Agronomic Response of Sweet Corn (*Zea mays* L. var. *rogusa*) to Fermented Agar-agar (*Eucheuma cottonii*) and Methods of Application

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Abstract — This experiment was conducted to find out the effects of fermented agar-agar and the methods of application on the different agronomic parameters of sweet corn. Experimental plots were laid out using split-plot in randomized complete block design (RCBD) with rates of fermented agar-agar (FA) such as commercial organic foliar fertilizer (COFF), 20 ml L⁻¹, 30 ml L⁻¹, and 40 ml L⁻¹ in the main plot and the methods of application - surface and sub-surface in the sub-plot. Indigenous microorganisms (IMO) 7 at the rate of 7.5 t ha⁻¹ was applied as a base in all experimental plots. Results revealed that the FA and the methods of the application did not influence on the plant height, ear height, leaf area index (LAI), ear diameter, ear length, number of kernels per ear, number of rows, weight per ear, and ear yield (t ha⁻¹). The interaction effects of fermented agar-agar and the methods of application influenced on the 50% tasselling of sweet corn. The combined effects of COFF and sub-surface application resulted in early tassel formation which is one day earlier compared to other treatment combinations. In terms of ear yield, COFF produced the heaviest weight at 12.05 t ha⁻¹ while sub-surface application produced the heaviest weight at 11.10 t ha⁻¹. Results provide additional information on the effects of fermented agar-agar and the methods of application on sweet corn production. Replication of this study in other locality is recommended to further confirm the results.

Keywords — Agronomic, fermented agar-agar, methods, sweet corn, yield.

I. INTRODUCTION

Most of the farmers are aiming for an abundant harvest every cropping season. Higher production can be achieved if all of the needed requirements for plant growth and development are met. Any improvement or modification in an agricultural system that may result in higher production is important if it respects the environments and nature. Sweet corn is a monocot plant that is popularized in the 19th century when a single gene mutated in the cornfield (Rubatzky & Yamaguchi, 1997). The mutant corn had kernels with a sugary and creamy endosperm. The low level of starch makes the kernel wrinkled when matured. Sweet corn is protected with a thin seed coat than the common field corn (Yang *et al.*, 2018). Fresh green husks with light brown silks are indications of good-quality ears. Green husk indicates that the corn is fresh and light brown silk denotes that each kernel has been successfully pollinated (Duncan & Howard, 2010). Every strand of silk must be pollinated for successful kernel development. Sweet corn is a result of the naturally-occurring recessive mutation in the genes which control the conversion of sugar to starch inside the kernels (Singh *et al.*, 2014). Sweet corn is picked or harvested when the ears are at its ideal stage at 70 – 75 days after planting.

Organic farming is an urgent need for all farmers to heal the degrading environment and to sustain crop production (Villaver *et al.*, 2019). The use of biofertilizers improves crop quality and yield (Zarabi *et al.*, 2011). The long-term indiscriminate use of synthetic fertilizers will result in the degradation of soil fertility, disturbing the microbial universe, and ultimately contaminating the water sources (Kraaijvanger & Veldkamp, 2015). Due to these reasons, the farmers are compelled gradually to turn towards various options like the use of manures, biofertilizers, and growth regulators. Fermented agar-agar is one of the biofertilizers which is the potential for the enhancement of growth and development of the common field and horticultural crops. Liquid substances obtained from the fermented agar-agar have recently gained importance as foliar fertilizer for many crops including various cereals, pulses and different vegetable species (Pramanick *et al.*, 2013).

Fermented agar-agar contains macronutrients like nitrogen, phosphorus, and potassium (Villaver, 2019). Fermented agar-agar also contains micronutrients such as amino acids, vitamins, cytokinins, auxin and abscisic acid (Zhang *et al.*, 2003). The use of fermented agar-agar in crop production increases nutrient uptake from the

soil and enhances antioxidant properties (Turan & Köse, 2004). Unlike chemical fertilizers, fermented seaweeds are biodegradable, non-toxic, and non-hazardous to humans, animals, and birds (Dhargalkar & Pereira, 2008). Proper and timing of application are also the things to be considered when using biofertilizers. The uptake of solutes in the stomata is of great significance in improving crop production (Fernández & Brown, 2013). This study investigated the effectiveness of fermented agar-agar applied as foliar fertilizer and the methods of application on the growth and yield of sweet corn.

II. MATERIALS AND METHODS

A. Time and Place of the Study

The study was conducted at the crop science experimental area of the Zamboanga del Sur Provincial Government College, Aurora, Zamboanga del Sur from January to March 2019.

B. Research Design

The study was conducted in a split-plot design with rates of fermented agar-agar (commercial organic foliar fertilizer, 20 ml L⁻¹, 30 ml L⁻¹, and 40 ml L⁻¹) as the main plot and the methods of application (surface and sub-surface) as sub-plot. Each treatment was replicated three times. Ten sample plants were chosen from the two inner rows for plant height and leaf area analyses.

A total land area of 500 m² was divided into 24 equal plots at a dimension of 4.5 m x 4 m. Plants were planted at a distance of 75 cm between rows and 25 cm between hills. Detail of treatment and treatment combinations is shown in table 1.

Table 1. Treatments and treatment combinations

A – Rates of Fermented Agar-agar	B- Methods of Application	Treatment Combination	Treatment Code
A ₁ – COFF (control)	M ₁ – Surface	A ₁ M ₁	T ₁
	M ₂ – Sub-surface	A ₁ M ₂	T ₂
A ₂ – 20 ml L ⁻¹	M ₁ – Surface	A ₂ M ₁	T ₃
	M ₂ – Sub-surface	A ₂ M ₂	T ₄
A ₃ – 30 ml L ⁻¹	M ₁ – Surface	A ₃ M ₁	T ₅
	M ₂ – Sub-surface	A ₃ M ₂	T ₆
A ₄ – 40 ml L ⁻¹	M ₁ – Surface	A ₄ M ₁	T ₇
	M ₂ – Sub-surface	A ₄ M ₂	T ₈

C. Preparation of Fermented Agar-agar

Eight kilograms of agar-agar were chopped and mixed with eight liters of molasses in a basin. After mixing, the materials were placed in a bamboo pole and stored in a cool place to undergo fermentation for seven days.

D. Fertilizer Application

Indigenous microorganisms (IMO) 7 is an organic fertilizer produced from the combination of different manures, topsoil, carbonized rice hull, and vermicompost which undergo a series of aerobic and anaerobic fermentation (Villaver & Borres, 2018). The IMO 7 was applied as a base in the experimental plots 3 days before planting. The fermented agar-agar was applied in the field four times at 20, 30, 40, and 50 days after planting.

E. Harvesting

Harvesting was done at 75 days after planting. Husks were removed, and ears were classified into small, medium and large.

F. Data Gathered

The data gathered in this study were as follows: plant height, ear height, leaf area index, ear diameter, ear length, weight per ear, kernels per ear, and yield (unhusk and husked). Steel tapes were used to measure plant height, ear height, and ear length. Vernier caliper was used to measure the diameter of the ear. A digital weighing scale was used to determine the weight per ear. The leaf area index was done at 45, 55, 65, and 75 days after planting using the formula below:

$$LAI = \frac{\text{length} \times \text{width} \times \text{number of leaves} \times \text{correction factor of 0.75}}{\text{area}}$$

The ground area allotted per hill

The ear yield was computed using the formula:

$$\text{Yield (t ha}^{-1}\text{)} = \frac{\text{Plot yield (kg)}}{\text{Plot size}} \times \frac{10,000 \text{ m}^2}{1,000 \text{ kg}}$$

G. Data Analysis

The analysis of variance (ANOVA) was used to determine the difference among treatments. Pearson correlation coefficient (r) was used to measure the association of selected variables. Tukey's test was used to analyze the significant difference among treatment means using STAR 2.0.1 software.

III.RESULTS AND DISCUSSION**A. Plant Height and Ear Height (cm)**

Table 2 presents the height of sweet corn as influenced by the rates of fermented agar-agar and the methods of application. The data show that the rate of 30 ml L⁻¹ produced the tallest plant height at 169.08 cm and the ear height of 49.05 cm while the surface application produced the tallest plant height and ear height at 165.48 and 48.49 cm respectively.

Table 2. Plant height and ear height of sweet corn in response to rates of fermented agar-agar and methods of application at 75 DAP

Treatments	Plant Height (cm)	Ear Height (cm)
A – Rates of Fermented Agar-agar		
COFF	167.87	47.54
20 ml L ⁻¹	163.58	47.80
30 ml L ⁻¹	169.08	49.05
40 ml L ⁻¹	160.48	48.05
B – Methods of Application		
Surface	165.48	48.49
Sub-surface	165.03	47.72
F-test		
A	ns	ns
B	ns	ns
A x B	ns	ns
C.V. (a) %	4.20	3.88
C.V. (b) %	2.93	6.48

ns = non significant

B. Days to 50% Tasseling and 50% Silking

Table 3 presents the days to 50% tasselling and silking as influenced by rates of fermented agar-agar and the methods of application. The statistical analysis for the effects of rates of fermented agar-agar and the methods of application did not reveal any significant differences in the days to 50% tasselling and silking. Despite its difference, the data show that the tassel and silk formation of sweet corn applied with 20 to 30 ml L⁻¹ is earlier compared to other treatments. It further shows that the surface application of fermented agar-agar hastens the silk formation as revealed by 57.83 which is two days earlier compared to the sub-surface application at 60.25. The interaction effects between the rates of fermented agar-agar and the methods of application revealed a significant difference in the days to 50% tasselling.

Table 3. Days to 50% tasselling and silking of sweet corn in response to rates of fermented agar-agar and methods of application

Treatments	Days to 50% Tasseling	Days to 50% Silking
A – Rates of Fermented Agar-agar		
COFF	56.83	60.00
20 ml L ⁻¹	56.67	58.50
30 ml L ⁻¹	56.67	58.50
40 ml L ⁻¹	57.33	59.20
B – Methods of Application		
Surface	56.92	57.83
Sub-surface	56.83	60.25
F-test		
A	ns	ns
B	ns	ns
A x B	*	ns
C.V. (a) %	1.45	2.24
C.V. (b) %	0.72	1.52

ns = non-significant *=significant at 5% level of significance of Tukey's test

C. Interaction Effects of Fermented Agar-agar and Methods of Application

Table 4 presents the interaction effects of fermented agar-agar and the methods of application on the number of days to 50% tasselling. As shown, the data revealed that the tassel formation of sweet corn is a day earlier with the sub-surface application of COFF. Sweet corn has stomata on both upper and lower leaf surfaces (Kirkham, 2014). Stomata are very important for respiration, transpiration as well as the absorption of carbon dioxide and solutes when sprayed with foliar fertilizers (Eichert, 2008; McElrone *et al.*, 2013). The number of stomata in the upper and the lower surface of leaves of the monocot plants are almost the same except in the dicot plants (Dunn *et al.*, 1965). However, retention and absorption of solutes on the surface may always be affected by rain. The application of FA in the sub-surface would be more advantageous. In this case, the sweet corn plant absorbs more amount of nutrients when sprayed with fermented agar-agar in the sub-surface, thus the tasselling formation was hastened.

Table 4. Interaction effects of fermented agar-agar and the methods of application on the number of days to 50% tasselling of sweet corn

A – Rates of Fermented Agar-agar	B - Methods of Application	
	Surface	Sub-surface
COFF	57.33 ^a	56.33 ^b
20 ml L ⁻¹	56.67 ^{ab}	56.67 ^{ab}
30 ml L ⁻¹	56.67 ^{ab}	56.67 ^{ab}
40 ml L ⁻¹	57.00 ^a	57.67 ^a

Means within the same columns and rows with a different letter are significant at 5% level of significance of Tukey's test

D. Leaf Area Index (LAI)

Table 5 shows the LAI of sweet corn at 45, 55, 65, and 75 DAP in response to fermented agar-agar and the methods of application. The data show that the sweet corn applied with COFF obtained the highest LAI at 45 and 55 DAP with 1.13 and 2.39 respectively. At 65 to 75 DAP, the rate of 30 ml L⁻¹ produced the highest LAI at 2.52 and 2.46 respectively. For the methods of application, the sub-surface application produced the highest LAI at 45 DAP (1.08), 65 DAP (2.45), and 75 DAP (2.36). Statistical analysis did not reveal any significant difference in the LAI of sweet corn at 45, 55, 65, and 75 DAP.

Table 5. Leaf area index of sweet corn in response to rates of fermented agar-agar and methods of application at 45, 55, 65, and 75 DAP

Treatments	Leaf Area Index			
	45 DAP	55 DAP	65 DAP	75 DAP
A – Rates of Fermented Agar-agar				
COFF	1.13	2.39	2.39	2.43
20 ml L ⁻¹	1.04	2.22	2.38	2.30
30 ml L ⁻¹	1.02	2.23	2.52	2.46
40 ml L ⁻¹	1.07	2.20	2.31	2.24
B – Methods of Application				
Surface	1.04	2.29	2.36	2.35
Sub-surface	1.08	2.24	2.45	2.36
F-test				
A	ns	ns	ns	ns
B	ns	ns	ns	ns
A x B	ns	ns	ns	ns
C.V. (a) %	19.76	10.18	10.99	12.77
C.V. (b) %	11.31	13.68	8.78	8.92

ns = non significant

E. Ear Length, Ear Diameter, Number of Rows, Number of Kernels Per Ear, and Weight Per Ear

Table 6 presents the ear length, ear diameter, number of rows, number of kernels per ear, and weight per ear as influenced by rates of FA and the methods of application. The data revealed that the sweet corn applied with COFF produced the longest ear at 163.07 cm, the biggest ear at 4.65 cm in diameter, the most number of rows at 16, the most number of kernels per ear at 584, and heaviest weight per ear at 243.93 grams. For the methods of application, the sub-surface application produced the biggest ear diameter (4.62), number of rows (16), number of kernels per ear (560), and weight per ear (233.50). Statistical analysis did not reveal any significant difference in the ear length, ear diameter, number of rows, kernels per ear, and weight per ear of sweet corn in response to different rates of fermented agar-agar and the methods of application.

Table 6. Ear length, ear diameter, number of rows, number of kernels per ear, and weight per ear of sweet corn in response to rates of fermented agar-agar and the methods of application

Treatments	Ear Length (cm)	Ear Diameter (cm)	Number of Rows	Number of Kernels Per Ear	Weight Per Ear (g)
A – Rates of Fermented Agar-agar					
COFF	163.07	4.65	16	584	243.93
20 ml L ⁻¹	153.90	4.57	15	538	223.37
30 ml L ⁻¹	160.93	4.60	15	564	228.48
40 ml L ⁻¹	158.12	4.50	15	547	224.22
B – Methods of Application					
Surface	159.20	4.54	15	557	226.50
Sub-surface	158.81	4.62	16	560	233.50
F-test					
A	ns	ns	ns	ns	ns
B	ns	ns	ns	ns	ns
A x B	ns	ns	ns	ns	ns
C.V. (a) %	10.44	2.15	2.84	7.93	8.45
C.V. (b) %	4.79	2.53	3.70	5.97	8.84

ns = non significant

F. Ear Yield ($t\ ha^{-1}$) and Percentage of Marketable Ears

The yield and the percentage of marketable ears are shown in table 7. The data show that the COFF obtained the highest yield of unhusk ($12.05\ t\ ha^{-1}$), husked ($8.98\ t\ ha^{-1}$), and the percentage of marketable ears (91.50%). The sub-surface application also obtained the highest yield of unhusk, husked, and the percentage of marketable ears with $11.07\ t\ ha^{-1}$, $8.53\ t\ ha^{-1}$, and 89.09% respectively. Statistical analysis did not reveal any significant difference in the ear yield of unhusk, husked, and percentage of marketable ears of sweet corn in response to rates of fermented agar-agar and the methods of application.

Table 7. The yield of unhusk, husked sweet corn, and the percentage of marketable ears

Treatments	Yield of Unhusk Sweet Corn ($t\ ha^{-1}$)	Yield of Husked Sweet Corn ($t\ ha^{-1}$)	Percentage of Marketable Ears (%)
A – Rates of Fermented Agar-agar			
COFF	12.05	8.98	91.50
20 ml L^{-1}	9.42	7.28	80.60
30 ml L^{-1}	11.40	8.95	87.38
40 ml L^{-1}	10.56	8.33	83.88
B – Methods of Application			
Surface	10.64	8.24	82.59
Sub-surface	11.07	8.53	89.09
F-test			
A	ns	ns	ns
B	ns	ns	ns
A x B	ns	ns	ns
C.V. (a) %	19.97	21.82	13.90
C.V. (b) %	8.42	8.76	9.16

ns = non significant

G. Correlation of Yield and Yield Components of Sweet Corn

Table 8 presents the correlation between the yield and yield components of sweet corn. The data revealed that the ear yield (husked) is highly positively correlated with the ear diameter, ear length, kernels per ear, and weight per ear. The weight per ear also is highly positively correlated with the ear diameter, ear length, kernels per ear, and yield (husked). Results revealed that the yield of sweet corn increased if the weight per ear, kernels per ear, ear length, and ear diameter increases further. The yield of sweet corn is increased with increased ear length and diameter (Ilker, 2011). The experiment of Villaver (2019) reported that the ear yield of sweet corn is increased when the yield components like the weight per ear, kernel per ear, ear length and ear diameter are increased.

Table 8. Correlation of selected yield and yield component parameters

	Ear Diameter	Ear Length	No. of Rows	Kernels per Ear	Weight per Ear	Yield (husked)
Ear Diameter		0.7161**	0.6158**	0.8613**	0.9349**	0.6651**
Ear Length	0.7161**		0.2527ns	0.9024**	0.8817**	0.6985**
No. of Rows	0.6158**	0.2527ns		0.5441**	0.4505*	0.3277ns
Kernels Per Ear	0.8613**	0.9024**	0.5441**		0.9624**	0.6492**
Weight Per Ear	0.9349**	0.8817**	0.4505*	0.9264**		0.6810**
Yield (husked)	0.6651**	0.6985**	0.3277ns	0.6492**	0.6810**	

IV. CONCLUSIONS

The application of rates of fermented agar-agar and the methods of the application did not influence on the plant height, leaf area index, ear diameter, ear length, number of kernels per ear, number of rows, weight per ear, and ear yield. For the interaction effects, the surface application of COFF influenced the number of days to 50% tasselling which resulted in a day earlier when compared to other treatment combinations. Despite its effects, COFF produced the highest yield at 12.05 t ha⁻¹, which is closely followed by 30 ml L⁻¹ of FA at 11.40 t ha⁻¹. The sub-surface application of FA produced the highest yield at 11.07 t ha⁻¹. Moreover, the percentage of marketable ears is higher when applied with COFF at 91.50% and the sub-surface application at 89.09%. The results provide additional information on the effects of rates of fermented agar-agar in the surface or sub-surface application on sweet corn production in Aurora, Zamboanga del Sur, Philippines.

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