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Evaluation of compost of swine waste as amendment for production of cut wallflowers(*Matthiolaincana*)

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Summary: *The intensification of swine production systems generates accumulation of manure, which if not stabilized can generate negative impact on the environment. At the same time, the demand for organic materials to amend the soil for the production of cut flowers has increased. The objective of the work was to evaluate the use of swine compost as an amendment in different proportions through the growth of wallflowers (Matthiolaincana). The trial consisted of four treatments with three repetitions each: T1: 15l/m^2, T2: 30l/m^2, T3: 60 l/m^2 and T4: no incorporation of compost. A 12m x 1m flowerbed was used, divided into 12 experimental units. Phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K), nitrates (NO_3^-), pH and electrical conductivity (EC) in a ratio of 1 / 5 (v/v sample / water), and organic matter (OM) were analyzed for each treatment. In addition compost quality and the presence of Escherichia coli and Salmonella spp. were also analyzed. The carbon / nitrogen (C / N) ratio of the compost was 14.1 and the respirometric index (IRE) of 0.55 mg O_2 g^{-1} MO h^{-1} According to the TMECC (2001)[1], these values establish that the compost was stable and mature, on the other hand, the absence of pathogens E. coli and Salmonella ssp. was verified. The high electrical conductivity (CE) (5.53 dS.m^{-1}) and the high concentration of sodium (11464 mg/l) in the compost were limiting for the development of wallflower (wallflower plant). The amendment with doses superior to 30 l/m^2, caused a reduction of the growth and consequently lower quality of the floral stick. The evaluated swine compost is viable as an amendment to produce cut wallflowers up to 15l/m^2.*

Keywords*: swine compost, organic amendment, cut flowers*

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I. Introduction

For agricultural intensification to be sustainable, the well-being of rural communities, the reasonable use of natural resources and the ecosystem services they offer must be considered. There are various technologies and management techniques to intensify agricultural production in a sustainable way.The world swine production is in constant growth and Argentina follows this trend ,especially in the Pampean region near peri-urban areas One of the problems of this production is the generation of large volumes of organic waste concentrated in small spaces, which without proper management can cause environmental problems such as water, soil and air pollution. The composting of these residues allows the aerobic stabilization of the organic matter so that it could be reused in agriculture [2, 3 and 4].

Currently, compost is among the materials used to formulate substrates, as an alternative bioinsumption to the use of river hangover, among others. Composting is one of the few natural processes capable of stabilizing organic waste, destroying most of the parasites, pathogens and decreasing, considerably, the emission of bad odors [5]. It is important the possibility of agricultural valorization of the composted product, due to the enhance of organic matter and other nutrients that can contribute to the soil.In addition, the nutrients of the mature compost are released to the plants in a slow and constant way [6]. On the other hand, it has been shown that the compost may have properties of inhibitory activity against phytopathogenic agents, due, among other factors, to the presence of microorganisms that decrease the incidence in diseases [7].

Thus, composted materials have been used successfully for a wide spectrum of species, from floral and horticultural seedlings [8,9, 10 and 11] to forestry [12,13]. The compost used as organic amendments in soils originate a physical, chemical and biological behavior characteristic of soils rich in organic matter: increase in water retention capacity, better water intake and conduction, increased irrigation efficiency, facilities for tillage, maintenance of pH, increase in nutrient content [14]. On the other hand, there is a strong growth in the production of flowers in flowerbed and under cover in peri-urban areas, coexisting close to the production of pigs. There is an opportunity for composted waste from this animal production to be used as an input for sustainable floral production. Therefore, the introduction of stable and mature compost of pigs can be an option that would improve the chemical and biological properties of the soil, thus increasing the content of both macronutrients and micronutrients.

Although compost contains a certain amount of plant nutrients, they are rarely found in sufficient concentrations to satisfy all the requirements of an ornamental crop [15].Maynard (2003)[16] reported thatcut flowers can be one of the most profitable crops on the farm, and that yields of *Zinnia*sp. amended only with compost were equivalent to unamended full fertilized plots, so compost utilization could reduce the possibility of ground water contamination with nitrogen . Zinnias can be fertilized by a variety of sources, and Stephen (2004) [17] found that the poultry manure was the most effective manure for zinnia to grow taller. The average height for plants, after 18 days in poultry manure was 52.67 mm .From an environmental focus, it is more convenient the use of composted materials. Nutrients in compost are not immediately available but are released slowly at a rate in which plants can use most profitable for optimum growth (Maynard, 2004) [18]. Chang et al (2010) [19] used for *Anthuriumandreanum*, cultivated for cut flower productionunder soilless conditions, two organic fertilizers: pea and rice hull compost (PRHC) and cattle dung with tea leaf residue compost (CDTC), to compare them to inorganic fertilizers. The results showed that the growth, yield, and cut flower quality of plants receiving PRHC were the same as those receiving inorganic fertilizers, but the plants receiving the CDTC showed the lowest increase in leaf area and number of flowers. Results obtained by Perner et al (2007) [20] using *Pelargonium peltatum* as a test plant showed that addition of compost in combination with mycorrhizal inoculation can improve nutrient status and flower development of plants grown on peat-based substrates.

The objective of the work was to evaluate the use of swine compost in different proportions for growth and development of wallflower plants (*Matthiolaincana*).

II. Materials And Methods

Compost

The compost was elaborated with pig residues coming from a production type called deep bed system obtained in a production module that depends on the Estación Experimental AgropecuariaMarcos Juarez (Experimental Station Marcos Juarez) of INTA (InstitutoNacional de TecnologíaAgropecuaria) in Córdoba province, Argentina. This residue was composed of urine, droppings and wheat stubble. The composting of the waste was carried out using piles that were aerated using a compost stirring machine every 4 days, during the mesophilic and thermophilic phase, and every 7 days during the cooling and maturation phase. The moisture content was maintained by 60%, by manual irrigation. The entire compost process lasted 85 days.

Compost analysis

For the compost analysis, the techniques proposed by the "Test Methods for the Examination of Composting and Compost" (2001) [1] were implemented. The variables analyzed were: pH, EC, total nitrogen (Nt), ammonium ($N\text{-}NH_4^+$), phosphorus total (Pt), total organic carbon (TOC), organic matter (OM), dry matter (DM), density and nitrate ($N\text{-}NO_3^-$) [21]. The determination of total pathogens (aerobes, *E. coli*, total coliforms and *Salmonella*spp.) was carried out using the method proposed by Fasciolo et al., 2005 [22]. The parasitological analysis of Helminth eggs was carried out using the technique of egg recovery of the samples. This technique is based on the use of a series of sieves of which the last one has a measure of mesh that retains all the eggs and the previous ones, retain the larger particles. The last sieve is washed with ahypertonic solution that facilitates the flotation of the eggs and a sample of that wash is taken to be read in a Mac Master chamber. The count of eggs, multiplied by the dilution factors give the number of eggs per liter. In addition, the static respirometric index proposed by Barrena et al. (2005) [23] was measured.

Greenhouse experiment

The trial was carried out in a greenhouse of the Instituto de Floricultura of INTA Castelar, province of Buenos Aires, Argentine. It consisted of four treatments with different doses of compost incorporated into the soil of the flowerbed: Treatment 1: 15 l/m^2 or 8.7 kg/m^2, Treatment 2: 30 l/m^2 or 17.4 kg/m^2, Treatment 3 : 60 l/m^2 or 34.7 kg/m^2 Treatment 4: no incorporation of compost. A 12m x 1m flowerbed was used, armed on the ground level with wooden boards that was divided into 12 sections of 1m x 1m separated with wooden boards, each part was an experimental unit, with three repetitions per treatment. The test was carried out with wallflower plants (*Matthiolaincana*) whose seedlings were obtained by sowing in alveolate trays. These were transplanted at a distance of 0.15m x 0.15m in each experimental unit, resulting in 44 plants / m^2. At the end of the trial, harvest of the floral rods, a soil sample was taken from each experimental unit, and the following parameters were analyzed: organic matter (Ansorena Miner, 1994); pH and EC at a ratio of 1 /5vol:vol sample / water [10], phosphorus concentration (P), Kjeldahl nitrogen (NTk), calcium (Ca), magnesium (Mg) and potassium (K) analyzing the filtrate of the solution 1 / 5 with an atomic absorption spectrophotometer (Varian model 220 A) and the nitrates (NO_3^-) with selective ion electrode (Orion model 920 A). PH and EC were analyzed with a multiparametric equipment (Horiba model F-54 BW); Ca, Mg, K and Na with an atomic absorption spectrophotometer (Varian model 220 A); NO_3^- with selective ion electrode (Orion model 920 A); chlorides and bicarbonates by titration. The irrigation of the crop was carried out according to the demand with well water with pH values of 7.18, CE 0.79 d.Sm^{-1}, NO_3^- 7.7 mg./l, Ca 10.3 mg/l; Mg, 7.5 mg/.l; chlorides, 24.3 mg/l and bicarbonates 427 mg/l.

At the end of the trial, when more than 50% of the plants opened a third of the flowers of the inflorescence, the rods of 10 plants were harvested by repetition. The fresh mass, rod length, inflorescence length, and number of buds were measured for each rod. In addition, a chemical analysis was carried out on the aerial dry matter obtained in each treatment. Each sample was ground and 0.20 g of material was weighed and placed in a porcelain crucible of 25 ml capacity.The crucible with the ground material was introduced in a muffle furnace at 500 °C for 4 h; when the temperature of the muffle furnace was lowered, the crucible was removed with the ashes, 20 ml of 2N HCl was added and it was boiled for 2 min. The contents of the crucible were transferred to a test tube and brought to a final volume of 50 ml with distilled water; finally everything was transferred to a test tube. In the solution resulting from the test tube, the concentration of Ca, Mg, K and Na in g.kg^{-1} was analyzed with an atomic absorption spectrophotometer (Varian model 220 A).The experimental design of the trial was completely randomized. The variables measured to the substrates as well as to the plants were analyzed by variance and the Tukey test ($P \leq 0.05$) for comparison of means. The statistical software used was the InfoStat program, version 2009 [25].

III. Results & Discussion

Compost analysis

Table 1 shows the results of the physical-chemical analysis for porcine compost. The analyzed material had a high EC and a slightly alkaline pH, similar results were described by Rizzo et al. (2013) [26] and Riera et al. (2014) [27], when evaluating compost from monogastric animals (birds), with the high contents of salts. According to studies conducted by Barbaro (2013) [11] compost from animal droppings with EC of 1.4 to 2.7 dS.m^{-1} and pH from 8 to 9, can be used up to 20% in formulations of substrates composed by acid and low salinity materials, such as pine bark compost. If the EC is lower than 1.4 dS.m^{-1} and pH less than 8, compost could be used up to 50%, also in formulations with acid and low salinity materials.

Table 1: Physical-chemical, microbiological and parasitological characterization of swine compost

variables	*Units*	*swine compost*
pH		8,3 ± 0,06
Ce	dS.m^{-1}	5,53 ± 0,08
Mo	%	28,2 ± 0,8
Ms	%	78,8 ± 1,0
Cot	%	14,1 ± 0,4
H	%	21,1 ± 1,0
Pt	mg/kg	10,2 ± 3,1
Nt	%	1,0 ± 0,04
N-NO_3^-	mg/l	40,0 ± 0,9
N-Nh_4^+	mg/kg	58,8 ± 9,4
Cu	mg/l	0,03 ± 0,06
Mn	mg/l	0,63 ± 0,1
Fe	mg/l	49,8 ± 10,7
Zn	mg/l	0,07 ± 0,06
Ca	mg/l	118 ± 20,8
Mg	mg/l	401 ± 16,8
Na	mg/l	11464 ± 45,9
K	mg/l	15948 ± 98,7
$Ca_{soluble}$	mg/l	0,6 ± 0,2
$Mg_{soluble}$	mg/l	5,3 ± 0,5

$K_{soluble}$	mg/l	33 ± 4
$Na_{soluble}$	mg/l	33 ± 2,6
$Zn_{soluble}$	mg/l	0,5 ± 0,1
$Mn_{soluble}$	mg/l	0,9 ± 0,1
$Cu_{soluble}$	mg/l	0,1 ± 4,7
$Fe_{soluble}$	mg/l	26,4 ± 4,7
IRE	mg O_2 g^{-1} OM h^{-1}	0.55 ± 0.3
C/N		14,1
Salmonela		Absence
E. coli		Absence
Coccidios		Presence
Helminth	eggs/L	Absence

The compost was stable and mature, according to the limits established by TMECC (2001)[1, 28], whose values of carbon / nitrogen ratio (C / N) should be less than 20 and the static respirometric index (IRE) less than 0.5 mg O_2 g^{-1} OM h^{-1} (Table 1). The final compost quality was high in terms of N and P, the most limiting nutrients for plant growth. It also showed high amounts of Ca and substantial amounts of K. swine manure was the main source of nutrients. The concentrations rich in phosphorus can be due to the fact that the swine excretes this element as phytic acid (organic acid that contains phosphorus, present in vegetables, especially in seeds and fibers). The majority of non-ruminant animals, such as pigs, are fed, mainly, with cereals such as corn and soybeans. Since the phytate phosphorus of these foods is not available for intestinal absorption by these non-ruminant animals, the unabsorbed phytatepasses through the gastrointestinal tract, raising the amount of phosphorus in the manure. Phosphorus is excreted, both in the urine and in the feces.Also, microbiological analyzes are an important aspect to determine the sanitary quality of the compost [29]. The presence of coliforms in a high number is a possible indicator of the presence of pathogenic bacteria such as *Salmonella*, *Shigella* and *E. coli*. Its presence in high concentrations in a compost or organic material indicates that the thermal process has been insufficient [30], either because the compost did not reach the adequate temperatures due to time period under thermophilic conditions, that could have been very short , or due to the fact that contamination occurred during the maturation stages. In raw materials such as manures, pathogenic bacteria for humans and animals can be found, being of special interest the presence of *Salmonella* spp. This microorganism is one of the main agents of foodborne diseases and can be a normal inhabitant of the digestive tract of animals [31]. Regarding the sanitary requirements, Table 1 showed an absence of pathogenic bacteria *E. coli*, *Salmonella*spp. and Helminth parasites.

Table 2: Soil analysis for all the treatments. Different letters between rows of the same column indicate significant differences according to the Tukey Test ($p \leq 0.05$).

Variables	*Units*	*Treatment 1*	*Treatment 2*	*Treatment 3*	*Treatment 4*
pH		6,6 b	6,5 b	6,3 c	7,3 a
EC	ds/cm	2 c	2,8 b	0,3 b	1,4 d
NTk	%	0,27 b	0,27 b	0,39 a	0,25 a
NO_3^-	mg/l	2040 b	3150 b	3430 b	1570 a
Mg	mg/l	22 ab	44 b	1200 c	33 a
K	mg/l	2540 a	3550 a	46550 b	3550 c
Na	mg/l	3620 ab	4510 bc	3850 c	1500 a
Zn	mg/l	8 b	7 b	8 a	10 b
Mn	mg/l	3 a	4 ab	8 b	4 ab
Cu	mg/l	2 a	2 a	2 a	2 a
Fe	mg/l	190 a	141 a	77 a	379 b
S	mg/l	480 b	620 bc	1020 c	70 a
Ca	mg/l	26 ab	46 b	1363 c	11 a

The statistical analysis showed significant differences between T1, with respect to T2 and T3. However, all the treatments presentedEC values greater than 1 $dS.m^{-1}$. Amendments with values less than 1 $dS.m^{-1}$ of EC are recommended for use. When soils with incorporation of amendments, under cover, exceed these EC concentrations, plants may be affected due to salinity problems, which will depend on the type of species and management practices used [32]. It could also be observed that when the percentage of compost added to the mixtures decreased, they had a lower concentration of nutrients (Table 2).

With respect to NO_3^- and K, Ansorena (1994) [24] attributed excessive salinity to these two compounds. $NO_3^-$is not fixed on the exchange soil capacity, remaining in solution and directly available, contributing greatly to soil salinity [33, 11]. High concentrations of Na and K, associated with EC, were found in treatments amended with swine compost. The K and Na ions are added in animal diets to improve the growth rate and prevent the deficiency of these minerals. It is estimated that pig excretes 66% and 59% of Na and K, respectively, consumed in the diet [34].

Regarding the pH values (Table 2), all the treatments that used compost showed lower pH values (6.6, 6.5 and 6.3 for T1, T2 and T3, respectively), with significant differences between all treatments, with respect to control ($p \leq 0.05$). This is important since pH has a great influence on the availability of nutrients [24, 35]. In organic substrates, zinc, copper, manganese, phosphorus and iron increase their availability with the decrease in pH, while magnesium and calcium increase their availability with the increase in pH. The swine compost had pH values of 8.3; however, when used in beds, soil pHpresented lower values.According to the reference values of the INTA Institute of Floriculture [36], the levels of K and Na (Table 2) were high, coinciding with the results found by Barbaro et al (2013)[11], who recorded high levels of K in the substrates with guano compost chicken, in relation to the other nutrients. The K when found in high concentrations, causes imbalances in other elements such as Mg, and there may be deficiencies of the latter, given by a ratio of K and Mg greater than 3: 1 [37]. With respect to the concentration of Ca and Mg it was very low in T4; being 11 and 33 mg/l respectively; while in the treatments with addition of compost they were acceptable as shown in Table 2.

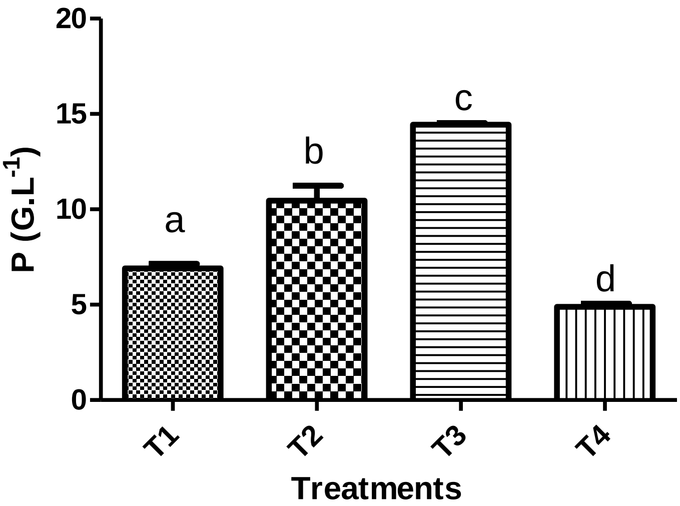

Figure 1: Phosphorus concentration ($g.L^{-1}$). Different letters indicate significant differences according to the Tukey test ($p \leq 0.05$).

Figure 1 shows the increasing P concentrations with the highest application of compost (T1 754.3, T2 856.7 and T3 1161 $g.l^{-1}$), showing significant differences ($p \leq 0.05$) in all treatments. Although P and N, would be the most limiting nutrients for plant growth, there is a growing concern about the over application of P when animal fertilizers are applied in accordance with the Nitrogen requirements of the plants , as plants require approximately 6-8 times more N than P [38]. In our case, a high proportion of extractable P is a disadvantage that should be considered more thoroughly when calculating the application rates of compost to the soil or when they are part of a substrate. An alternative is to increase the proportion of carbonized material during composting, which would contribute to reducing the excess of available nutrients, increase recalcitrant organic matter and avoiding environmental problems due to P overfertilization[39].

Evaluation of growth parameters and nutrient concentration in wallflower plants (Matthiolaincana)

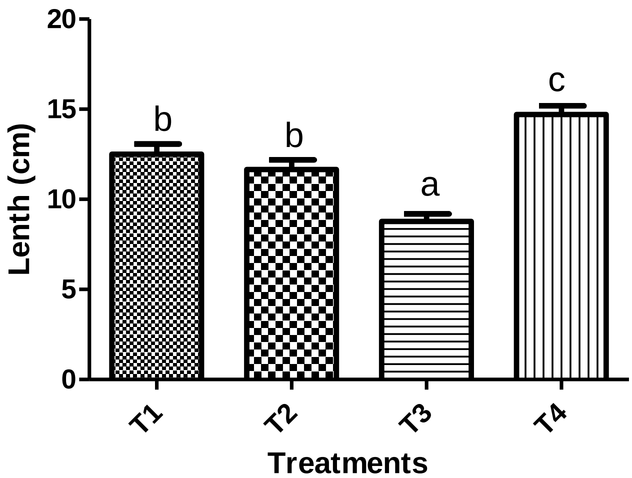

Figure 2: Inflorescence length (cm). Different letters indicate significant differences according to the Tukey Test ($p \leq 0.05$).

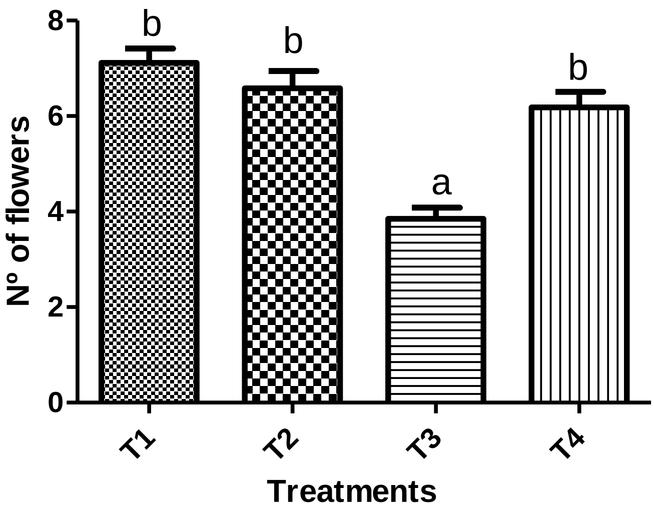

Figure 3: Number of flowers measured in the inflorescence. Different letters indicate significant differences according to the Tukey test ($p \leq 0.05$).

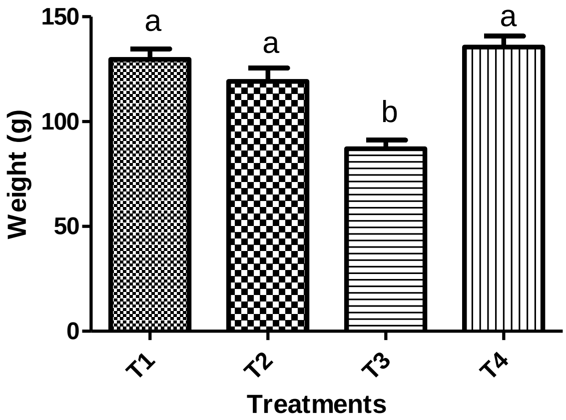

Figure 4: Rod weight (g.). Different letters indicate significant differences according to the Tukey test ($p \leq 0.05$).

Figures 2, 3 and 4 plant parameters of*Matthiolaincana* are shown: inflorescence length, number of flowers and rod weight.Rod weight showed shows a trend similar to that of the other parameters

The main limitations that were observed in the use of swine compost as an amendment were mainly the high EC values and the sodium concentration, where in doses higher than 15 l/m^2, showed a reduction in the vegetative growth of all the parameters measured. At doses lower than 30 l/m^2 no significant differences were found in the number of flowers and number of buds.In addition, foliar analysis of P, K, Ca, Mg, Fe, Cu, Mn, Zn and Na was performed, without finding significant differences between treatments, except for the foliar Cu. Figure 5 shows the results obtained from the Cu foliar analysis

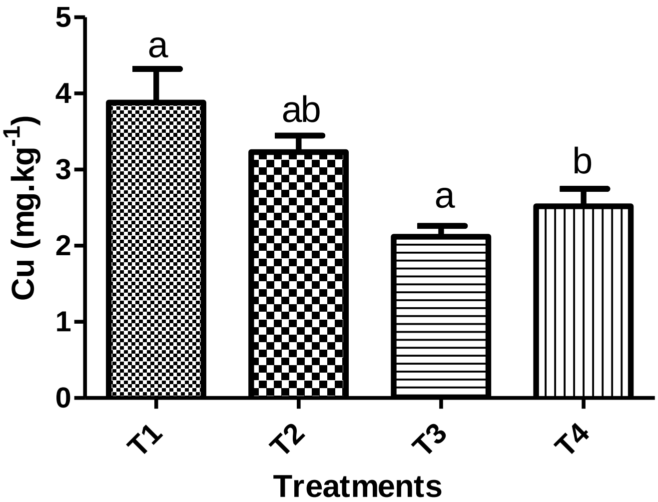

Figure 5: Foliar Cu concentration ($mg.kg^{-1}$dry leaf material). Different letters indicate significant differences according to the Tukey test ($p \leq 0.05$).

The salts of copper are used as additives in balanced feed, to guarantee a good yield, increase the efficiency of feeding and productivity [40]. Cu is eliminated mainly in the feces; according to Hatfield et al. (1998)[34], the pig excretes up to 86% of Cu consumed in the diet. The accumulation of metals in soils should be monitored to avoid adverse effects on the environment [41, 42].

As a general discussion about the use of swine compost in cut flowers, it was reported by Chang et al (2010) [19] that there is scant information available concerning the use of organic fertilizer as the sole source of nutrients in flower production and that the use of organic fertilizer made from agronomic waste regenerates natural resources and reduces the consumption of fossil energy as well as phosphorus (P) and potassium (K) deposits. Compost application in floriculture was also studied by Hussein et al (2006) [43] that found that compost applications to *Dracocephalummoldavica*L. (dragonhead) had a promoting influence on most of vegetative growth parameters and accelerated essential oil accumulation and chemical constituents including total carbohydrate and photosynthetic pigments content.

According to Maynard (2003) [16], we can emphasize that the long-term benefits of compost application are a cleaner environment with less pollution of ground water and reduced runoff of fertilizers.

IV. Conclusions

The evaluated swine compost studied in this experiment is viable as an amendment to produce plants of wallflower (*Matthiolaincana*) up to 15 l/m^2. This type of amendments must take into consideration the regulation of application dose, to be considered an appropriate product to improve the chemical fertility of soils in intensive cultivation of this cut flower.

The possibility of using swine compost in floriculture, is an interesting option of use, and leads to an agronomic valorization of treated swine waste for intensive production, that represents an environmental relevant issue.

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