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Influences of the Origin and Method of Application of Chicken Manure on Tomato Production in Lubumbashi

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Abstract: Tomato is one of the most consumed fruits in the world due to its nutritional richness and its role in the agro-food industry, giving rise to a wide range of derived products. However, its production in Lubumbashi is constrained by several factors, particularly the infertility of the soils in this region. Among the solutions proposed by researchers to address this issue, organic fertilization stands out due to its capacity to restore and improve soil properties and fertility. Consequently, farmers resort to exogenous fertilization without knowing the origin and method of application that could allow for the rational use of fertilizers. It is in this context that this study was initiated with the objective of evaluating the influence of the origin of organic fertilizers and the method of application on tomato behavior. To this end, an experiment was conducted in the experimental field of the Faculty of Agricultural Sciences following a factorial design (3x2) with four repetitions. The observations during this study focused on growth and production parameters. The collected data were subjected to two-factor analysis of variance at a 5% significance level using R software, and Tukey's test was applied in case of significant differences. The results indicate that significant differences were obtained for all parameters except for the survival rate. In terms of plant height under the effects of the application methods, the treatment with 30 t/ha of localized chicken manure produced the tallest plants, estimated at 26.125 ± 2.947 cm, compared to the shortest with the broadcast treatment of 30 t/ha of manure, evaluated at 13.250 ± 2.435. Neither the interactions nor the sources of manure induced significant differences. For the collar diameter of the plants, only the methods of applying fertilizers induced significant differences.

Regarding interactions, the treatment with 30 t/ha of chicken manure from the Congo Egg farm localized yielded a production estimated at 36.08 ± 4.17 t/ha compared to the lower yield obtained from 30 t/ha of manure from the Hasna farm by broadcasting, estimated at 27.08 ± 1.38 t/ha.

Introduction

Since the beginning of the 21st century, there has been a rising trend in agricultural input prices, coupled with uncertainties about the sustainability of mineral resources essential for plant nutrition in certain soils (Mpundu et *al*., 2012; Baker et *al*., 2014). The availability of certain essential elements for plant nutrition in the soil and environmental conditions impose more than ever the need to optimize the efficiency of fertilizer inputs (Baker et *al*., 2014). The goal is to maintain the productivity of cropping systems by using fewer synthetic inputs and adopting better cultural practices (Arnold et *al*., 2012). Among the multiple available techniques to achieve this, localized fertilization, which involves burying the fertilizer near the seed or seedling, seems to be the ultimate solution to losses and environmental damage (Zougmoré et *al*., 2004). It specifically promotes the direct availability of fertilizer to young seedlings (Bertani et *al*., 2016). In the case of solanaceae crops, where the need for phosphorus and potassium is the highest, localized applications ensure quicker contact with the root system of the plants (Khag et *al*., 2007). Furthermore, in tropical soils, major elements are generally less mobile in the soil solution, while their need manifests at the stage of plant development (Zougmoré et *al*., 2000). In contrast to localization, broadcasting involves spreading fertilizing elements over the entire field (Bast et *al*., 2009), which over time becomes a source of pollution or encourages the growth of weeds. However, broadcasting not only nourishes the plant but also contributes to renewing the soil's nutritional base (Useni et *al*., 2013; Ngoy et al., 2020; Mukendi et *al.*, 2016). This technique is very costly and increases production costs for farmers (Lahy, 2012). Additionally, several research studies indicate that the nutritional composition of an organic fertilizer is strongly linked to its source (Lumpungu et *al*., 2016). This brings to light the importance of feed in livestock, the mode of preservation, and mixing with other exogenous components to the manure (Baker et *al*., 2014). However, it is not easy to procure a large quantity of organic fertilizers of animal origin to adequately cover an agricultural area in our environment (Lahy, 2012). It is necessary, in the context of low agricultural production and difficulty in sourcing organic fertilizers, to encourage alternative practices to complete broadcasting of fertilizers in the field (Bast et *al*., 2009).

It is in this context that this study was initiated with the goal of evaluating the behavior of tomatoes under the influence of the origin and method of application of chicken manure within the agricultural context of Lubumbashi. Specifically, this study will focus on:

Comparing the yield of tomatoes under the influence of the origin of chicken manure. The hypothesis is that, depending on its origin, chicken manure would contain different fertilizing elements that would lead to varying tomato production.

Comparing the behavior of tomatoes based on the method of application of chicken manure.

The hypothesis is that tomato production would depend on the availability of nutrients resulting from the method of application.

Determining the best combination of origin and method of application of chicken manure on tomato production. The hypothesis is that there exists a combination of origin and method of application of chicken manure that allows for optimal tomato production in the agricultural context of Lubumbashi.

Materials and Methods

This study was conducted in Lubumbashi (the capital of the Haut-Katanga province) in the Democratic Republic of Congo, at the experimental field of the Faculty of Agricultural Sciences at the University of Lubumbashi. This field is located at an altitude of 1278 m, 12°36’51’’ South latitude and 27°28’5144 East longitude (Mukalay et *al.*, 2008). The experimental site, like the city, enjoys a climate typical of dry tropical regions of type CW6 according to Köppen classification (Mujinya et *al*., 2011). There are two well-defined seasons: the rainy season from November to March with 1240 mm of rainfall per year, peaking in January and February. The average annual temperature is about 20.5°C with significant interannual stability. The temperatures are lowest in the first half of the dry season.

Biological Material

Chicken manure was collected from various sites (farms) where intensive poultry farming is practiced, namely Hasna Farm, Matata Farm, and Congo Eggs Farm. Before their use in the experiment, a sample from each type of manure was subjected to chemical analysis. Below, Table 1 presents the results of the chemical analysis of chicken manure based on its origin.

Table 1: Results of different chicken manures according to their origins

Code labo	p^H	N(%)	P(%)	K(%)	C/N
FH1	8,5	2,2	1,95	1,20	10
FM 2	7,9	1,82	1,35	0,98	10,9
F CO 3	8,6	2,78	2,15	2,08	13

Legend: FH = Manure from Hasna Farm, FM2 = Manure from Matata Farm, FCO3 = Manure from Congo Eggs Farm.

Location of Chicken Manure Collection Sites
Map

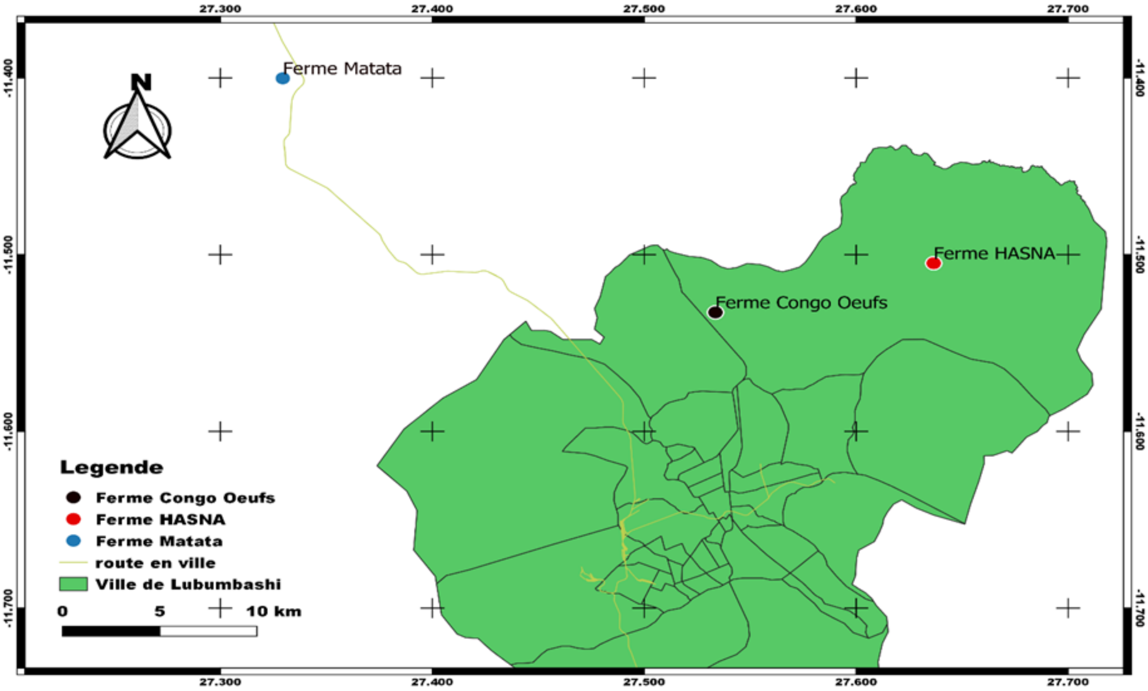

Figure 1. Location of the various sites supplying organic matter

Types of Poultry Feed by Site
Hasna Farm generally uses the FFF compound for feeding its chickens.
Matata Farm generally uses the Nutri compound for feeding its chickens.
Congo Eggs Farm generally uses a mixture of Nutri, bean waste, and soy for feeding its chickens.

Methodology

A trial was set up at the Faculty of Agricultural Sciences to evaluate the behavior of tomatoes under different types of biological fertilizer (chicken manure) sourced from three different sites. The experiment was conducted outdoors using a factorial design (3x2) with four repetitions. The six treatments included: FH1L (30 t/ha of manure from Hasna Farm, localized), FH1V (30 t/ha of manure from Hasna Farm, broadcast), FM2L (30 t/ha of manure from Matata Farm, localized), FM2V (30 t/ha of manure from Matata Farm, broadcast), FCO3L (30 t/ha of manure from Congo Eggs Farm, localized), and FCO3V (30 t/ha of manure from Congo Eggs Farm, broadcast). The experimental unit for this study was a plot of 1.5 m² with a 1 cm space between plots.

Results

No significant difference was observed between treatments regarding the survival rate under the effects of the origin of chicken manure, application methods, and their interaction. Significant differences were obtained for plant height and collar diameters. For plant height, a significant difference was observed under the effects of application methods. The treatment L (application of 30 t/ha of localized manure) resulted in the tallest plants 30 days after transplanting, estimated at 26.125 ± 2.947 cm, compared to the shortest plants in treatment V (30 t/ha of broadcast manure) evaluated at 13.250 ± 2.435 cm. Neither the interactions nor the sources of manure induced significant differences. For the collar diameter of the plants, only the methods of fertilizer application induced significant differences.

Table 2. Survival rate, plant height, collar diameter, and number of fruits under the influence of the origin and method of application of chicken manure.

Legend: FH1L (30 t/ha of manure from Hasna Farm, localized), FH1V (30 t/ha of manure from Hasna Farm, broadcast), FM2L (30 t/ha of manure from Matata Farm, localized), FM2V (30 t/ha of manure from Matata Farm, broadcast), FCO3L (30 t/ha of manure from Congo Eggs Farm, localized), FCO3V (30 t/ha of manure from Congo Eggs Farm, broadcast).

Source of variation	Reversal rate	Haight of plantes 30 days after transplanting	Neck diameter after transplanting
Fertilizer origin			
FH1	100 ± 0,0	24,500 ± 2,914	15,734 ± 1,319
FM2	96± 8,8	24,250 ± 4,703	16,928± 1,372
FCO3	96±8,8	22,200± 2,017	19,469± 1,857
p	***0,614***	***0,103***	***0,081***
Method of application			
L	100,92± 5,92	26,125± 2,947 a	19,542 ± 1,787 a
V	97,92 ± 92	13,250± 2,435 b	15,794± 1,987 b
p	***0,10***	***0,003***	***0,015***
Interaction			
FH1L	100,0 ± 0,0	24,725 ± 2,734	16,754± 1,032 a
FH1V	100,0 ± 0,0	24,125 ± 3,437	14,225 ± 1 ,559
FM2L	100,0 ± 0,0	25,187 ± 3,357	15,275 ± 1,444
FM22V	93,75 ± 1,50	23,250± 6,947	12,356 ± 1,517
FCO3L	100,0 ± 0,0	20,0± 2,466	16,650±1,866
FCO3V	93,75 ± 1,50	19,400± 2,238	17,287 ± 1,599
p	***0,564***	***0,407***	***0,0701***

Production Parameter Results

The results of the variance analyses presented in Table 3 below, conducted on production parameters, revealed significant differences across all parameters. For the parameter of the number of fruits per plant, the treatment L (application of 30 t/ha of localized chicken manure) resulted in a higher number of fruits per plant, estimated at 44.167 ± 3.091, compared to the lower number of fruits per plant obtained in treatment V (30 t/ha of broadcast chicken manure), which was evaluated at 36.5 ± 2.902.

For the average weight of the fruits under the influence of the sources of chicken manure, no significant difference was observed. Under the effects of the mode of application, treatment L (30 t/ha of localized manure) produced a higher weight, estimated at 82.90 ± 7.196 g, while the lowest weight was obtained in treatment V (30 t/ha of broadcast manure), evaluated at 66.92 ± 3.522 g. Regarding interactions, treatment FCO3L (30 t/ha of chicken manure from Congo Egg farm localized) yielded a higher weight, estimated at 89.58 ± 4.96 g, compared to the lower weights obtained in FH1V (30 t/ha of manure from Hasna farm broadcast), estimated at 27.08 ± 1.38 g.

In terms of yield, no difference was observed under the effects of the sources of fertilizers. However, under the effects of the modes of application, treatment L (30 t/ha of localized manure) resulted in a higher yield, estimated at 39.80 ± 7.35 t/ha, compared to the lower yield obtained in treatment V (30 t/ha of broadcast manure), evaluated at 32.76 ± 12.71 t/ha. For interactions, treatment FCO3L (30 t/ha of chicken manure from Congo Egg farm localized) yielded an estimated 36.08 ± 4.17 t/ha, while the lower yield in FH1V (30 t/ha of manure from Hasna farm broadcast) was evaluated at 27.08 ± 1.38 t/ha.

Table 3 Number and weight of fruits and yield in tomatoes under the influence of the source and mode of application of chicken manure. FH1L (30 t/ha of manure from Hasna farm localized), FH1V (30 t/ha of manure from Hasna farm broadcast), FM2L (30 t/ha of chicken manure from Matata farm localized), FM2V (30 t/ha of manure from Matata farm broadcast), FCO3L (30 t/ha of chicken manure from Congo Egg farm localized), FCO3V (30 t/ha of chicken manure from Congo Egg farm broadcast).

Source of variation	Number of fruits per plant	Fruit weight per plant	yeild
	Fertilizer origin		
FH1	35,125±1,202	54,34± 3,12	30,73 ± 7,69
FM2	36,25±3,012	55,86± 5,79	27,07± 3,372
FCO3	34,250±2,008	59,34±2,504	35,99± 3,870
p	***0,532***	***0,421***	***0,270***
	Method of application		
L	44,167±3,091 a	82,90 ± 7,196 a	39,80± 7,35 a
V	36,5±2,902 b	66,92± 3522b	32,76± 12,71b
p	***0,032***	***0,025***	***0,007***
	Interaction		
FH1L	34,750±7,034	53,750± 3,82b	31,275± 1,032 b
FH1V	33,5±1,240	54,56±2,52 ab	27,08 ± 1,38 b
FM2L	33,250±3,304	54,57± 5,13ab	25,09 ± 1,444 ab
FM2V	35,250±3,001	80,15± 6,65 ab	31,02 ± 2,26 ab
FCO3L	33,750±3,096	89,58± 4,96a	36,08±4,17 a
FCO3V	35,20±2,309	69,10 ± 2,160ab	28, 252± 1,49 ab
p	***0,293***	***0,030***	***0,004***

Discussions

No significant differences were observed between treatments for the recovery rate under the effects of the origin of poultry manure, application methods, and their interaction. This may be explained by the quality and equitable distribution of organic fertilization provided to the plants, which may have enhanced the genetic potential of the plants to resist biotic stressors (Polese, 2007). Muhammad et *al.*, (2007) attribute this similarity to the vigor of the young transplanted plants, aligning with the results of Useni et *al.*, (2014).

For growth parameters such as plant height and collar diameter, significant differences were observed at various levels. Regarding plant height, under the effects of application methods, treatment L (application of 30 t/ha of localized manure) resulted in taller plants and those with larger collar diameters. These results can be explained by the directly available form of nitrogen to the plants after the mineralization of poultry manure, given that nitrogen is the main regulatory element for plant growth (Christianson et *al.*, 2016). Conversely, nitrogen is highly leachable when not buried (Boles et *al.*, 2015). From this perspective, Dolan et al. (2005) suggest appropriate agricultural practices such as hilling and weeding, but especially localized application, as effective means to significantly curb the risks of nutrient losses while improving availability for optimal crop growth compared to broadcasting.

For the number of fruits per plant, treatment L (application of 30 t/ha of localized manure) produced a greater number of fruits compared to treatment V (30 t/ha of broadcast poultry manure). According to Yoni et *al.*, (2005), the performance of solanaceous plants in terms of fruiting is highly dependent on the genetic heritage of the cultivar used. Our results align with those found by Biaou et al. (2016), who noted that using poultry manure as an amendment in vegetable crops, particularly solanaceous ones, provides sufficient potassium, which is crucial for fruiting. This hypothesis is supported by the work of Christianson et *al.*, (2016), who found an increase in fruiting when fertilizers were applied localized at the plant base compared to broadcasting. Climatic factors such as rain or sun can lead to runoff or evaporation due to solar radiation, causing nutrient losses essential for plant metabolism (Taonda et *al*., 1995).

For the average fruit weight under the effects of application methods, treatment L (30 t/ha of localized manure) resulted in a greater weight compared to the lower weight obtained from treatment V (30 t/ha of broadcast manure). In interactions, treatment FCO3L (30 t/ha of localized poultry manure from Congo Eggs farm) showed greater weights compared to treatment FH1V (30 t/ha of broadcast manure from Hasna farm). This result may be attributed to the mineral quality of the feed given to the hens at Congo Eggs farm, which has a high concentration of potassium, responsible for good fruiting and growth (Zougmoré et *al.*, 2004). Broglie et *al.*, (2005) and Taonda et al. (2015) revealed that while fruit weight is influenced by water availability and the genetic potential of the variety used, this parameter can also be influenced by plant biomass, which is nitrogen-dependent. These findings confirm the importance of applying nitrogen- and potassium-rich poultry manure locally, as this technique makes these elements available and reduces their evaporation into the atmosphere, ensuring exclusive absorption by the plants (Zougmoré et *al.*, 2004).

Significant differences were obtained under the effects of application methods. Treatment L (30 t/ha of localized manure) achieved a higher yield compared to treatment V (30 t/ha of broadcast manure). These results can be explained by the availability of potassium to the plants influenced by localized application (Dolan et *al.*, 2005). In soil, this element is highly mobile and therefore difficult to fix in the absorbing complex, making it unavailable to plants (Lumpungu et *al*., 2015). This is consistent with the results of Chaffin et *al.*, (2011) on chili cultivation, which demonstrated that the availability of potassium in high concentrations directly available to the plant, facilitated by the mineralization of organic matter and the mode of application, increased production by up to 20% compared to treatments where potassium was applied broadcast.

Conclusion

This work was initiated with the objective of assessing the influence of the origin of organic fertilizers and the application method on tomato behavior. To this end, an experiment was conducted in the experimental field of the Faculty of Agricultural Sciences following a factorial design (3x2) with four repetitions. The observations during this study focused on growth and production parameters. The collected data were subjected to two-factor variance analysis at a 5% significance level using R software, and Tukey's test was applied in case of significant differences. The results indicate that significant differences were obtained across all parameters except for the recovery rate. The highest yield was achieved in treatment L (30 t/ha of localized manure), which yielded 39.80 ± 7.35 t/ha, compared to the lower yield obtained in treatment V (30 t/ha of broadcast manure), estimated at 32.76 ± 12.71 t/ha. In interactions, treatment FCO3L (30 t/ha of localized poultry manure from Congo Eggs farm) resulted in an estimated yield of 36.08 ± 4.17 t/ha compared to the lower yield obtained from FH1V (30 t/ha of broadcast manure from Hasna farm), estimated at 27.08 ± 1.38 t/ha. This yield appears relatively higher than those obtained by local farmers, who rarely exceed 25 t/ha. Based on the results obtained during this study, we recommend the use of 30 t/ha of localized manure from Congo Eggs farm to local producers for achieving good yields in Lubumbashi.

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