat various types of animal wastes [21]. Composting is in fact a practical way for pathogen inactivation due to the self-heating process carried out by microorganisms [22].

Regarding type of fertilizer used 56% of grower's surveyed reported applying solid animal manure in its pure form while 22% and 15% of farmers used manure mixed with chemical fertilizers and water respectively. Only a minority of farmers (7%) used chemical fertilizers alone. This is because manure is considered a more holistic source of plant nutrients than

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synthetic fertilizers [23]. In addition to nitrogen, phosphorous and potassium, manure contains many micronutrients and other beneficial substances. In addition, solid manure provides a more conducive medium for the growth of beneficial microorganisms than synthetic fertilizers [24]. It also supplies organic matter to soils and helps reduce soil erosion [2]. Farmers could thus make significant savings by replacing inorganic fertilizers totally or partially by farm manure [25], especially since farmers face continued shrinking of their profit margins [2]. At the same time, given the relatively low price of mineral fertilizers and their ease of application [2], most farmers are not willing to completely replace mineral fertilizers by livestock manure. The inherent variability in the physico-chemical characteristics of manure also makes them less reliable than chemical fertilizers [26]. In addition, the health risks associated with the use of animal manure render them a potentially unsafe material.

Annicciarico et al. [26] thus deduced that some of the benefits of using manure fertilizer are often negated by the extra expenditure in handling costs along with some degree of uncertainty of the actual nutrient content. When asked about the reasons for using manure as a natural fertilizer, most (84%) crop growers mentioned the organic aspect as the primary reason and appreciated the variety of benefits brought to the soil. Indeed, these benefits span from increased nutrient content, improved soil granulation, improved water infiltration and holding capacity, higher soil biota activity and overall productivity [27]. A few farmers also mentioned that using manure helps the animal production industry as a way to manage its animal waste.

Growers interviewed in the study, typically ploughed manure into soil prior to sowing of seeds. Mc Nulty & Grace [28] indicated that land application has remained the most widespread disposal technique for animal manures. In addition to ploughing, other methods of application documented in the literature include surface broadcasting, banding, injection, lump spreading, tank wagon and gun irrigation [29]. Surface broadcasting is the primary method of application for solid manure. Banding involves the placement of fertilizer in a concentrated layer or location (band) in the soil, commonly 8-15 cm below the surface. Fertilizer bands can be placed with the seed, below the seed, or both. Injection methods are beneficial as they place liquid manure below the soil surface, eliminating both surface runoff on sloping soils, and volatilization of ammonia from the manure of any soil [30]. We also noted that, poultry and cattle manure, were more commonly used by carrot and lettuce growers respectively. The type of manure used by farmers depended primarily on its availability in the locality. Since poultry manure usually decomposes faster than cattle manure, it is more readily available and is thus more frequently used. Growers also mentioned applying manure after each crop cycle and keeping left-over for use in the next cycle.

It was also observed in this study that there was no standard operating procedure (SOP) adopted by farmers for manure amendment of soil. For instance, manure was not added to soil at any specific ratio. The absence of a consistent procedure for manure treatment and amendment of soil could present adverse environmental and public health consequences [31]. Since manure is rich in microorganisms and nutrients, it should be carefully incorporated into soil at well-defined proportions and frequencies of application. Hutchison et al. [32] mentioned that land spreading of raw or partially decomposed animal manure can lead to the introduction of pathogens such as *E. coli* O157:H7, *Salmonella* and *L. monocytogenes* in soil [33,34], which can subsequently contaminate vegetables grown in soil fertilized with manure [35]. The safe use of manure is complicated by the variability in the characteristics and nutrient content of manure and this is further compounded by difficulty in tracing back the original manure supplier(s). Most of the growers mentioned receiving manure from multiple suppliers: 74% of them received manure from >3 suppliers, 22% of them received manure from 3 suppliers and 4% sourced manure from <2 suppliers. Growers sourced from manure from large-scale, medium-sized and small animal farms in nearby rural areas.

Controlling pathogen populations in animal wastes used for agricultural production is of prime importance in reducing pathogen introduction in the pre-harvest environment. However, most farmers (89%) thought that animal wastes were safe and free of disease-causing microorganisms. Moreover, the majority of farmers (93%) surveyed, thought that manure carried little to no occupational health risks while 7% of farmers acknowledged the risks of zoonotic disease transmission. In fact, infection can be spread on a farm by use of inadequately decomposed manure [36]. Traditionally, livestock slurries have been spread onto land with little concern for risks of environmental pollution or biosecurity risks [37]. However, Jiang & Shepherd [38] have indicated that zoonotic diseases can be spread from animal farms to crop plantations directly through excrement or indirectly. Such diseases include parasitic diseases (e.g. helminthoses), viral diseases (e.g. rotavirus infections) and a variety of bacterial diseases such as hemolytic uremic syndrome from *E. coli* O157, salmonellosis, lepto spirosis and tularemia [38]. Because the intestinal tract of animals is an important reservoir of these microorganisms, cattle and poultry feces and manure are potentially loaded with these pathogens, and care should be taken during the handling of manure. In addition to risks of direct contamination of vegetable crops, the application of manure to land may also lead to the infection and re-infection of livestock hence perpetuating the survival of these pathogenic microorganisms on the farm. Hence, a systematic assessment of the health risks of using livestock manure for crop cultivation needs to be undertaken in Mauritius. As Bihn & Gravani [39] have indicated, refraining from using manureis a precautionary principle. However, the better option is to understand the risks that exist and minimize these risks through GAPs implementation [39]. The USDA National Organic Program guidelines recommend a 90-day interval between the application of raw manure and harvest of crops for those whose edible portion does not come into contact with the soil and a 120-day interval for those whose edible portion has direct contact with the soil [40]. Another

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option is to formally compost raw manure to reduce the pathogen load prior to soil application.

All carrot growers (100%) reportedly used hands, rather than tools, to uproot these underground vegetables. Indeed, harvesting operations of root crops are traditionally carried out by hand [41]. Most carrot planters used their bare hands (93%) while a minority wore gloves (7%) to harvest the crops. Only 23% of planters admitted washing their hands before harvest. The health and hygiene of all workers who handle fresh produce, whether at the farm, the packinghouse, terminal market, grocery store or foodservice operation is of paramount importance in preventing produce-associated outbreaks [38]. Workers should thus regularly wash their hands before any manual handling of vegetables. Organisms such as *Shigella* spp., *E. coli* O157:H7, Hepatitis A virus and norovirus can easily spread to produce via the fecal-oral route of transmission from infected workers or farmers who work when they are ill. Hence, measures for preventing contamination by workers and farmers should involve education and training programs [42] that include information on the importance of good health and hygiene to produce safety, proper use of field toilets, effective hand-washing practices, and the appropriate use of gloves [38]. It is also important for farmers to be reminded that they are handling ready-to-eat products and are regarded as food handlers. According to Bihn & Gravani [39], the onus is on farm owners to provide clean, sanitary and well-stocked toilets for their workers, with adequate hand-washing facilities containing water, soap and single-use paper towels that are in close proximity to where they are working. It is not only a legal requirement, but it is a matter of common decency and privacy to provide clean and sanitary toilets and hand-washing facilities to all workers [39].

All lettuce growers (100%) used knives and manually harvested the leafy vegetables. Thompson [43] mentioned that mechanical aids are frequently used to harvest leafy vegetables such as lettuce, cauliflowers and cabbages and this involves cutting the vegetables by hand. Most of growers worked bare-handed (74%) while 26% of them wore gloves. Only 17% of growers reported washing their tools beforehand. In fact, the state of the equipment used to harvest produceis of utmost importance and yet often neglected. As a matter of fact, surfaces of all equipment that come in contact with produce can over time accumulate plant residues, exudates and juices, soil, debris, and other materials and can become an eventual source of contamination [44]. Equipment should be thus be made of smooth materials that are impervious to dirt and moisture and easily cleanable [39]. The farms should also have access to clean water in order to encourage regular cleaning and sanitization of their equipment as well as washing of produce [45]. A significant proportion of small growers (74%) regularly washed vegetables after harvest. The only cleaning agent used for vegetable washing was tap water or river water.

None of the vegetable growers interviewed were aware or understood any risks of produce contamination from wild or feral animals. The growers did not appear to have any rodent and other pest control measures in place on their farms. Moreover, many of the farms did not have any barriers or fences to keep stray or feral animals out of the production area. Farmers ought to be educated to minimize wild animal and bird traffic through fields where possible. Moreover, the storage room should be properly designed, constructed, protected from animals, and maintained in a clean and sanitary manner [39]. The main reason put forward for not having pest control interventions was that harvested produce was not generally stored on-site. The majority of growers (78%) did not store their produce and sold them to vegetable mongers and to the local market or warehouses soon after harvest was over whereas a minority stored their produce indoor (15%) or outdoor (7%). For the minority of growers who stored the vegetables, little to no consideration were paid to sanitary design and sanitation of their storage area.

Conclusion

In the light of this study, we can infer that cattle and poultry manure is an important crop resource for many smallholder vegetable farmers in Mauritius. However, we should enhance awareness of farmers on the health risks of using raw manure and educate them on methods to mitigate these risks. Additionally, guidelines should be developed for animal farmers and crop growers on how to treat and use animal waste with due consideration paid to food safety and environmental protection. The importance of Good Agricultural Practices (GAPs) in relation to manure management, such as effective composting, proper application of manure to soil and appropriate waiting periods for harvesting, should be emphasized heavily in training programs. Although they are not mandatory regulations, GAPs have been successfully implemented by produce growers in other countries, to reduce the contamination of their products, and these could be realistically adopted and implemented by farmers in Mauritius.

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