Comparative Study Between an Organic Liquid Fertilizer Developed by Fish Waste and Department of Agriculture Recommended Inorganic Fertilizer on Growth and Yield of Chilli (*Capsicum frutescens* L.) in Sri Lanka

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Abstract – *The increased and long-term use of chemical fertilizers has led to numerous environmental, economic, and social issues in Sri Lanka. To ensure the long-term sustainability of agriculture, the application of liquid organic fertilizers produced from agricultural and industrial wastes is becoming much more popular. At the same time, the Sri Lankan fish processing industry is looking for ways to utilize the inedible fish wastes from their plants. Therefore, the present study was carried out to examine the effect of novel organic liquid fertilizer (NOLF) produced from fish wastes on the growth and yield of green chilli. Five different formulas of NOLFs i.e. 1% NOLF (T_1), 2% NOLF(T_2), 3% NOLF (T_3), 4% NOLF (T_4), 5% NOLF (T_5), and the recommended chemical fertilizer for Chilli by the Department of Agriculture (DOARF) were used as the treatments of this experiment. The plant height, number of branches/plant, number of leaves/plant, leaf area at the time of flowering and number of fruits/plant were recorded as growth and yield parameters of Chilli, respectively. Analysis of variance (ANOVA) was performed to analyze the data by using the SPSS software package. The significance of means was analyzed with the least significant differences (LSD) between treatment means at $P < 0.05$. The results revealed that the growth and yield parameters of Chilli plants added with DOARF are significantly better than the plants added with different formulas of NOLFs (T_1 to T_5).*

Key words: *Chilli, fish waste, novel organic liquid fertilizer, Sri Lanka*

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1 INTRODUCTION

The application of any fertilizer improves the amount of plant nutrients in the soil, making it more fertile and conducive to crop growth and development, ultimately increasing the final yield of crops. The sources of fertilizer vary from natural to industrial products (Sherer *et al*., 2009). Therefore, the sources of fertilizer can be classified into two broad categories; organic fertilizer and inorganic or chemical fertilizer. As the name suggests, organic fertilizer comes from organic sources such as animal and plant materials, which are natural. Chemical fertilizer comes from inorganic sources, which are synthetic in nature.

Major plant nutrients or the primary nutrients are Nitrogen (N), Phosphorus (P) and Potassium (K) which are consumed by crop plants in relatively large quantities. Crop plants also need minor nutrients or secondary nutrients such as Calcium, Magnesium, Sulfur, Boron, Copper, Chlorine, Iron, Manganese, Molybdenum, and Zinc which are consumed by crop plants in relatively smaller quantities. The response to the fertilizer application of high yielding crop varieties developed during and after the Green Revelation is very high. Therefore, the Application of chemical fertilizers becomes more important in present developing intensive agriculture (Adesemoye *et al.*, 2009 and da Costa *et al.*, 2013). With the Green Revolution usage of nitrogen fertilizer in the world increased by 800% (from 1961 to 2019) which also increased the productivity of conventional food systems by more than 30% per capita (Mbow *et al.*, 2019).

However, increased and long-term use of chemical fertilizer has led to lots of environmental, economic and social issues. Air pollution, water pollution, soil pollution, increase in production cost and human health issues due to food safety problems, and deterioration of quality of agricultural products are some of them. To overcome the problems in the use of chemical fertilizer and to ensure the long-term sustainability of agriculture organic farming has become acceptable. Though organic farming is always associated with lower yields, it has experienced fast growth globally.

Organic farming systems involve the natural management of soil with the help of organic fertilizer such as compost, animal manure and application of soil organic matter. Organic fertilizer improves the physical, chemical, and biological properties of soil and thus improves soil fertility. Various research carried out by various researchers revealed that the use of organic fertilizer as an alternative to chemical fertilizer minimizes food safety and quality issues and associated other negative impacts (Caris-Veyrat *et al.*, 2004, Luthria *et al.*, 2010, Vallverdú-Queralt *et al.*, 2012 and Oliveira, A. B. *et al*. 2013). Furthermore, the application of organic fertilizer improves the nutritional quality of certain vegetable crops such as tomatoes. For example, organic tomatoes had significant amount of vitamin C, carotenoids and polyphenols when compared to the tomatoes harvested from a conventional system of cultivation (Caris-Veyrat *et al.*, 2004).

Liquid organic fertilizers produced from agricultural residues and industrial wastes are becoming much more popular among farmers nowadays. The above wastes can be used as a carbon substrate and a simple fermentation process carried out with the help of microorganisms is the principle behind the production of liquid organic fertilizers. Fish waste is one such carbon substrate that can be easily converted into liquid organic fertilizer. The fish processing industry produces large amounts of fish waste (Jung, H.Y. and Kim, J.K. 2016) which causes marine and land pollution due to inappropriate disposal in the sea or on land (FAO, 2018). Therefore, the conversion of fish waste into liquid organic fertilizer has the added advantage of reducing soil and water pollution. However, the application of fish waste as an organic fertilizer can attract mice and flies due to its bad smell (Bhagwat *et al.,* 2018). Biodegradation of fish waste through proper fermentation solves this problem. Therefore, the production of liquid organic fertilizer by using fish waste provides a solution to the problem of waste disposal and the resultant liquid organic fertilizer can be used as an effective plant growth promoter (Jung *et al.,* 2016, Dao *et al,.* 2011). The liquid organic fertilizer acts faster than solid organic ones and is short-acting compared to the dry organic once which are longer acting.

Further, in Sri Lanka, the fish processing industry is looking for the ways to dispose of inedible fish wastes from their plants. Therefore, the present study was carried out with the intention of introducing a new liquid organic fertilizer developed from fish wastes and assessing its performance by comparing it with inorganic fertilizer recommended by the Department of Agriculture in Sri Lanka for the growth and yield of green chilli (*Capsicum frutescens* L.).

2 METHODOLOGY

2.1 Experimental Site

The study was carried out in a field belonging to Ceylon Agro Chain (Pvt) Ltd, Anamaduwa in Sri Lanka during the period from March to July 2023. Anamaduwa is situated in the Puttalum administrative district in the North Western Province of the country. Green Chilli (*Capsicum frutescens* L.) belonging to the family Solanaceae and the Genus Capcicum, one of the important spice crops widely grown in Sri Lanka has been selected as the test crop for the experiment. This is a short term crop with a life spans of three and half months.

2.2 Production of Novel Organic Liquid Fertilizer (NOLF)

The novel liquid organic fertilizer was produced using fish waste remains after processing fish for the export market by Ceylon Agro Chain (Pvt) Ltd. Ten Kilograms (10kg) of fish waste and 7kg of crushed Jaggery (local name - Sakkara) were mixed and added into an airtight container, allowing for anaerobic digestion (fermentation) for a period of 15 days at ambient temperature. At the end of 15th day another 3kg of crushed Jaggery was added to the container, stirred thoroughly and allowed for another 15 days for to complete the fermentation under the same anaerobic condition. On the 30th day the mixture was filtered using 1mm mesh. The fermented filtrate was used as the novel organic liquid fertilizer. The newly produced organic liquid fertilizer was analyzed for its color through visual inspection, odor through sniffing, pH with the help of pH meter, N % using Kjeldhal method, P % by using Olsen method and K % with the help of Flame Photometer.

2.3 Treatments

Before use, the NOLF was diluted with distilled water to produce five different formulas of NOLF; 1% NOLF - 10ml NOLF + 1leter of distilled water, treatment one (T_1), 2% NOLF – 20ml of NOLF + 1leter of distilled water, treatment two (T_2), 3% NOLF - 30ml of NOLF + 1leter of distilled water, treatment three (T_3), 4% NOLF – 40ml of NOLF + 1leter of distilled water, treatment four (T_4) and 5% NOLF - 50ml of NOLF + 1leter of distilled water, treatment five (T_5). The Sri Lankan Department of Agriculture recommended inorganic fertilizer (DOARF) for Chilli used as the control treatment in this experiment. Accordingly there were 6 treatments in this experiment.

2.4 Experimental Design and Allocation of Treatments

The experimental design was the completely randomized design (CRD). All 6 treatments were replicated 5 times. Poly bags filled with a medium of top soil : compost : paddy husk charcoal, 3:2:1 were used to transplant the Chilli plants. Each poly bag was planted with two Chilli plants, properly selected from a Chilli nursery managed as recommended by the Department of Agriculture (DOA) Sri Lanka. All treatments were allocated among the experimental units (polybags) randomly. The different formulas of NOLFs (i.e., 1%, 2%, 3%, 4% and 5%) were added to the relevant polybags once in four (04) days until the fruiting stage of Chilli plants. DOARF was added to the relevant poly bags with Chilli plant as recommended by the DOA of Sri Lanka. All other cultural practices were performed as recommended by the DOA of Sri Lanka.

2.5 Growth and Yield Parameters Recorded

Plant height, the number of branches/plants, number of leaves/plant, and leaf area were recorded at the time of flowering as growth parameters. Number of fruits/plants was recorded as yield parameter.

2.6 Data Analysis

Analysis of variance (ANOVA) was performed to analyze the data by using SPSS software package. The significance of means was analyzed with the least significant differences (LSD) between treatment means at $P < 0.05$.

3. RESULTS AND DISCUSSION

Color, odor, pH, N%, P%, and K% of the NOLF were measured and the results are shown in Table 1.

Table 1 Characteristics of NOLF

Characteristic	Feature or value
Color	Vine red in color
Odor	Ripen wood apple odor
pH	4.4
N%	0.06
P%	1.1
K%	0.67

The color and odor of the NOLF were acceptable. The pH of the NOLF is acidic. pH of most liquid organic fertilizers ranges from 3 to 5 which is considered as a suitable pH for crop production (Saelee, 2004). The pH value of the NOLF was 4.4 which is within the range of above finding, pH = 3 – 5. According to the standards given for any liquid organic fertilizer by the Sri Lanka Standards Institute (SLSI), good quality liquid organic fertilizers should normally have a pH range from 6.0 - 8.5 (SLSI 2021). The pH value of NOLF is slightly acidic when compared with the SLSI standards. After 30 days of fermentation the NOLF had 0.06% total N, 1.1% total P and 0.67% total K. According to the standards given by the SLSI 2021, any liquid organic fertilizer should be consisted of 1.0 N (as N, percent by mass), 0.5 P (as P_2O_5 percent by mass), and 0.5 K (as K_2O_2 percent by mass). According to the present finding the amount of N present in the NOLF was relatively low (0.06%). The total amount of P was higher (1.1%) than standard amount given by the SLSI. The total K content was slightly higher than the recommended value of SLSI. According to Sureshkumar *et al.*, 2013, the presence of large population of phosphate dissolving microorganisms, results more mineralizing P. Denitrification can be the reason for low amount of N in the NOLF.

The effect of all six (06) treatments on the plant height (cm) of Chilli at the time of fruiting showed that the plants cultured under the treatment DOARF had the tallest mean plant height of 32.05cm which was significantly different ($P < 0.05$) from all other five treatments i.e. from T_1 to T_5. The chilli plants under the application of different formulas of NOLFs i.e. from T_1 to T_5 had the mean plant height of around 28cm. However, there was no significant difference between the mean plant heights among the treatments T_1 to T_5 (Table 2).

Table 2 Mean plant height (cm) of the Chilli plants under different treatment

Treatments	Mean Plant Height (cm)	SD	Std. Error
DOARF	32.05[a]	0.69	0.31
T_1 (1% NOLF)	28.42[c]	0.38	0.17
T_2 (2% NOLF)	28.29[c]	0.39	0.18
T_3 (3% NOLF)	28.95[c]	0.13	0.05
T_4 (4% NOLF)	28.43[c]	0.45	0.19
T_5 (5% NOLF)	28.31[c]	0.16	0.16

Note: Means in a column with the same letter/s are not significantly different at p = 0.05

When it comes to the mean number of branches/plant at the time of fruiting, the plants cultured under the treatment DOARF had the highest mean number of branches/plant, i.e. around 8 and significantly different ($P < 0.05$) from all other treatments from T_1 to T_5.

The chilli plants under the application of different formulas of NOLF had a mean number of 6 – 8 branches/plant which was closer to the mean number of branches/plant produced by the treatment DOARF. Treatment T_3 produced a mean number of 8 branches/plant which was significantly different from the mean number of branches/plant under the treatments T_1, T_2, T_4 and T_5 (Table 3).

Table 3 Mean number of branches/Chilli plant under different treatments.

Treatments	Mean number of branches/plant	SD	Std. Error
DOARF	8.20[a]	0.837	0.374
T_1 (1% NOLF)	7.10[b]	0.418	0.187
T_2 (2% NOLF)	6.80[b]	0.837	0.374
T_3 (3%NOLF)	8.40[a]	0.548	0.245
T_4 (4% NOLF)	6.90[b]	0.652	0.291
T_5 (5% NOLF)	7.10[b]	0.652	0.291

Note: Means in a column with the same letter/s are not significantly different at p = 0.05

At the time of the fruiting stage, the number of leaves/plants was counted manually. No significant difference of number of leaves/plant among the treatments DOARF, T_3, T_4 and T_5. However, the highest number of leaves/plant was recorded in treatment DOARF (40 leaves). The number of leaves/plants in treatment T_1 and T_2 were significantly different from all other treatments. However, the number of leaves/plants in each treatment was less (Table 4). The number of leaves in a plant is important for the photosynthesis of the plant. Increased number of leaves increases the leaf area of a plant which can contribute to a high yield.

Table 4 Mean number of leaves/plant under different treatments

Treatments	Mean number of leaves/plant	SD	Std. Error
DOARF	40.90[a]	3.5249	1.5764
T_1 (1% NOLF)	32.20[b]	1.9875	0.8888
T_2 (2% NOLF)	30.30[bc]	2.2528	1.0075
T_3 (3% NOLF)	38.30[a]	1.9875	0.8888
T_4 (4% NOLF)	36.90[a]	2.8592	1.2787
T_5 (5% NOLF)	33.40[a]	1.3874	0.6205

Note: Means in a column with the same letter/s are not significantly different at p = 0.05

The leaf area is also considered one of the growth parameters of this experiment. At the time of fruiting the length and width of randomly selected leaves were measured in cm using ruler to calculate the leaf area. The leaf area (cm^2) was determined by multiplying both length and width of the leaf. The mean leaf area of the plants cultured under different treatments showed significant differences ($P < 0.05$) except for the treatments T_1 and T_5. The highest mean leaf area was recorded in the plants treated with the DOARF (15.38 cm^2). Leaf area of a plant is important its photosynthesis rate and net assimilation and thus influencing the final yield. No significant difference on mean leaf areas of the plants cultured under T_1 and T_5 (Table 5).

Table 5 Mean leaf area of Chilli plant under different treatments

Treatments	Mean leaf area (cm^2)	SD	Std. Error
DOARF	15.38[a]	0.4302	0.1924
T_1 (1% NOLF)	10.30[e]	0.1914	0.0856
T_2 (2% NOLF)	11.99[cd]	0.2931	0.1311
T_3 (3% NOLF)	14.22[b]	0.1412	0.0631
T_4 (4% NOLF)	12.92[bc]	0.5589	0.2499
T_5 (5% NOLF)	10.76[e]	0.2728	0.1220

Note: Means in a column with the same letter/s are not significantly different at p = 0.05

Seventy (70) days after transplanting, the harvesting performed. The number of chilli fruits per plant was counted manually. The number of fruits per plant is the most important yield component of chilli. The mean number of fruits in the plants under different treatments were significantly ($P < 0.05$) different except the two treatments DOARF and T_3. The highest mean number of fruits per plant (19) was counted in chilli plants cultured under DOARF (table 6).

Table 6 Mean number of chilli fruits per plants under different treatments

Treatments	Mean number of fruits/plant	SD	Std. Error
DOARF	19.10[a]	1.4318	0.6403
T_1 (1% NOLF)	14.90[bc]	0.8216	0.3674
T_2 (2% NOLF)	12.70[cd]	1.5248	0.6819
T_3 (3% NOLF)	16.70[a]	1.2042	0.5385
T_4 (4% NOLF)	13.50[bd]	1.7321	0.7746
T_5 (5% NOLF)	11.60[d]	0.8216	0.3674

Note: Means in a column with the same letter/s are not significantly different at p = 0.05

4. CONCLUSIONS AND RECOMMENDATIONS

This research revealed that the Department of Agriculture recommended inorganic fertilizer is effective for the growth and yield of Chilli compared to the newly produced organic liquid fertilizer. The colour, odor, and the pH value of the newly produced organic liquid fertilizer are acceptable. The P% of newly produced organic liquid fertilizer is higher than the expected value of SLSI and the K% is similar to the expected value of SLSI. The N % of the newly produced organic liquid fertilizer is lower than the expected value of SLSI. This could be the reason for less effectiveness of newly produced organic liquid fertilizer.

Further research is recommended to improve the N% of the newly produced organic liquid fertilizer and adjust the pH value to achieve similar performance as inorganic fertilizer.

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