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EFFECTS OF ORGANIC SOIL AMENDMENTS FOR GROWTH, YIELD, AND FRUIT CONTENTS OF HOT PEPPER *(Capsicum frutescens* L.*)*

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Abstract — Hot pepper is a widely-used vegetable and spice crop due to its flavor and pungent taste, rich nutritive value, and medicinal uses. Its capsaicinoids content, which caused the pungency, is known to have anti-inflammatory, anti-oxidant, and medicinal properties. A field experiment evaluated the growth, yield, and fruit quality of organically grown hot pepper Tinghala variety. It was laid-out using Randomized Complete Block Design with twelve treatments and three replications of soil amendments with organic sources. The results indicated that growth variations were significant ($p<0.05$) at different periods with the effects of VC+Calphos+FFJ, VC+FPJ, and VC significantly highest at the early stages of plant development. The number of days to flowering and percent fruit set varied significantly, but the days to fruit set remained the same. The different fertilization caused significant effects on the yield performance of hot pepper ($p<0.05$), with the VC+Calphos providing the highest in the total number of fruits per plant, total weight, and economic yield. The capsaicinoid content in fruits was highest in VC+Calphos+FFJ but, the differences across treatments were insignificant. The nitrogen, organic matter, and pH contents of soil slightly improved while potassium decreased. Phosphorus significantly increased with organic fertilization. Organic soil amendments, therefore, can be a viable option for hot pepper production.

***Keywords* — Capsaicinoids content, *Capsicum frutescens*, fruit quality, organic soil amendments, soil analysis.**

INTRODUCTION

Organic soil amendments are organic materials added to the soil to enhance its properties and to provide nourishment for plants' growth and development. It includes all products such as organic fertilizers, composts or soil conditioners, microbial inoculants, and organic plant supplements (Bureau of Agriculture and Fisheries Standards, 2016).

As modern agriculture dominates agricultural production through high yields using chemical fertilizers, it is not sustainable and creates an unfavorable impact on the environment and consumers' health. The use of the environment and health-friendly organic fertilizers is advocated today as new insights to achieve sufficient and sustainable yields and to meet the increasing global demands for food and agricultural products (Ertani *et al.*, 2015). Inorganic fertilization, commonly used included vermicompost, indigenous microorganisms, fermented plant juice, fermented fruit juice, calphos, oriental herbal nutrients, and many others (Zamora *et al.*, 2016).

Capsicum is an economically important, widely consumed vegetable and spice crop throughout the world (Hegde *et al*., 2014; Saleh *et al*., 2018; Jarret *et al*., 2019; Batiha *et al*., 2020). *Capsicum spp.* contain several bioactive compounds with nutritional and pharmaceutical importance varying between pepper types (Olatunji, 2020). Many species of Capsicum are being cultivated worldwide as a commercial crop for their economic value (Reddy *et al*., 2016).

Capsicum frutescens L. is a species utilized and studied for its capsaicinoids, the alkaloid compounds responsible for the pungency of Capsicum species (Hamed *et al*., 2019). The crop has a promising potential given its phytochemical, nutritive, medicinal, and economic value.

The interest in the production and use of hot pepper is increasing. In the locale of the study, some farmers are growing hot peppers both for family consumption and for commercial purposes. To establish organic production of hot pepper and to improve yield and fruit quality, studies on the use of locally available materials as organic soil amendments would provide solutions to constraints on productivity and food safety while determining the crop's performance, specifically, on the effect on growth, yield, and fruit quality; alkaloid content of fruits, and; macronutrient content of the soil after production.

MATERIALS AND METHODS

Experimental Site

The study was conducted at San Jose, Camarines Sur, situated at the southern part of the Province, with coordinates 13º 42' North and 123º 31' East, 30.4 meters of elevation above mean sea level (PhilAtlas, 2020).

The Tinghala variety of hot pepper was used as the test crop in the experiment.

Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with 12 treatments and three replicates: T1- Recommended Rate of Inorganic fertilization (RRI), T2- vermicompost (VC), T3-Calphos, T4- fermented plant juice (FPJ) of water spinach, T5- fermented fruit juice (FFJ) banana, T6- VC + Calphos, T7- VC + FPJ, T8- VC + FFJ, T9- Calphos + FPJ, T10- Calphos + FFJ, T11- VC + Calphos + FPJ and T12- VC + Calphos + FFJ.

Each block had 12 plots, measuring 410 cm x 420 cm. Each plot had 42 plants arranged in six rows with seven hills in a row. Ten plants were used as samples for the parameters observed.

Experimental Procedures

Soil Sampling and Analysis

Soil samples were collected from nine sites in the experimental area following an X pattern (Mondal, 2020) at about 2.5 cm thick and 5 cm wide at specified depth using a spade, mixed and collected 1 kg soil, air-dried and sieved, packed and labeled in a plastic bag. It was analyzed at the Soil Laboratory of the Department of Agriculture (DA) – Regional Field Office No. 5 at Naga City. The following methods were used in the analysis: N by modified Kjeldal method, P by Olsen method, K by ammonium acetate method (PCARRD, 1980), and pH by potentiometric method. The soil contained 0.15% Nitrogen, 16.62 ppm Phosphorus (medium), 0.14 meg/100g Potassium (deficient), 2.93% (medium) organic matter content and pH of 5.13 (slightly acidic).

Land preparation, Seedling Production, and Transplanting

The land and plot beds were prepared in October 2018 following the experimental design. Seeds were sown in seedling trays with a mixture of equal amounts of vermicompost, rice hull charcoal, and garden soil. Regular watering was done to maintain adequate moisture. Seedlings were hardened through gradual exposure to sunlight and withdrawal of water one week before transplanting. Four-week-old healthy and sturdy seedlings were transplanted in the field at a distance of 70 cm between rows and 60 cm within a row, and one seedling per hill at a depth of 5 cm, covered with soil pressing lightly near the stem to ensure maximum contact between roots and soil and for better plant establishment.

Preparation and Application of Fertilizer

Fertilizer application was based on the treatments used, and on the result of soil and nutrient analysis. The nutrient requirement of hot pepper: N - 60 kg/ha; P - 40 kg/ha, and; K - 150 kg/ha. Table 1 presents the preparation, rate, and frequency of application of the treatments used. FPJ, FFJ, and calphos were chemically analyzed at the Agricultural Systems Institute, Division of Soil Science of the University of the Philippines, College of Agriculture and Food Science at Los Baños, Laguna.

Data Collection

Growth Parameters

The growth parameters include the plant height, days to flowering, days to fruit set, and percent fruit set. Plant height was measured every fifteen days after transplanting up to the start of harvesting.

The number of days from transplanting to the first flowering was recorded when 50% of the plants flowered.

The number of days from flowering to the first fruit set was taken when 50% of the plants had set fruits.

The percent fruit set was obtained using the formula:

$$\text{Fruit Set}(\%) = \frac{\text{No. of Fruits}}{\text{Total No. of Flowers}} \times 100$$

Yield Parameters

The yield parameters were the number of fruits per plant, the weight of fruits per plant, economic yield, and harvest index. The total number of fruits harvested per plant from the ten sample plants was counted. The total weight of fruits in grams was measured. The economic yield was computed using the total weight of harvested fruits per plant and the number of plants in a hectare.

The Harvest Index was determined by using the formula:

$$\text{HI} = \frac{\text{Economic yield (kg)}}{\text{Biological Yield (kg)}} \times 100$$

Table 1. Soil amendments, the nature, and the rate or frequency of application for hot pepper plots.

Soil Amendments	Nutrient Analysis N (%)	P (%)	K (%)	Ca (%)	Raw Materials Used and Preparation	Rate and Frequency of Application
Recommended Rate of Inorganic Fertilization	14.0 46.0 -	14.0 - -	14.0 - 60.0	- - -	Complete fertilizer Urea Muriate of Potash	Basal: 492 grams per plot measuring 17.22 m^2 Side dress: a mixture of 74.9 grams Urea and 315.7 grams Muriate of Potash per plot
Vermicompost	1.19	1.31	0.37	-	African Night Crawler, mud press, cow manure; Organic Agriculture Development Program (OADP) of CBSUA-Pili, Cam. Sur;	Basal: 69.8 kgs per plot
Fermented Plant Juice (water spinach)	0.33	0.13	2.0	-	Water spinach and molasses at 1:1 ratio, fermented for 14 days	6 tbsp/L H_2O; weekly application
Fermented Fruit Juice (Saba banana)	0.31	0.1	1.57	-	Fruits of Saba banana and molasses at 1:1 ratio, fermented for 14 days	6 tbsp/L H_2O; weekly application
Calphos	-	0.16	-	0.75	Eggshells, coco vinegar; a ratio of 2 kilos of eggshells to 5 gallons of coconut vinegar, fermented for 20 days	2 tbsp/L H_2O; weekly application

Alkaloid Content of Fruits

The pungency level of hot pepper fruits was determined through its alkaloid content. Fruit samples were obtained from freshly-harvested ripe hot pepper fruits in each treatment, packed in boxes, labeled, and were brought to Societe Generale de Surveillance (SGS) Philippines, Inc. Laboratory at Makati City for analysis. Capsaicinoids content of the fruits was analyzed based on the Association of Official Analytical Chemists (AOAC) Official Methods of Analysis (AOAC International & Latimer, 2012).

Soil Analysis

After crop production, soil samples per treatment were obtained and submitted to the Soil laboratory of the Department of Agriculture – Regional Field Office No. 5 at Naga City for N, P, K, pH, and OM content analyses, using the following methods: N by modified Kjeidal method, P by Olsen method, K by ammonium acetate method (PCARRD, 1980) and pH by potentiometric method.

Data Analysis

Data were analyzed using frequency count, mean, percentage, and ranking. The significant difference among treatments was analyzed through Analysis of Variance (ANOVA) and the comparison of treatment means through the Duncan Multiple Range Test (DMRT) at 5% level of probability using the Statistical Tool for Agricultural Research (International Rice Research Institute, 2013).

RESULTS AND DISCUSSION

Growth Parameters

The analysis of variance showed that treatments caused a significant ($p<0.05$) effect on plant height at a different time of measurements. Plant height was significantly highest at T12 (23.27 cm) at 15 days after transplanting (DAT); T12 (25.07 cm) and T7 (24.90 cm) at 30 DAT; and T2 (31.97 cm) and T7 (31.77 cm) at 45 DAT. From 45 to 90 DAT, the effect of organic fertilization, other than those with combined foliar fertilizers in T9 and T10, was not significant compared with T1. Nutrients provided by vermicompost and foliar spray or their combinations have a synergistic effect on the plant growth comparable with inorganic fertilizers. The vermicompost, as an organic fertilizer provides some essential nutrients supporting plant growth compared to chemical fertilizers (Dinani *et al*., 2014), thus its application enriches the soil microorganism, plant growth and nutrient content, and shelf life of the produce (Motcha Rakkini *et al*., 2017).

A significant difference (p=0.003) among treatments was observed in the number of days to flowering. Plants in T9 (33 days), T11 (33 days), and T6 (35 days) significantly flowered earlier than plants in T4 (44 days), T10 (45 days), T2 (47 days), and T5 (49 days). T5 - FFJ Banana (49 days) flowered significantly late than the other treatments. The duration was comparable with the normal flowering period of most hot peppers at 7 – 8 weeks (Balfour, 2006). As vermicompost has been shown to promote flowering, the number and the biomass of the flowers, and the production of fruit yield (Zaefarian *et al*., 2016), the result confirmed that Calphos primarily acts in inducing flowering among plants, promoting higher yield, inducing longer shelf-life of fruits, and providing added resistance to plants against pests and harmful insects. Calcium and phosphorus provide plants with their nutrient requirement for the changeover period from growing to flowering or fruiting (Schulert, 2016).

Hot pepper plants set fruits at an average of six (6) days after flowering, ranging from five to eight days. Inorganic and organic fertilization showed no significant difference in this parameter.

The percent fruit set was significantly higher in T6 (94.33%) and all other treatments ranging from 88.33% to 92.00% than T2 (VC) with 80.33% and T5 (FFJ Banana) with 76.67% fruit set, at p=0.002. Application of foliar fertilizers, excluding FFJ Banana alone, aided in improving percent fruit set in hot pepper, providing a significantly higher fruit set from plants grown using T2 only.

Yield Parameters

The analysis of variance showed that the different treatments caused significant (p=0006) effects on the total number of fruits per plant. Hot pepper plants grown using T6 gave significantly the highest number of fruits (203 fruits) than the other treatments. Plants applied with combined vermicompost (T2) or supplemented with other foliar fertilizers (T7, T8, T11, and T12), excluding T9, were similar in the number of fruits produced. Nutrients supplied by foliar fertilizers supplement the requirement of hot pepper to support growth, flowering, and fruiting. Foliar fertilizers enhanced the performance of hot pepper in the production of the number of fruits per plant, as particularly found in T6.

Treatments varied significantly (p=0.0072) in their effects on the weight of fruits per plant. T6 (239.47 grams), T1 (186.65 grams), and T8 (174.41 grams) gave a significantly higher total weight of fruits per plant compared with T9. Other types of organic fertilization were similar in effect with conventional practice. The analysis of variance was recorded at p=0.072. Similar to the total number of fruits and weight of fruits, organic fertilization in T6 (5.64 t/ha) and T8 (4.11 t/ha) were similar with T1 (4.40 t/ ha). The combined benefits provided by the vermicompost and foliar fertilizers in the growth, flowering, fruit set, and fruit development were seemed to have been optimized by hot pepper plants in T6 and T8. Foliar application only provided a supplemental source of nutrients. Hence, when only foliar fertilizer was applied, the yield was significantly reduced, as evident in T9.

The total number and weight of fruits per plant are determinants of its economic yield. The economic yield then determines the production returns that can be obtained from the crop. As cited by Hegazi *et al.* (2017) in their study in sweet pepper, the increase in the availability of Phosphorus and Potassium significantly improved both the growth and yield parameters as the number of fruits per plant, fruits fresh weight, fruit length, and fruit diameter.

The harvest index of hot pepper plants was not significant across treatments (p=0.151) with the highest obtained in T3 (96.49%), followed by T8 (67.21%) while the lowest harvest was in T9 (36.88%). Harvest index, the measurement of the yield of the crop obtained by its economic yield over biological yield, is a factor that affects crop production and acts as an efficiency indicator (AgriHunt, 2016).

Alkaloid Content of Fruits

The analysis of the pungency level of hot pepper, Tinghala variety, receiving different fertilizers showed that T12 produced the hottest fruits (13,970 SHU) while the least was in T6 (8,787 SHU).

The effect on the level of capsaicinoids of hot pepper fruits varied yet not significant. The result of the study produced fruits that fall under Medium Peppers (2,000 to 19,999 SHU) based on the characterization described in the Philippine National Standard (2018) and is comparable to Jalapeno and Serrano hot peppers (Wagonner, 2017). Aside from the genetic makeup of the plant, the amount of capsaicinoids in hot pepper fruits is also dependent on the environment, light intensity and temperature at which the plant is grown, the age of the fruit, and the position of the fruit on the plant (Popelka *et al.*, 2017).

Soil Analysis

The result of the analysis was

Table 2. Effect of different organic fertilizers on yield of hot pepper plants.

TREATMENT[1]		TOTAL NUMBER OF FRUITS PER PLANT	TOTAL WEIGHT OF FRUITS PER PLANT (grams)	ECONOMIC YIELD (t/ha)	HARVEST INDEX (%)
T1	RRI	149 b[#]	186.65 ab	4.40 ab	53.35
T2	VC	92 cd	115.29 bc	2.72 bc	54.43
T3	Calphos	86 cd	113.80 bc	2.68 bc	96.49
T4	FPJ Water Spinach	98 bcd	123.55 bc	2.91 bc	50.27
T5	FFJ Banana	93 bcd	121.91 bc	2.87 bc	59.46
T6	VC + Calphos	203 a	239.47 a	5.64 a	60.24
T7	VC + FPJ	111 bcd	135.82 bc	3.20 bc	42.05
T8	VC+ FFJ	142 bc	174.41 ab	4.11 ab	67.21
T9	Calphos +FPJ	59 d	67.26 c	1.59 c	36.88
T10	Calphos+ FFJ	85 cd	110.19 bc	2.60 bc	56.05
T11	VC+Calphos+ FPJ	113 bcd	134.87 bc	3.18 bc	56.61
T12	VC+Calphos+ FFJ	99 bcd	125.55 bc	2.96 bc	54.54
CV%		**26.24**	**30.30**	**30.28**	**34.54**
Pr(>F)		**0.0006*****	**0.0072****	**0.0072****	**0.1510[ns]**
F Value		**5.12**	**3.38**	**3.39**	**1.66**

[#]Means in a column with the same letter are not significantly different at the 5% level according to DMRT.

[1]*Legend:* *RRI – Recommended Rate of Inorganic Fertilizer*; *VC – Vermicompost*; *Calphos – Calcium phosphate*; *FPJ – Fermented Plant Juice*; *FFJ – Fermented Fruit Juice*

Table 3. Capsaicinoids content of hot pepper fruits grown using different organic fertilizers.

TREATMENT[1]	CAPSAICINOIDS CONTENT (Scoville Heat Units or SHU)[2]
T1 – RRI	10,145
T2 – VC	12,121
T3 – Calphos	10,750
T4 – FPJ	11,773
T5 – FFJ	10,149
T6 – VC + Calphos	8,787
T7 – VC + FPJ	10,253
T8 – VC + FFJ	9,098
T9 – Calphos + FPJ	12,361
T10 – Calphos + FFJ	10,171
T11 – VC + Calphos + FPJ	9,511
T12 – VC + Calphos + FFJ	13, 970

Means in a column with the same letter are not significantly different at the 5% level according to DMRT.

[1]***Legend:*** *RRI – Recommended Rate of Inorganic Fertilizer; VC – Vermicompost; Calphos – Calcium phosphate; FPJ – Fermented Plant Juice; FFJ – Fermented Fruit Juice*

[2]***SHU –*** *Determined based on the Association of Official Analytical Chemists (AOAC) Official Methods of Analysis (AOAC International & Latimer, 2012).*

interpreted as provided by the Department of Agriculture Regional Field Office No. 5. For pH or soil reaction: intensely acidic, pH of 5.0; moderately acidic, pH of 5.6 to 6.0; slightly acidic, pH of 6.0 to 6.5; neutral, pH of 6.6 to 7.0, and; slightly alkaline, pH of 7.1 to 8.0.

For Nitrogen: low, with organic matter (OM) lower than 2.0%; medium, with 2.1 to 4.5%OM, and; high, with OM higher than 4.5%. For Phosphorus: low, lower than 10 ppm; medium, 10 to 20 ppm, and; high, higher than 20 ppm. Potassium is deficient when the soil contains lower than 75 ppm (0.2 meq/100g of soil) and sufficient when it contains higher than 75 ppm.

The final soil analysis showed that the variations in the N, pH, OM, and K contents of the soil were not significant at 5% level, though highest at T12 for pH (5.97) and K (0.13 meq/100g) and T7 for OM (3.71%) and N (0.185%). Comparing these results with the analysis in T1 with pH of 4.72, 3.09% OM, 0.154% N, and 0.12 meq/100g K, it indicated that organic fertilization aids in improving the soil properties.

On the other hand, P content significantly (p=0.001) increased from 16.62 ppm to 79.88 ppm in T12. Other organic treatments were not significantly different from inorganic fertilization.

Generally, organic fertilization gave a better result than inorganic fertilization, which indicates that it improves soil characteristics (Assefa and Tadisse*,* 2019) and will gradually aid in enhancing soil chemical properties continuous application (Li *et al.,* 2018).

For Nitrogen: low, with organic matter (OM) lower than 2.0%; medium, with 2.1 to 4.5%OM, and; high, with OM higher than 4.5%. For Phosphorus: low, lower than 10 ppm; medium, 10 to 20 ppm, and; high, higher than 20 ppm. Potassium is deficient when the soil contains lower than 75 ppm (0.2 meq/100g of soil) and sufficient when it contains higher than 75 ppm.

The final soil analysis showed that the variations in the N, pH, OM, and K contents of the soil were not significant at 5% level, though highest at T12 for pH (5.97) and K (0.13 meq/100g) and

Table 4. Effect of different organic fertilizers on the N, P, K, pH, and OM contents in soils after growing hot pepper.

TREATMENT[1]		pH (1 soil:1 water)	OM (%)	N (%)	P (ppm)	K (meq/100g)
Initial Soil Analysis		5.13	2.93 (M)	0.15	16.62 (M)[a]	0.14 (D)
Final Soil Analysis						
T1	RRI	4.72	3.09	0.154	46.45 bc	0.12
T2	VC	4.95	3.09	0.154	62.21 ab	0.12
T3	Calphos	4.75	3.01	0.150	34.55 c	0.12
T4	FPJ Water Spinach	4.78	3.04	0.152	39.43 bc	0.11
T5	FFJ Banana	4.94	3.09	0.154	44.35 bc	0.12
T6	VC + Calphos	5.07	3.21	0.160	61.93 ab	0.12
T7	VC + FPJ	5.11	3.71	0.185	80.63 a	0.11
T8	VC+ FFJ	5.23	3.17	0.158	60.52 ab	0.12
T9	Calphos +FPJ	4.88	2.89	0.144	35.21 c	0.12
T10	Calphos+ FFJ	4.95	3.04	0.152	41.21 bc	0.12
T11	VC+Calphos+ FPJ	5.13	3.17	0.159	54.66 bc	0.11
T12	VC+Calphos+ FFJ	5.97	3.61	0.180	79.88 a	0.13
CV%		8.54	11.28	11.31	23.68	10.95
Pr(>F)		0.1167[ns]	0.2626[ns]	0.2659[ns]	0.0010***	0.9230[ns]
F Value		1.80	1.35	1.34	4.72	0.43

means in a column with the same letter are not significantly different at the 5% level according to DMRT.

[1]***Legend:*** *RRI – Recommended Rate of Inorganic Fertilization*; *VC – Vermicompost*; *Calphos – Calcium phosphate*; *FPJ – Fermented Plant Juice*; *FFJ – Fermented Fruit Juice*

T7 for OM (3.71%) and N (0.185%). Comparing these results with the analysis in T1 with pH of 4.72, 3.09 % OM, 0.154% N, and 0.12 meq/100g K, it indicated that organic fertilization aids in improving the soil properties.

On the other hand, P content significantly (p=0.001) increased from 16.62 ppm to 79.88 ppm in T12. Other organic treatments were not significantly different from inorganic fertilization.

Generally, organic fertilization gave a better result than inorganic fertilization, which indicates that it improves soil characteristics (Assefa *et al.,* 2019) and will gradually aid in enhancing soil chemical properties through continuous application (Li *et al.,* 2018).

CONCLUSION

The growth and yield of hot pepper fertilized with vermicompost supplemented with either calphos, FPJ or FFJ were comparable to those applied with inorganic fertilizers. In particular, vermicompost alone, VC+calphos and VC+calphos+FFJ promoted plant height; VC+calphos+FPJ and calphos+FPJ stimulated flowering, and; VC+calphos enhanced fruit setting of hot pepper. Moreover, VC+Calphos significantly improved the yield of hot pepper. VC+Calphos+FFJ provided the best combination for high capsaicinoid content.

The use of soil amendments with organic sources in growing hot pepper, specifically VC+FPJ, increased Nitrogen, Phosphorus, and organic matter contents of soil while VC+Calphos+FFJ improved the soil's pH than the conventional practice. Both the organic and inorganic fertilization promoted uptake of Potassium by plants hence, decreased its amount in the soil. It is recommended that VC+Calphos be used as an organic soil amendment for hot pepper production, with Calphos applied as a foliar fertilizer.

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