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Growth, yield and economic efficiencies of tomato (*Solanum lycopersicum* L.) applied with different farm manure teas

Cabahug, A. G. and Villaver, J. P.*

School of Agriculture, Forestry and Environmental Studies, J.H. Cerilles State College – Dumingag Campus, Dumingag, Zamboanga del Sur, Philippines.

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Abstract Results showed that the application of swine manure tea gave better effects on the growth (*P<0.05*) and yield performance of tomatoes *(P<0.01*). The swine manure tea produced taller plants, shorter number of days from transplanting to flowering and produced the heaviest and highest number of harvested tomato fruits (*P<0.01*). Correlation coefficient (r) revealed a moderate to high positive correlation (0.503 – 0.976) on the plant height, number of fruits, and yield when applied with swine manure tea due to its high content of soluble potassium (K_2O). Economically, the application of swine manure tea obtained the highest net income at ₱298, 200.00 ha^{-1}, and a return of investment of 244.50% as compared to the rest of the farm manure.

Keywords: Manure, Return on investment, Tea, Tomato, Yield

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important crops cultivated in the world. This is considered a favorite vegetable of most people because it is a good appetizer and at the same time, rich in vitamins and nutrients (Ali *et al*., 2020). It can be eaten raw or processed into canned products. The predicted 90 thousand metric tons of tomatoes produced from January to March 2022 was a 6.1 percent decrease from the 95.87 thousand metric tons produced during the same period in 2021. The Zamboanga Peninsula generated only 553.7 metric tons, whereas the Ilocos area produced the most of 35.83 thousand metric tons (PSA, 2022). Despite being produced as an annual plant, tomatoes are considered a perennial crop. It is a trailing, hairy herbaceous plant with branching stems. Depending on the cultivar, plants typically grow to a height of 1-3 meters. There are varieties of tomatoes that are tall, while some are short. Protein, lipids and crude fiber are additional key nutrients found in tomatoes (Opadotun *et al*., 2016). The antioxidant lycopene and beta carotene can be found in abundance in tomatoes (Saksomboon *et al*.,

* **Corresponding Author:** Villaver, J. P.; **Email:** jepoy_villaver@yahoo.com.ph

2020) and (Soytong *et al*., 2021). A diet that is balanced and healthy should include tomatoes. They are abundant in dietary fiber, carbohydrates, vital amino acids, minerals, and vitamins (Szabo *et al*., 2018). Iron, phosphorus, and vitamins A and C are all abundant in tomatoes. They also include trace levels of thiamine, niacin, and riboflavin, and a small amount of the B complex. Fresh tomato fruits are used in salads, and cooked tomatoes are used in soups and sauces (Naika *et al*., 2005). They can be transformed into juices, sauces, and purees. Additionally, significant in terms of the economy are tomatoes in cans and dried form (Jayathunge *et al*., 2012).

This vegetable needs careful attention particularly during its growing stages due to its susceptibility to pathogens. Most often, farmers encountered *Fusarium* wilt that causes wilting during daytime when the temperature is high while normal during nighttime when the temperature is cool (El-Mohamedy *et al*., 2013b). This symptom happens due to the fungal hyphae that block the xylem vessels making them deficient in the water supply. Several leaf diseases in tomatoes will affect their yield are bacterial spots, late blight, and leaf molds (Sivagami and Mohanapriya, 2021). Fruit borer is also a very prevalent pest that leads to the application of pesticides by the growers. The high cost of inputs such as fertilizers, pesticides, and seeds are problems that need a solution from the government. The continuous price hike of inputs may reduce the income of the farmers. The majority of the farmers are dependent on synthetic fertilizers and pesticides which are not friendly to the environment. Besides, the consumers also are at risk due to the residues from pesticides. By using potassium salts and inorganic acids, or by using organic fertilizer like vermicompost, diseases in tomatoes can be reduced (Ambo *et al*., 2010) and (El-Mohamedy *et al*., 2013a). The biological pesticide also can inhibit the development of diseases (Sibounnavong *et al*., 2012). Seed coating with endophytic bacteria is also important in the prevention of fungal infection of tomatoes (Koohakan *et al*., 2020).

Considering the abovementioned problems, organic farming is one of the major solutions. There are inputs available within the farm that are underutilized by the farmers due to a lack of information. Farm manures are less expensive compared to synthetic fertilizers. Farm manures can be processed into teas to supply the essential nutrients for plant growth and fruit development. Manure teas could be the best organic fertilizer because it is readily available in farmers' fields, especially for those who are raising farm animals. Manure teas contain readily available essential nutrients for normal plant growth and development. It also improves the fertility and productivity of the soil. The objective was to investigate the effects of manure teas on the growth, yield, and economic efficiencies of tomato plants.

Materials and methods

The study was conducted from September 12, 2018, to January 9, 2019, at the crop science experimental area of J.H. Cerilles State College – Dumingag Campus, Dumingag, Zamboanga del Sur, Philippines. The area is 356.31 meters above sea level and situated at 7°11'18.99" North latitude, 123°17'32.43" East longitude. The area of 357 m^2 was laid out using Randomized Complete Block Design (RCBD) which was divided into four treatments and four replications. The treatments were as follows, T_1 – control, T_2 – cattle manure tea, T_3 – swine manure tea, and T_4 – goat manure tea. The area was cleared by slashing the weeds. It was plowed twice at weekly intervals using an animal-drawn plow and harrowed after each plowing to pulverize the soil. The study was composed of 16 plots randomly designated as an experimental unit to accommodate the four treatments and replicates. Each experimental unit had a dimension of 3 x 4 m.

Manures of different animals were collected from the animal science projects of the school. In manure tea preparation, the bucket was filled with 20 liters of water. Ten kilograms of manure were placed inside the sack using a shovel and then tied with straw. Then the sack filled with 10 kg of manure was soaked in a bucket with 20 liters of water. The bucket was covered with a canvass to keep flies away. The sack with manure was allowed to soak in the water for 25 days until manure tea reaches a deep, golden-brown color. After 25 days, the sack was allowed to hang over the bucket until it no longer drips. A commercial variety of tomato was procured from a reliable agricultural supplier. The seeds were sown in a well-prepared seedbox. The medium was a mixture of one part garden soil, one part sand, and one part goat manure by volume which was sterilized with hot water. As soon as tomato seedlings produced two pairs of leaves, pricking was done in rolled banana leaves filled with vermicompost and topsoil. Pricked tomato seedlings were hardened by gradually exposing them to sunlight. Hardening was done to acclimatize the tomato seedlings making them ready for transplanting to the experimental plots. Tomato seedlings were transplanted in the experimental area two weeks after hardening at a distance of 75 cm between rows and 50 cm between hills. Missing hills were replanted by reserved seedlings one week after transplanting. The application of farm manure teas was done at the rate of 100 ml liquefied fertilizer to every plant. The initial application was done by pouring the manure tea around the base of each plant two weeks after transplanting and was repeated at one-week intervals until the fruiting stage. Decapitation was implemented two weeks after transplanting to enhance the production of branches of all plants. Removal of the apical bud was done using

pruning shears. The plants were properly taken care of throughout the growing period. Weeds were controlled to prevent nutrient competition with the crops. Hilling up was done using a shovel and blunt bolos to support the plants from lodging. Hand-picking of insect pests was done in the morning to control twig and fruit borers of tomato. Trellising was also provided in all plants to support from lodging and to prevent the fruit from touching the ground. Trellising was done using bamboo posts connected with a tie wire. Individual plants were tied with plastic twine and connected to the tie wire to support the plant throughout the whole growing period. Harvesting was done when the fruits of tomatoes reached the breaker stage. The representative plants were harvested first together with all plants within each plot for proper data gathering. The data gathered were plant height, number of days from planting to 50% flowering, number of fruits per harvest, the weight of fruits per harvest, yield per hectare, and cost and return analysis. Agrometeorological data were also monitored in the area throughout the study period. The area was also analyzed to determine the soil pH, organic matter, and NPK content. The data were analyzed using Statistical Tool for Agricultural Research (STAR) software. The mean comparison was done using Tukey's test or the honestly significant difference (HSD) test. Correlation of selected parameters was also performed using Pearson correlation (r) in Minitab 17.

Results

Agrometeorological data during the conduct of the study

The weekly average temperature (℃) and weekly average relative humidity (%) are shown in Figure 1. At 8:00 AM, the weekly average temperature was 26.0 ℃. At noon, the weekly average temperature was 28.85 ℃. At 3:00 PM, the weekly average temperature was 27.33 ℃. The overall weekly average temperature was 27.93 ℃. The weekly average relative humidity at 8:00 AM was 81%. At noon, the weekly average was 70.82%. At 3:00 PM, the weekly average relative humidity was 73.73%. The overall weekly average relative humidity was 75.18%.

Soil analysis before the conduct of the study

The monthly rainfall reading during the conduct of the study is shown in Table 1. In September had a total rainfall of 99 mm, in October with 156 mm, in November with 58 mm, in December with 268 mm, and in January with 32

mm. The total amount of rainfall from the start until the end of the study was 613 mm.

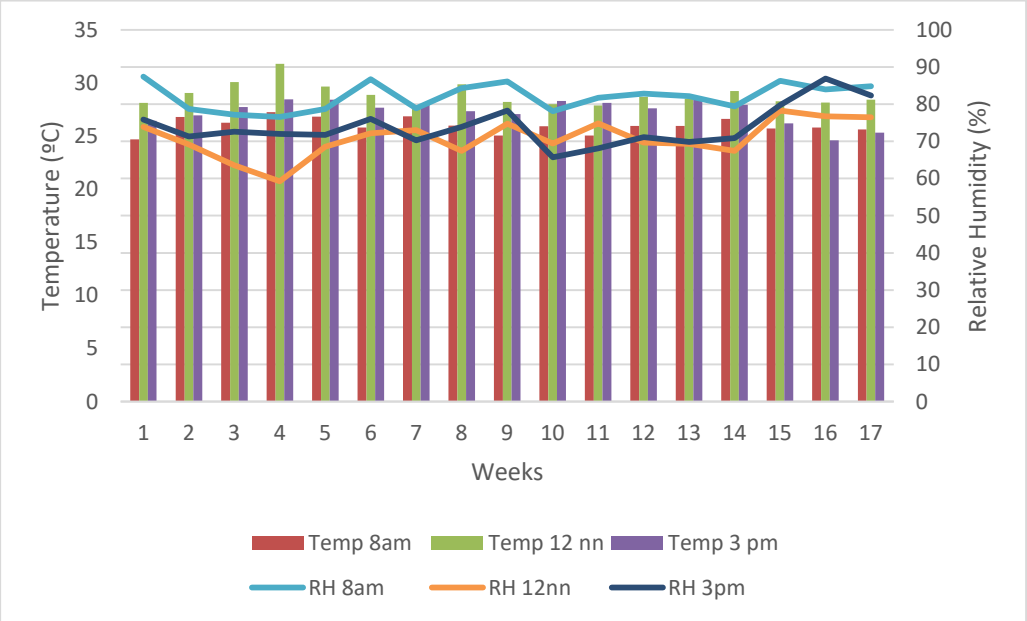

Figure 1. Graph showing the weekly meteorological data on relative humidity and temperature in the locality from September 12, 2018, to January 9, 2019

Table 1. Rainfall reading of the area during the conduct of the study

Months	**Rainfall (mm)**
September 1-30, 2018	99
October 2018	156
November 2018	58
December 2018	268
January 1-8, 2019	32
Total	613

The result of the soil analysis done before the conduct of the study is shown in Table 2. The result of the soil analysis revealed that the soil was strongly acidic with a pH level of 5.57; had a very low content of organic matter 2.58%; very high in potassium 749.0 ppm, and low in phosphorus 7.10 ppm.

Table 2. Soil analysis before the conduct of the study

Test requested	Result	Interpretation
Organic matter (Walkley-Black method)	2.58	Very low
Phosphorus (ppm) Olsen method	749.00	Very high
Potassium (ppm) Cold H_2SO_4 Extraction	7.10	Low
pH (Potentiometric)	5.57	Strongly acidic
Cation Exchange Capacity CEC (meg/100g)	19.34	
Calcium (meg/100g)	2.20	

Result of the analysis of manure teas before the conduct of the study is shown in Table 3. The result of the analysis revealed that swine manure had the highest K_2O content with 11.93%, followed by goat manure with 3.61% and cattle manure with 1.81%. Goat manure also obtained the highest percentage of P_2O_5 content with 2.81%, followed by swine manure at 2.42%, and cattle manure at 0.69%. For nitrogen content, goat manure obtained the highest percentage at 1.97%, followed by cattle manure at 1.63%, and swine manure at 0.83%. Goat manure obtained the highest pH at 8.75, followed by cattle manure at 7.75 and swine manure at 5.55.

Table 3. Analysis of manure teas before the conduct of the study

Farm manure teas	Test analyses			
	N (%)	P_2O_5 (%)	K_2O (%)	pH
Swine manure	0.83	2.42	11.93	5.55
Goat manure	1.97	2.81	3.61	8.75
Cattle manure	1.63	0.69	1.81	7.75

Plant height

The average plant height of tomatoes at 15, 30, 45, and 30 DAT is shown in Table 4. Treatment 3 (swine manure tea) was consistent with the highest in terms of plant height at 15, 30, 45, and 60 DAT with 16.90, 42.70, 74.43, and 86.88 cm, respectively. Statistical analysis revealed a significant difference in the plant height of tomatoes at 30 and 45 DAT ($P<0.05$).

Table 4. Plant height at 15, 30, 45, and 60 DAT

Treatments	Plant height (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
T_1 - Control	14.02	32.60^{b}	59.30^{b}	77.85
T_2 – Cattle manure tea	15.10	34.35^{b}	59.10^{b}	76.78
T_3 – Swine manure tea	16.90	42.70^{a}	74.43^{a}	86.88
T_4 – Goat manure tea	15.42	38.85^{ab}	65.70^{ab}	80.05
F- test	ns	*	*	ns
C.V. (%)	11.54	11.13	10.32	7.49

ns – not significant, * - significant at 5% level of confidence; DAT – Days after transplanting

Days from transplanting to 50% flowering

The number of days from transplanting to 50% flowering of tomato plants is shown in Table 5. The plants applied with swine manure tea were the earliest to bear flowers at 38.25 with ±0.25 standard error deviation when compared to plants assigned to other treatments. However, the results were non-significant differed from farm manure teas. It did not affect the number of days from transplanting to 50% flowering of tomato plants.

Table 5. Number of days from transplanting to 50% flowering

Treatment	Days to 50% flowering ±SE
T_1 - Control	39.00 ±0.41
T_2 – Cattle manure tea	39.50 ±0.50
T_3 – Swine manure tea	38.25 ±0.25
T_4 – Goat manure tea	40.00 ±2.38
F- test	ns
C.V. (%)	6.68

ns – not significant, * - significant at a 5% level of confidence

Number of tomato fruits per harvest

The number of fruits harvested per treatment is shown in Table 6. The data showed that the highest number of fruits harvested per treatment which obtained during the first to third harvest. Statistically, the result was significantly (*P<0.01*) differed. The swine manure tea obtained the highest total number of harvested fruits at 683, followed by goat manure tea at 550, cattle manure at 541, and control with 459 fruits.

Table 6. Number of fruits harvested per treatment at 1st to 10th harvest

Treatment	Number of fruits										
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Total
T_1 - Control	83[b]	54[b]	45[b]	31	37	36	54	35	33	54	459[b]
T_2 – Cattle manure tea	106[b]	66[b]	47[b]	35	39	32	69	49	47	53	541[b]
T_3 – Swine manure tea	158[a]	92[a]	76[a]	36	46	41	62	50	54	68	683[a]
T_4 – Goat manure tea	107[b]	76[b]	60[b]	34	46	39	51	36	37	65	550[b]
F- test	*	**	**	ns	ns	ns	ns	ns	ns	ns	**

ns – not significant, * - significant at a 5% level of confidence

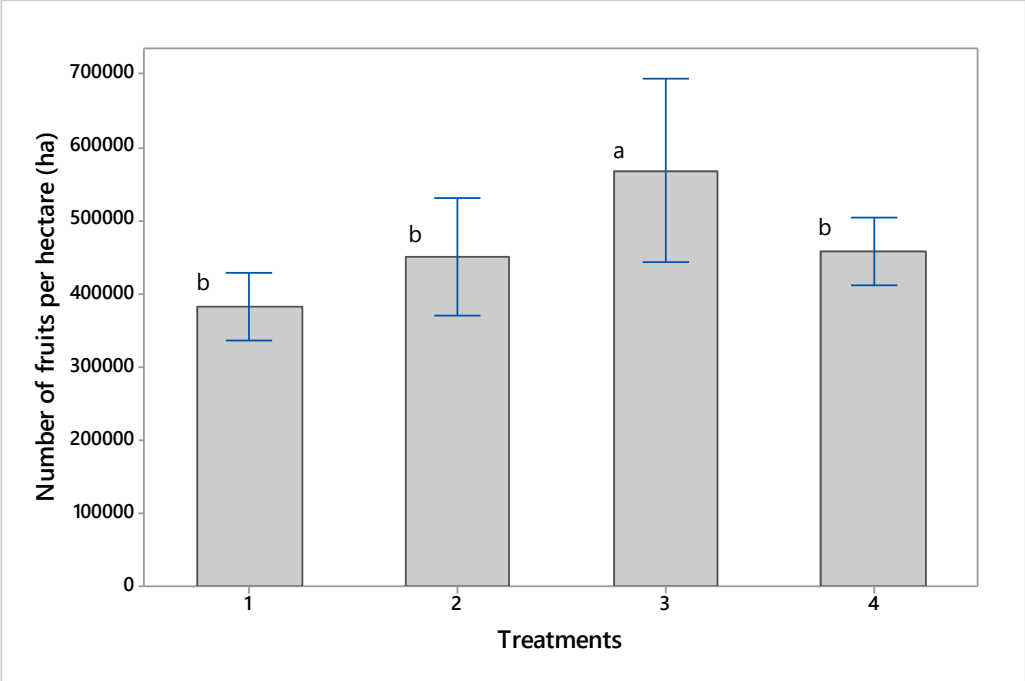

Figure 2. Number of tomato fruits per hectare (ha) in response to different farm manure teas (1 – control, 2 – cattle manure, 3 – swine manure, 4 – goat manure)

The number of tomato fruits harvested per hectare in response to different farm manure teas applied is shown in (Figure 2). It showed that the tomato plants applied with swine manure tea produced the most harvested fruits per hectare (568, 750), followed by goat manure (458, 333).

Weight of fruits per harvest

The weight of fruits per harvest is shown in Table 7. It showed that the tomato plants applied with swine manure tea significantly produced the highest weight of fruits at 1st (5.67kg), 2nd (3.88 kg), and 3rd (2.75 kg) harvest. Treatment 3 (swine manure tea) was also consistent in producing the highest weight of fruits per harvest at 4th, 5th, 6th, 8th, 9th, and 10th harvest.

The yield of tomato (t ha^{-1}) as applied with different farm manure teas is presented in Figure 3. As presented, Treatment 3 (swine manure tea) produced the highest yield per hectare at about 20 t ha-1, followed by Treatment 4 (goat manure), Treatment 2 (cattle manure), and Treatment 1 (control).

The correlation coefficient among selected parameters of tomato is shown in Table 8. The correlation analyses revealed a strong positively associated with the yield, plant height, number of fruits, and the farm manure

teas used. It also revealed a moderate positively correlated between the number of fruits and yield to plant height.

Table 7. Weight of fruits per treatment at 1st to 10th harvest

Treatments	Weight of fruits (kg)									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
T_1 - Control	3.15[b]	2.17[b]	1.55[b]	1.15	1.15	0.92	1.70	0.95	0.62	1.85
T_2 – Cattle manure tea	3.52[b]	2.65[b]	1.68[b]	1.35	1.35	0.88	2.27	1.40	1.10	1.50
T_3 – Swine manure tea	5.67[a]	3.88[a]	2.75[a]	1.40	1.40	1.15	2.05	1.77	1.17	2.10
T_4 – Goat manure tea	3.62[b]	3.23[ab]	2.12[ab]	1.25	1.25	1.05	1.52	1.10	0.80	1.90
F- test	*	**	**	ns	ns	ns	ns	ns	ns	ns

ns – not significant, * - significant at 5% level of confidence, T_1 – control, T_2 – cattle manure, T_3 – swine manure, T_4 – goat manure

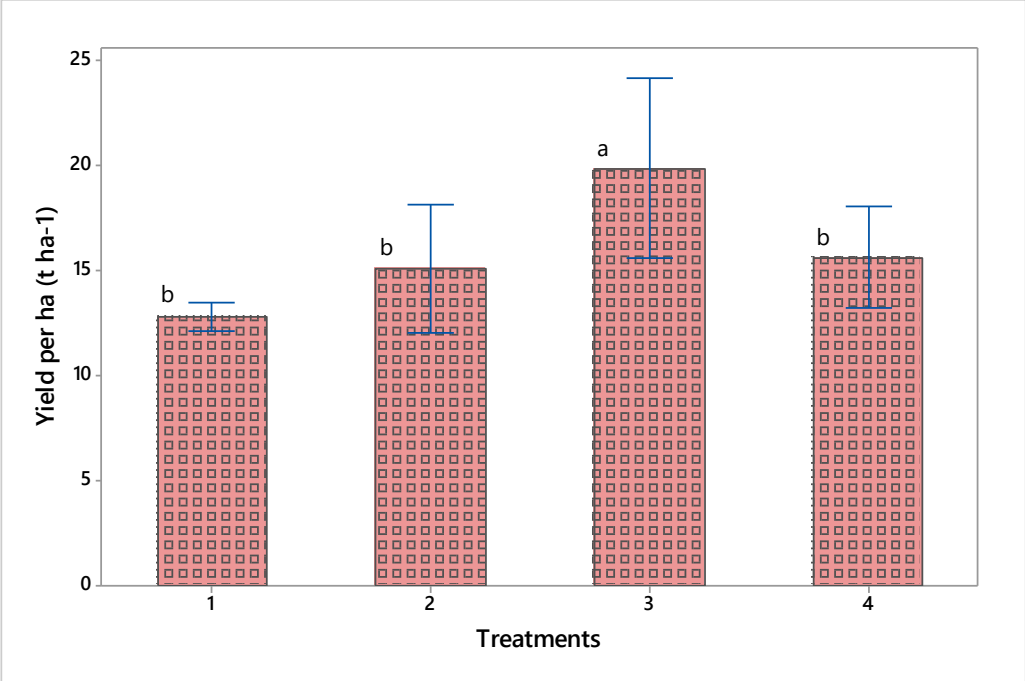

Figure 3. Yield of tomato (t ha^{-1}) in response to different farm manure teas (T_1 – control, T_2 – cattle manure, T_3 – swine manure, T_4 – goat manure)

Table 8. Correlation coefficient (r) among the selected parameters with the different farm manure teas applied

Parameters	Plant height (cm)	Number of fruits	Weight per fruit (g)	Yield (t ha^{-1})	Days to flowering
Number of fruits	0.559*				
Weight per fruit (g)	0.347	0.286			
Yield (t ha^{-1})	0.593*	0.976**	0.485		
Days to 50% flowering	-0.230	-0.166	-0.096	-0.176	
Farm manure teas	0.503*	0.812**	0.404	0.831**	-0.058

* - significant at 5% level, ** - significant at 1% level

Net income and return on investment

The net income and return of investment of tomatoes applied with farm manure teas is shown in Figure 4. Treatment 3 (swine manure tea) obtained the highest net income of ₱211,611.00, and followed by T_4 (goat manure) get ₱141,591.00. Treatment 3 was achieved the highest return on investment of 244.50%, and followed by T_4 (goat manure) at 148.45%.

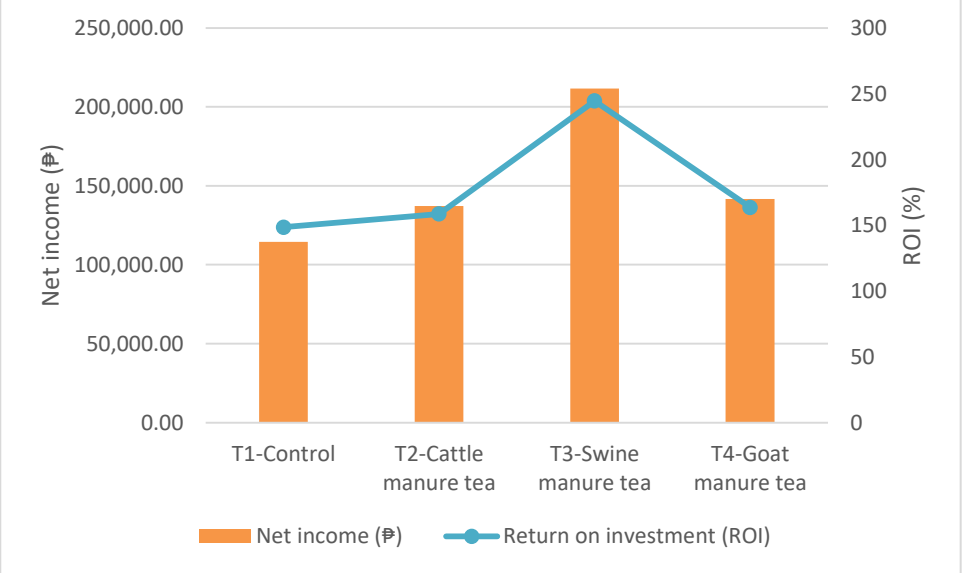

Figure 4. Net income and return of investment of tomato applied with farm manure teas

Discussion

Based on the agrometeorological data observed, the overall temperature was 27.33 ℃ while relative humidity was 75.18%. The tomato plants were in the minimum requirement of the temperature of 10 – 30 ℃. The minimum temperature requirement of tomatoes is 18-22 ℃ (Adams *et al*., 2001) and (Verkerk, 1955). The relative humidity requirement of tomatoes is between 50-70% (Shamshiri *et al*., 2018). Too much temperature may have detrimental effects on the fruiting performance of tomatoes (Van Ploeg and Heuvelink, 2005). The results of the study revealed significant results on the plant height, the number of fruits harvested, and yield per hectare when applied with farm manure teas. In this study, the farm manure teas were utilized to improve the growth and yield performance of tomatoes. Manure tea is absorbed readily by the plant compared to manure fertilizer alone. The release of the nutrient is much faster when applied in the form of tea. Based on the analyses of the different manure teas, swine manure obtained the highest total plant food of 15.18% which is higher than goat and cattle manure teas with 8.39% and 4.13%, respectively. Potassium is responsible for fruit development (Ahammed *et al*., 2022). Swine manure tea was observed as the best organic liquid fertilizer compared to the rest of the treatments. The growth and yield of tomatoes are increased when there is a sufficient supply of essential elements (Tiwari *et al*., 2017). The farm manure teas contained the essential elements. The nitrogen is used for maintaining the green coloring pigment of the plants, and widened the leaf size, thereby improving the photosynthetic efficiencies (Badr *et al*., 2016) and (Gonzaga *et al.*, 2020). The phosphorus improved the root system of tomatoes which is used in the absorption of water and minerals from the soil (Dixon *et al*., 2020). The potassium improved the flowering and fruiting performance of the plants. Deficient in potassium may lower the flowering performance of the plants. Successful flowers are dependent on the presence of a sufficient amount of potassium. Potassium also increases the quality of the fruits by improving their sweetness (Afzal *et al*., 2015). The plants applied with swine manure teas produced a greater number of fruits due to a sufficient amount of potassium. It was very clear that the photosynthetic activities of the plants with swine manure teas are very efficient due to the highest number of harvested fruits. The photosynthates and assimilates from the source towards the sink are efficiently translocated. The correlation coefficient (r) revealed a significant linear relationship with the plant height, number of fruits, and yield of tomato plants. It suggested that the total plant food from the swine manure tea had impacted the parameters, particularly on the number of fruits, and yield per hectare. Farm manure teas had a direct effect on the

parameters mentioned. According to the study by (Hariyadi *et al*., 2019), the application of potassium with nitrogen and phosphorus improved the yield performance of tomatoes. Additionally, the farm manure teas improved the income of tomato growers. The highest return of investment is achieved when applied with swine manure teas due to the high number of fruits harvested with lesser inputs acquired during the production period. As mentioned by (Villaver *et al*., 2021), the lack of capital to procure farm inputs is a problem felt by the farmers. Farmyard manures are just available in the locality and can be used by the farmers without involving a higher capital. Gebrtsadkan and Assefa, (2015) mentioned that the use of farm yard manure improved the net income of the tomato growers. This study concluded that the swine manure tea improved the growth, yield, and economic efficiencies of tomato plants. Another study may be conducted to use the different farm manure teas in different horticultural crops.

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