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Enhancing leaf mustard (*Brassica juncea* L.) productivity using nitrogen-based fermented plant juice (FPJ)

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Abstract

The use of fermented plant juice (FPJ) as liquid fertilizer is widely practiced in organic farms. However, the length of fermentation and levels of concentration vary and its use in leaf mustard production has not yet been explored. This study was conducted to enhance the productivity of *Brassica juncea* L. in terms of weight, yield, and yield-related parameters across three FPJ concentrations (1.5 tbsp/L, 2.0 tbsp/L, 2.5 tbsp/L) and three durations of fermentation (5 days, 10 days, 15 days). Results showed no significant effect of duration or concentration on the weight of marketable plants or plant biomass. However, for plant biomass, a significant interaction was found between duration and concentration. With respect to return on investment (ROI) and benefit-cost ratio (BCR), there was a significant effect of concentration. A higher concentration resulted to a higher production cost. Results revealed that the different durations of fermentation and concentrations of FPJ had no significant effect on the productivity of *B. juncea*. However, based on ROI and BCR, lower FPJ concentrations were shown to be cost-effective. Thus, the recommendation is to use FPJ at 1.5 tbsp/L fermented over a 5-day duration.

Keywords - fermented plant juice, leaf mustard, nitrogen-based

Introduction

As the world population is rapidly increasing, food security became a great challenge (Amtmann et al, 2008; Weidmann et al., n.d.). To meet the global demand for food, the use of synthetic chemicals is invetable for increased food production (Rivera, 2004). However, when concerns on soil and water pollution, food quality and safety (Setboonsarng & Markandya, 2015), socioeconomic conditions (Landicho et al, 2014) and health and lifestyle are considered (Porciuncula et al., 2014; Shimoguchi & Mojica, 2016), organic agriculture presents an alternative to conventional agriculture system (Setboonsarng & Markandya, 2015). This worldwide shift increased the demand for organically grown crops (Porciuncula et al. 2014; Rivera, 2004). In the Philippines, organic farming has been practiced even before the promulgation of the Philippine Organic Agriculture Act of 2010 (Landicho et al, 2014). Organic fertilizers like fermented and decomposed organic materials have been used in many organic farms (Rivera, 2004).

Fermented plant juice (FPJ) is one of the natural growth enhancers used in organic vegetable production (ATI, 2011). Several accounts have been reported regarding its use (Llamelo et al., 2016; Miller et al., 2013; Sakimin et al., 2017; Tagotong & Corpuz, 2015), but, the duration of fermentation varies. According to Jensen et al. (2006), fermentation should be kept for 5-10 days. Maghirang (2011) recommended that harvesting of fermented product should be done after 7-10 days. The Agricultural Training Institute (ATI, 2006, 2011) suggested that plant materials be fermented for 7 days only.

Various reports and studies recommended varying levels of concentration of FPJ. Miller et al. (2017) suggested that FPJ be generally used at a concentration of 1 part per 500 parts water (1:500) while Maghirang (2011) recommended a dilution rate of 2 tbsp/L of water. The same concentration was also recommended by Mante and Mante (2016) for the bio organic foliar fertilizer in *Dendrobium* spp. A dilution rate of 1 tsp per liter of water was suggested by the ATI (2006) while a concentration

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of 2 tbsp/5L water was recommended by Jensen et al. (2006). Hence, the study was conducted to determine which durations of fermentation and levels of concentration will enhance the productivity of leaf mustard (*Brassica juncea* L.).

Methodology

Experimental Design and Treatments

The study was laid out in a 3 x 3 factorial experiment in RCBD with the durations of fermentation as factor A (5, 10, and 15-day fermentation period) and the levels of concentration as factor B (1.5, 2.0 and 2.5 tbsp per liter of water concentrations) resulting in nine (9) treatment combinations replicated three times as shown below:

T1 – 5 days fermentation at 1.5 tbsp /L
T2 – 5 days fermentation at 2.0 tbsp /L
T3 – 5 days fermentation at 2.5 tbsp /L
T4 – 10 days fermentation at 1.5 tbsp /L
T5 – 10 days fermentation at 2.0 tbsp /L
T6 – 10 days fermentation at 2.5 tbsp /L
T7 – 15 days fermentation at 1.5 tbsp /L
T8 – 15 days fermentation at 2.0 tbsp /L
T9 – 15 days fermentation at 2.5 tbsp /L

Treatment Preparation

Nitrogen-based plant materials such as mung bean (*Vigna radiata* L.) at flowering stage and pseudostem of banana maiden sucker were gathered early in the morning when morning dew was still present. The fermentation procedure was adopted from Jensen et al. (2006). Plant materials were chopped and weighed accordingly in a 1:1:1 (mungbean: banana pseudostem: molasses) ratio. These were mixed thoroughly and stored in a container tightly covered with cloth. The container was placed in a cool dark room for fermentation depending on the number of days based on the treatments mentioned.

The 15-day fermentation treatment was set up 5 days earlier than the 10-day fermentation treatment, which in turn was set up 5 days earlier than the 5-day fermentation treatment. Harvesting of FPJ was done by squeezing the plant materials and straining them to get the extracts. The harvested juice was mixed according to treatment concentrations. The nutrient contents of FPJ across the different number of days of fermentation were analyzed by the Science Resource Center of the University of the Immaculate Conception, Davao City.

Planting and Transplanting

The experiment was conducted at Midsayap, North Cotabato in field conditions with a temperature of 27–34 °C. Mustard seeds were sown individually in cell trays. Seedlings with two leaves were transplanted to plots 15 days after sowing. Seedlings were transplanted late in the afternoon to avoid transplanting shock.

For each of the nine treatments, three plots were prepared as replicates, for a total of 27 plots. Each plot measured 1 m × 2 m, and was arranged in 3 rows of 9 (one row per replicate), with a gap of 0.5 m between plots. Same-sized plots were prepared as buffer plots to surround the 27 experimental plots.

The arrangement of plants within each experimental plot is shown in Figure 1. Ten sample plants were planted in two rows, and were surrounded by buffer plants. Plants were separated by 30 cm, which satisfies the minimum planting distance of 15 cm suggested by Bautista (1994).

Soil was analyzed at the start of the experiment before the addition of the FPJ and at the end of the experiment. Soil pH and percentage of nitrogen, phosphorus and potassium were determined by the Provincial Soils and Water Laboratory, Sultan Kudarat Province.

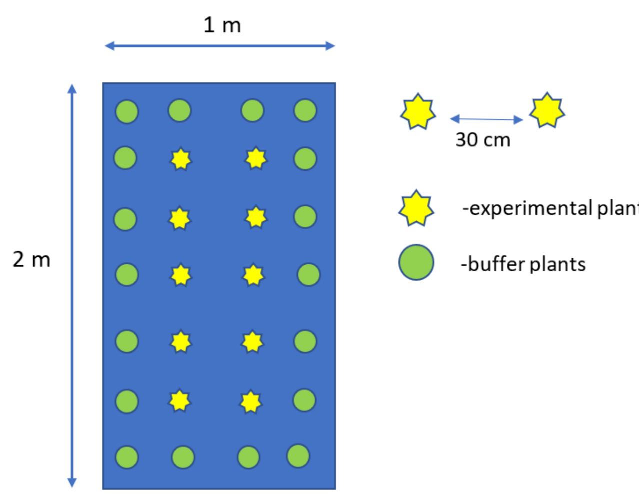


Figure 1. Arrangement of plants within each expiermental plot

Treatment Application

Treatments were applied using a calibrated sprinkler as soil drench during the seedling stage and as foliar spray during the vegetative stage. Following Miller et al. (2013), these were done late in the afternoon before sunset without rain according to treatment concentrations with 150 ml solution per plant. The first application was done weekly until a week before harvest.

Yield Measurement

The number of harvested plants was counted separately per treatment upon harvest. Marketable plants were those with excellent quality. These were field fresh, with no disease or insect pest damage (Figure 2). Non-marketable plants showed pest and disease damage, and were stunted in growth (Figure 3). Marketable and non-marketable plants were weighed separately in grams using a digital weighing scale. The total projected yield was computed as:

$$\text{Projected Yield (kg ha}^{-1}\text{)} = \text{Weight of harvested plants} \times \frac{\text{Projected number of plants}}{\text{Plot area}}$$

Figure 2. Marketable plants

Figure 3. Non-marketable plants

In this formula, the projected number of plants was based on the assumption that each plant is planted on a 0.3 m x 0.3 m plot.

All above ground plant parts were subjected to oven drying at 80°C for 24 hours. The standing biomass was computed using the formula:

$$\text{Biomass} = \frac{\text{Dry weight (above ground tissue)}}{\text{Plot area}}$$

The return on investment (ROI) was calculated, based on the income from the weight of marketable plants. Its formula is given by:

$$\text{ROI (\%)} = \frac{\text{Net income}}{\text{Total production cost}} \times 100$$

The cost and return benefits was analyzed using benefit-cost ratio (BCR), and was based on the gross income from marketable plants. Its formula is:

$$\text{BCR} = \frac{\text{Gross income}}{\text{Total production cost}}$$

Data Analysis

A 3 x 3 analysis of variance was used to analyze data on average number and weight of marketable plants, biomass, and yield and yield-related parameters using Statistical Tool for Agricultural Research (STAR) software. Significant differences were further analyzed using Tukey's HSD Test.

Results and Discussion

FPJ Nutrient Analysis

Table 1 shows tthe analysis of the nutrient content of the extracted FPJ. The FPJ used in this study contained the highest nitrogen concentration after a 15-day fermentation (0.56%) and the lowest nitrogen concentration after a 10-day fermentation (0.34%).

Pre- and Post-soil Analysis

Pre-soil analysis indicated that the site had a soil pH of 6.0 and contained 2.76 ppm nitrogen, 53.84 ppm phosphorus and 135 ppm potassium. The results of the post-soil analysis are shown in Table 2.

Table 2 shows that across all fermentation durations (5, 10, or 15 days), a concentration of 2 tbsp/L manifested the lowest level of nitrogen in the soil (2.1, 1.41 and 1.67 ppm), suggesting that the highest absorption rate occurs at a concentration of 2 tbsp/L.

Number and Weight of Harvested Plants

Table 1. Nutrient analysis of FPJ at 5, 10 and days of fermentation.

	Nitrogen, %	Phosphorus (as P_2O_5), %	Potassium (as K_2O), %
5 days fermentation	0.44	0.43	1.12
10 days fermentation	0.34	0.36	1.11
15 days fermentation	0.56	0.39	1.21

Table 3 shows the average number and weight of marketable and non-marketable plants. The data reveals that the average number of marketable plants ranged from 3.33-10.00 plants across all treatments. Further, all treatments produced a less number of non-marketable plants ranging from 1.33-6.67 plants except for the plot treated with 15-day FPJ at 2 tbsp/L in which all sample plants harvested were marketable. A possible reason why 15-day FPJ produced marketable plants was that it had the highest nitrogen (0.56%; see Table 1) as compared to the 10-day or 5-day fermented FPJ. It is known that nitrogen is essential in biochemical and physiological processes in plants, and enhances yield and quality (Leghari et al., 2016). However, the duration of fermentation did not significantly affect the number of marketable mustard plants (p = 0.403).

Table 3 also shows the average weight of marketable and non-marketable plants for each treatment. On one hand, the highest average weight was recorded from plants fertilized with 2.5 tbsp/L FPJ fermented for 5 days (61.80 g). This may be due to the highest concentration of phosphorus in the FPJ fermented for 5 days (0.43%; see Table 1) which is necessary for root growth (Heydari et al., 2018) leading to the increase of leaf surface area (Kim & Li, 2016) and can contribute about 0.2% on plant/s' dry weight (Schachtman, Reid & Ayling, 1998). On the other hand, statistical analysis no significant difference on the weight of marketable (p = 0.10) and non-marketable (p = 0.91) plants as affected by the duration of fermentation. The nutrients present both on soil and FPJ are within the range required for mustard growth; however, the number and weight of marketable and non-marketable plants harvested are inconsistently lower or higher. Pagluanan and Anical (2010) also found that in comparison with other organic fertilizers, FPJ yielded significantly more eggplants, but there was no significant effect observed in tomato, mungbean, cowpea, and pepper. This study confirms earlier results that FPJ cannot be assumed to singularly produce more marketable plants as the effect may be specific to particular plants and conditions. In this

Table 2. Results of post-soil analysis.

Fermented plant juice	Soil pH	Nitrogen (ppm)	Phosphorus (ppm)	Potassium (ppm)
5 days at 1.5 tbsp/L	6.0	2.47	23.46	138
5 days at 2 tbsp/L	6.0	2.1	50.26	120
5 days at 2.5 tbsp/L	6.0	2.15	16.72	140
10 days at 1.5 tbsp/L	5.8	2.26	20.16	145
10 days at 2 tbsp/L	6.0	1.41	25.8	110
10 days 2.5 tbsp/L	6.0	1.88	25.1	145
15 days at 1.5 tbsp/L	6.0	2.07	30.34	128
15 days at 2 tbsp/L	6.0	1.67	38.16	130
15 days at 2.5 tbsp/L	6.0	2.43	25.84	148

Table 3. Average number and fresh weight (g) of marketable and non-marketable plants of leaf mustard at harvest, Midsayap, Cotabato, 2019.

Duration of Fermentation	Level of Concentration	Average Number of Harvested Plants^{ns}		Fresh Weight (g) of Harvested Plants^{ns}	
		Marketable	Non-marketable	Marketable	Non-marketable
A1 (5 days fermentation)	B1- 1.5 tbsp/L	6.33	3.67	58.98	23.84
	B2- 2.0 tbsp/L	8.33	1.67	51.64	21.18
	B3- 2.5 tbsp/L	8.67	1.33	61.80	17.32
A2 (10 days fermentation)	B1- 1.5 tbsp/L	7.67	2.33	57.53	16.73
	B2- 2.0 tbsp/L	7.00	3.00	48.93	18.44
	B3- 2.5 tbsp/L	6.67	3.33	53.79	16.95
A3 (15 days fermentation)	B1- 1.5 tbsp/L	3.33	6.67	46.73	27.32
	B2- 2.0 tbsp/L	10.00	0.00	54.59	0.00
	B3- 2.5 tbsp/L	4.67	5.33	42.00	31.15

study, the presence of insect pests that attacked the plants during early vegetative stage might be the determinant factor contributing to non-marketability of plants and the non-significant results.

Table 4 shows the projected yield of harvested plants, computed on a hectare basis. The highest yields were recorded from plants fermented for 5 days, at 1.5 or 2.5 tbsp/L (9202.22 and 8791.48 kg/ha, respectively) while the lowest were noted from plants applied with an FPJ concentration of 2.0 tbsp FPJ/L water, fermented for 10 or 15 days (7485.19 and 6065.19 kg/ha, respectively). However, the yield was not significantly affected by duration (p = 0.27) or by concentration (p = 0.19). These results suggest that long duration for fermentation is not necessarily beneficial, confirming Miller et al.'s (2013) suggestion that fermentation should not take longer than 7 days because the "quality of FPJ appears to diminish thereafter" (*p*. 4). A possible reason is that FPJ enhances the production of auxin (Sakimin et al, 2017) and auxin in higher concentration becomes inhibitory to the growth of the shoot (Thimann, 1939). The lower concentration of auxin in FPJ fermented for 5 days might potentially lead to a more optimal use of auxin for proper plant growth. Another possible reason why longer fermentation does not necessarily lead to higher yield is that longer fermentation does not result to higher nitrogen content in the FPJ (Table 1) or higher uptake of nitrogen from the soil (which can be computed from the post-soil nitrogen concentration in Table 2). With higher nitrogen absorption, plants produce more succulent leaves (Fatima et al., 2019). Plants fertilized with 5 days fermentation may make use of the nitrogen more optimally, thereby producing healthier and heavier plants.

The standing biomass of mustard plant fertilized with nitrogen-based FPJ ranged from 4.18 to 17.20g (Table 5), but there was no significant effect of duration and level of concentration on biomass. However, there was a significant interaction between duration and concentration (p = 0.03), which is illustrated in Figure 4. The results suggest that increasing concentration or duration have varying effects on plant growth. For example, at 10 days fermentation, all three concentrations produced

Table 4. Comparison of projected total yield (kg ha^{-1}) of leaf mustard as affected by the durations of fermentation of nitrogen-based FPJ.

Durations of Fermentation	Levels of Concentration		
	1.5 tbsp/L	2 tbsp/L	2.5 tbsp/L
5 days	9202.22	8091.11	8791.48
10 days	8251.22	7485.19	8760.37
15 days	8226.67	6065.19	8128.52

Table 5. Standing biomass (g) of leaf mustard fertilized with different concentration levels of fermented plant juice with varying duration of fermentation.

Durations of Fermentation	Levels of Concentration		
	1.5 tbsp/L	2 tbsp/L	2.5 tbsp/L
5 days	4.18^{a}	17.20^{b}	16.13^{bc}
10 days	15.37^{bc}	14.33^{bc}	14.13^{bc}
15 days	12.83^{bc}	15.87^{bc}	8.57^{ac}

approximately the same biomass. Further, the effect of concentration is much larger in the 5-days fermented FPJ. The LSD post hoc test revealed that Treatment 1 (5-day fermentation at 1.5 tbsp/L) was comparable to Treatment 9 (15-day fermentation at 2.5 tbsp/L), but produced significantly less plant biomass than all other treatments.

Treatment 1 produced the highest yield, but the lowest biomass. Plants subjected to the two treatments resulting in lowest biomass (Treatments 1 and 9) possibly absorbed the least nitrogen, which can be assumed based on the post-soil nitrogen concentration in Table 2. The ability of the root system to absorb nutrients affects the plant's uptake

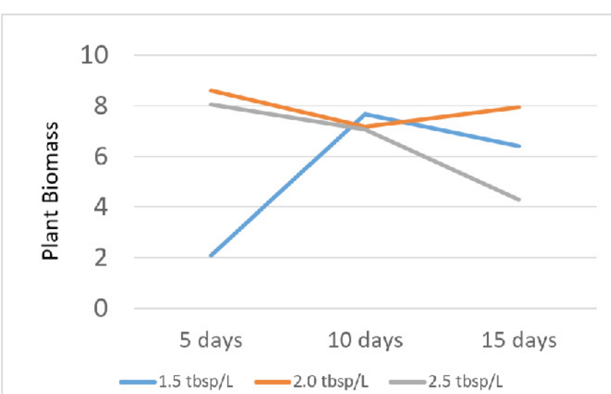
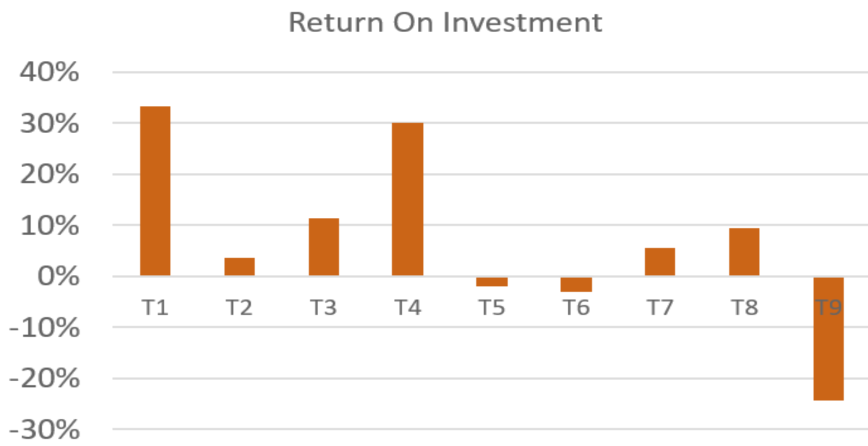


Figure 4. Plant biomass (g) affected by FPJ concentation and fermentation duration.

of nutrients, which in turn generally tends to occur before biomass accumulation (Jones & Olson-Rutz, 2016). Other studies have also shown that FPJ does not always produce a significant effect on plant biomass (Billups, 2016).

Figure 5 presents the return on investment of growing leaf mustard per hectare. The ROI is affected by the weight of marketable plants and the cost of the FPJ, which in turn is affected by the concentration. A higher weight and lower concentration will produce a higher ROI. The highest ROI (33.30%) was observed in the 5-day FPJ at 1.5 tbsp/L, and the lowest ROI (-24.31%) was observed from the 15-day FPJ at 2.5 tbsp/L. There was no significant effect of duration ($p = 0.11$), but there was a significant effect of concentration ($p = 0.01$). FPJ fermented at higher concentrations resulted in significantly less ROI because of the higher production cost required for higher concentrations. The results show that decisions must consider concentration rather than duration in FPJ production.

Corresponding with the return on investment, the highest benefit-cost ratio (BCR) was also gained from plants fertilized with 1.5 tbsp FPJ/L of water fermented for 5 days (Figure 6). In common with ROI, there was no significant effect of duration ($p = 0.11$), but there was a significant effect of concentration ($p = 0.01$). FPJ fermented for a shorter duration of 5 days fermentation with 1.5 tbsp/L concentration can already provide nutrients needed by the plants



Legend:
T1 - $A_1 B_1$
T2 - $A_1 B_2$
T3 - $A_1 B_3$
T4 - $A_2 B_1$
T5 - $A_2 B_2$
T6 - $A_2 B_3$
T7 - $A_3 B_1$
T8 - $A_3 B_2$
T9 - $A_3 B_3$

Fermentation
A1 - 5 days
A2 - 10 days
A3 - 15 days

Concentration
B1 - 1.5 tbsp FPJ/L water
B2 - 2.0 tbsp FPJ/L water
B3 - 2.5 tbsp FPJ/L water

Figure 5. The return on investment (%) of leaf mustard fertilized with nitrogen-based Fermented Plant Juice (FPJ).

Legend:
T1 - $A_1 B_1$
T2 - $A_1 B_2$
T3 - $A_1 B_3$
T4 - $A_2 B_1$
T5 - $A_2 B_2$
T6 - $A_2 B_3$
T7 - $A_3 B_1$
T8 - $A_3 B_2$
T9 - $A_3 B_3$

Fermentation
A1 - 5 days
A2 - 10 days
A3 - 15 days

Concentration
B1 - 1.5 tbsp FPJ/L water
B2 - 2.0 tbsp FPJ/L water
B3 - 2.5 tbsp FPJ/L water

Figure 6. The benefit cost ratio of leaf mustard fertilized woth nitrogen-based FPJ.

for enhanced growth, higher income and less production cost. This implies that growing mustard with the application of FPJ can be profitable at farm level.

Conclusion

This study investigated how the application of FPJ fermented for varying durations and with different levels of concentration can affect the production of leaf mustard based on weight of marketable plants, plant biomass, ROI and BCR. There was no significant effect of duration or concentration on the weight of marketable plants or plant biomass, but for plant biomass, a significant interaction was found between duration and concentration. For the 10-day fermented FPJ, all concentrations resulted in almost the same plant biomass, but for the other durations, the effect of concentration was larger. With respect to ROI and BCR, there was a significant effect of concentration. A higher concentration results to a higher production cost so that lower concentrations produce higher ROI and BCR as compared to the 2 tbsp/L and 2.5 tbsp/L concentrations. Taken all these things into consideration, the results demonstrate advantages of lower concentration (in terms of increasing ROI and BCR) and a non-significant effect of duration. The recommendation is to use FPJ at 1.5 tbsp/L, fermented over a 5-day duration because higher durations do not necessarily result to better productivity.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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