Bangladesh J. Bot. **46**(1): 405-412, 2017 (March) Supplementary

EFFECTS OF FERMENTED PLANT JUICE AND FRUIT JUICE ON GROWTH AND YIELD OF TOMATO FOR SUSTAINABLE PRACTICES

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Keywords: Tomato, Fermented fruit juice, Fermented plant juice, Organic fertilizer, Plant hormone

Abstract

The experiment consisted of five treatments of fermented plant juice (FPJ) and fermented fruit juice (FFJ). The treated plants with FPJ and FFJ produced early flowers and fruits compared to untreated plants due to the enhanced production of auxin and essential nutrients. Total soluble solids were also observed to increase after 10 weeks of FPJ and FFJ application. Photosynthesis rate increased in all treatments except T_3; while transpiration rate increased only at T_4 compared to control. The findings we clearly suggested to use both combinations as FPJ water spinach for enhancing the vegetative growth of tomato plants than FPJ bamboo shoots (T_3 and T_5), while FFJ pineapple for better reproductive development of tomato plants rather than FFJ banana (T_5) for ensuring future sustainable eco-friendly agriculture practices.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is among the local vegetables that are able to penetrate retail sector as well as export market. In Malaysia, Cameron Highlands is occupying the largest area for tomato production because of their suitability on the climate (Islam *et al*. 2012).

The usage of fermented plant juice (FPJ) and fermented fruit juice (FFJ) as foliar fertilizer along with the fertigation system is expected to increase and improve yield and quality of the tomato. The foliar application becomes promptly available to the crops because form of nutrient application is better than direct fertilization (Naz *et al*. 2011). The major aims of this study were to investigate the influence of different types and combinations of FPJ and FFJ on the performance and changes of vegetative growth, physiology, yield and quality of tomato.

Materials and Methods

The experiment was conducted in Control Environment System 2 (CES 2) at Agrotechnology Unit, University Agriculture Park, Universiti Putra Malaysia (UPM) using white polybags (16 inch × 16 inch) filled with coconut coir dust (CCD) and empty fruit bunch (EFB) at a ratio of 1 : 1 according to method of Zulkarami *et al.* (2010). The experiment was conducted in CRD with five replications. The seedlings of tomato cultivars MT1 was used in this study collected from Malaysian Agricultural Development Institute (MARDI), which has special adaptation to low-land environment and condition. Tomato seedlings were watered every 2 hrs for 5 to 10 minutes every day depending on the weather and growth stages using automatic fertigation system under the roof shelter of plastic film.

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Different combinations of FPJ and FFJ were applied at different developmental stages (vegetative and flowering/fruiting) and sprayed at weekly basis (Table 1). The formulations were sprayed until all parts of the plant wet. FPJ formulation was sprayed at the early stage of the plants, just a week after being transplanted to the polybags for 3 weeks. After that, different organic formulations made up from FFJ were applied at flowering during week 4 and 5 after transplanting and fruiting stage during week 6 to 10 after transplanting till the end of the experiment. For control treatments (T1) seedlings were only fertilized with copper formulation (Table 2) without spraying any FPJ and FFJ.

Table 1. Five different treatments were used in the study.

Treatment	Stage	
	Vegetative	Flowering and fruiting
T1 (Control)	Without FPJ	Without FFJ
T2	FPJ water spinach	FFJ banana
T3	FPJ water spinach	FFJ pineapple
T4	FPJ bamboo	FFJ banana
T5	FPJ bamboo	FFJ pineapple

Table 2. Copper formulation as a stock of chemical fertilizer used in the experiment.

Stock	Type of fertilizer	Gram (g)/160 l
A	Calcium nitrate [$Ca(NO_3)_2$]	15300.00
	Iron EDTA [Fe]	164.00
B	Potassium nitrate [KNO_3] 13:0:46	12000.00
	Monopotassium phosphate (MPK) [KH_2PO_4] 0:52:34	1800.00
	Magnesium sulphate [$MgSO_4$]	5640.00
	Manganese sulphate [$MnSO_4$]	16.60
	Boric acid [H_3BO_3]	40.00
	Zinc sulphate [$ZnSO_4$]	2.20
	Copper sulphate [$CuSO_4$]	0.78
	Natrium/ ammonium molybdate [$(NH_4)_6Mo_7O_{24}.4H_2O$]	0.78

Plant heights, the area of tomato leaves, fresh weight and dry weight of shoot and root were measured. Physiological parameters like; photosynthesis rate, stomata conductance and transpiration rate were measured from fully expanded leaf from the third or fourth node from the apex of the plant. The parameters were measured by using portable photosynthesis machine (Model LICOR, LI-6400) two times at 45 and 90 DAT. Measurement unit for photosynthesis rate, stomata conductance and transpiration rate were $\mu molCO_2/S$, $mmol/m^2/S$ and mmol/S, respectively.

Harvested fruits were manually counted and the fruit diameters were ranged as less than 1.5 cm, 1.6 - 3.0 cm, 3.1 - 4.5 cm and more than 4.5 cm. The total weight of marketable fruits in range of more than 4.5 cm was also measured. Fruits were cut and mixed homogenously prior mashed using pistil and mortar. Pure juice was placed on the prism glass of digital hand-held pocket refractrometer to obtain the soluble solids content (SSC) reading. The unit expressed as percentage.

Data were subjected to ANOVA using Statistical Analysis System (SAS version 9.3) software. Differences among means were separated using LSD at $p \leq 0.05$ level.

Results and Discussion

The effect of the five treatments: (T1) without application of fermented plant juice (FPJ) and fermented fruit juice (FFJ) as a control, (T2) FPJ water spinach + FFJ banana, (T3) FPJ water spinach + FFJ pineapple, (T4) FPJ bamboo + FFJ banana and (T5) FPJ bamboo + FFJ pineapple FPJ and FFJ treatments on plant height of tomato from 0 to 10 weeks after transplant (WAT) has been presented in Fig. 1. Higher plant height was observed in plant treated with FPJ bamboo shoot (T_4 and T_5) at vegetative stage and FPJ pineapples at flowering and fruiting stage on 3 and 5 WAT. Better performance of plant height might probably because new shoot plant has higher auxin content, therefore it might be useful to trigger generation and differentiation of new shoot cell. Our result is supported in manual of Cho's Global Natural Farming (Reddy 2011). The bamboo shoot FPJ also helps crops to obtain their needed N to increase in volume, thus suitable to be used during vegetative growth.

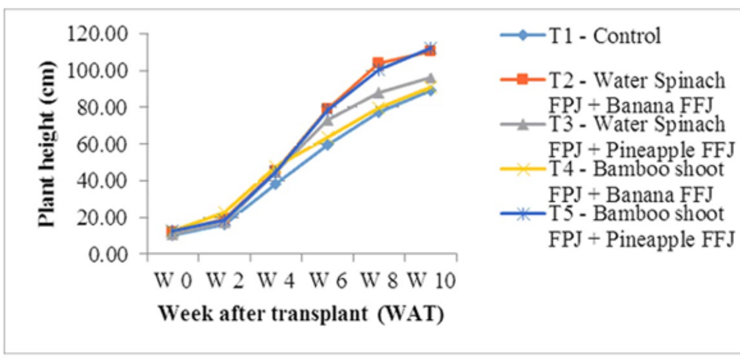

Fig. 1. Plant height of tomato as influenced by FPJ and FFJ treatments for every 2 WAT.

Table 3. Shoot fresh and dry weight (g) of tomato plants as influenced by FPJ and FFJ treatments for 45 and 90 DAT.

Treatment	Shoot fresh weight (g)		Shoot dry weight (g)	
	45 DAT	90 DAT	45 DAT	90 DAT
T1	14.04 d	223.22 c	8.3 d	71.91 d
T2	47.5 b	428.68 b	11.24 c	133.4 b
T3	41.58 c	460.44 a	12.61 a	139.42 a
T4	65.65 a	237.9 c	12.91 a	83.12 c
T5	41.89 c	446.6 ab	1.34 e	132.65 b

Mean values and ± SE with different lower case letters in a row are significantly different at $p \leq 0.05$.

The total leaf area differed significantly among the treatments applied at 45 and 90 DAT. Water spinach showed the highest shoot fresh and dry weight of tomato plants during 45 DAT (Fig. 2). It showed that FPJ water spinach gave better result in producing shoots and large leaf area compared to FPJ bamboo shoots. According to Borhan (2011), water spinach can be a good growth promoter as it grow fast and may contain high natural growth hormones such as auxin. FFJ pineapple gave better result in total leaf area rather than FFJ banana at 90 DAT. Pineapple contained with high amount of K which is about 109 mg in 100 g of fresh pineapple and it is good for stimulating early growth of plants (Rudrappa 2009).

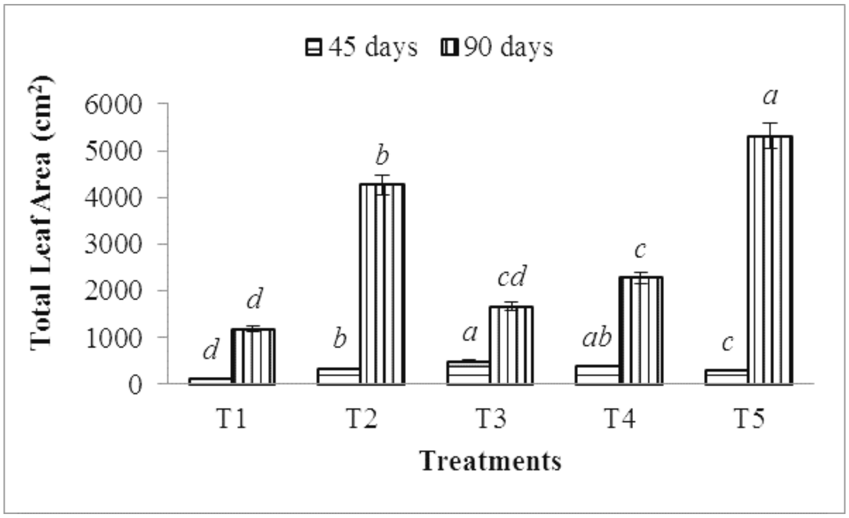

Fig. 2. Total leaf area of tomato as influenced by FPJ and FFJ treatments for 45 and 90 DAT. Each bar represents mean values (±SE) with different lower case letters are significantly different at $p \leq 0.05$.

The fresh root and dry weights for all treatments also differed significantly (Table 4). The effects of treatments on root fresh and dry weight were also significantly influenced by age of the plants after transplanting. Fresh and dry weight of root increased with the increasing of day of transplanting period.

Table 4. Root fresh and dry weight (g) of tomato plant as influenced by FPJ and FFJ treatments for 45 and 90 DAT.

Treatment	Root fresh weight (g)		Root dry weight (g)	
	45 DAT	90 DAT	45 DAT	90 DAT
T1	6.23 d	55.8 d	2.11 d	16 c
T2	9.7 c	107.17 c	2.66 b	21.48 a
T3	11.61 b	115.11 a	2.70 a	17.49 b
T4	14.74 a	59.48 d	2.73 a	12.46 d
T5	9.07 c	111.65 b	2.25 c	17.94 b

Mean values and ±SE with different lower case letters in a row are significantly different at $p \leq 0.05$.

Minor variation was observed between treatments and age of the plants on root to shoot ratio but the results was statistically non-significant (Fig. 3).

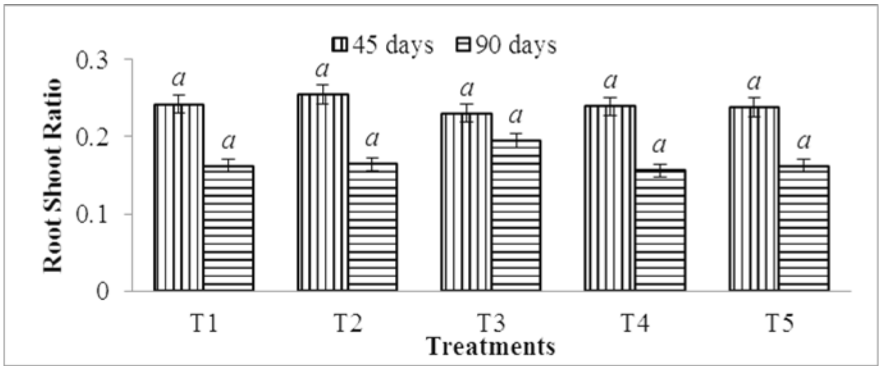

Fig. 3. Effect of FPJ and FFJ treatments on root to shoot ratio of tomato after 45 and 90 DAT. Each bar represents mean values (± SE) with same lower case letters are non-significantly different at $p \leq 0.05$.

Root to shoot ratio tends to increase with plant size which reflects the preferential assimilating partitioning above ground. Higher root to shoot ratio means the large proportion of roots which may compete more effectively soil nutrients, while low root to shoot ratio show there are high proportion of shoots that can receive more light energy for photosynthesis. Allaby (1998) opined that, large proportions of shoot are the characteristics of vegetation in early succession phase while high proportions of root growth are characteristics of climax vegetation phase. However, Atwell *et al.* (1999) reported that in herbaceous plants, root to shoot ratio typically decrease with age due to sustained investment of carbon in above-ground structures. Low root to shoot ratio indicates that the root were able to supply the shoot with water, nutrient, stored carbohydrates and certain growth regulators (Wira *et al.* 2011). Low root proportion compared to shoot proportion on the 90 DAT maybe due to the restriction of root growth in limited size of the polybags.

Table 5. Effect of FPJ and FFJ treatments on photosynthesis rate (Ps) stomatal conductance (g_s) and transpiration rate of tomato after 45 and 90 DAT.

Treatments	Photosynthesis rate (µmol CO_2/S)		Stomata conductance (mmol/m/S)		Transpiration rate (mmol/S)	
	45 DAT	90 DAT	45 DAT	90 DAT	45 DAT	90 DAT
T1	12.45 *d*	19.15 *bc*	0.6 *a*	0.38 *c*	6.28 *a*	4.13 *bc*
T2	15.08 *c*	19.8 *b*	0.29 *d*	0.45 *b*	3.92 *c*	4.85 *b*
T3	18.98 *a*	14.98 *d*	0.49 *c*	0.42 *bc*	5.39 *b*	3.72 *c*
T4	14.52 *c*	23.21 *a*	0.62 *a*	0.83 *a*	6.09 *ab*	6.39 *a*
T5	17.48 *b*	18.02 *c*	0.55 *b*	0.39 *c*	5.42 *b*	4.19 *bc*

Mean values and ±SE with different lower case letters in a row are significantly different at $p \leq 0.05$.

The interaction between treatments and age of the plants (45 and 90 DAT) on photosynthesis (P_s) rate, stomatal conductance (gs), transpiration rate, differed significantly (Table 5). The P_s rate was seen to increase with the increasing of plant age as well as treatments except T3, where a bit reduction was observed. Aleric and Kirkman (2005) reported the differences on P_s rates is based on mass and leaf area. In another finding Aleric and Kirkman (2005) showed that lack of P_s rate and shoot growth due to higher specific leaf area opposed to leaf thickness or higher root mass ratio as such occurred in *Triticum* species. According to Borowski and Michalek (2008), there was a direct relationship between the stomatal conductance of the leaves and the intensity of transpiration and P_s. The fluctuation in stomatal conductance influenced the changes in transpiration as mentioned earlier by Kang and van Iersel (2004).

Table 6. Number of flowers and fruits of tomato developed for each week after transplant as influenced by FPJ and FFJ treatments.

Treatment	T1		T2		T3		T4		T5	
WAT	# flower	# fruit	# flower	# fruit	# flower	# fruit	# flower	# fruit	# flower	# fruit
W3	1	-	2	-	2	-	2	-	3	-
W4	9	-	6	-	8	-	10	-	6	-
W5	11	1	17	0	19	1	16	3	14	1
W6	12	1	27	3	18	2	11	3	26	3
W7	23	4	28	3	26	3	9	6	39	3
W8	19	7	33	8	25	5	10	6	35	5
W9	19	14	37	12	23	8	19	5	40	11
W10	16	13	36	6	22	11	24	2	39	2

*Here WAT denotes week after transplant, W is for week and T is for treatment

Significant differences were observed for number of flowers and fruits produced by tomato plants influenced by FPJ and FFJ treatments after transplant (Table 6). There were several reasons for the fluctuation on numbers of fruits counted during the experimental period. Firstly, the branches that produced many fruits broke down because the branch could not support the fruit

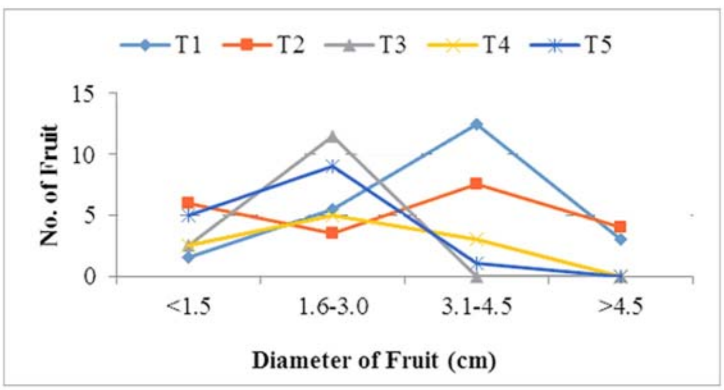

Fig. 4. Effect of FPJ and FFJ treatments on total marketable numbers of fruits under certain range of diameter produced after 10 WAT.

weight although it was already being staked. Secondly, some of the fruits have been attacked by the pests before being wrapped to prevent further damage occurs. Our results were similar to the work of Ali *et al.* (2013) who found that foliar application enhanced the growth, flowering and marketable yield of tomato.

Fig. 4 showed the effect of FPJ and FFJ treatments on numbers of marketable fruits under certain range of diameter produced. Most of the fruits produced on plants treated with T_3 had diameter range 1.6 - 3.0 cm and represent the highest number of fruits produced among the treatments in that range.

Fig. 5 represented the total soluble solid (TSS) of tomato fruits according to the range of diameter as influenced by the FPJ and FFJ application. T2 fruits showed the increasing of TSS when the diameter of the fruits increased. The increased TSS gradually occurred with the advancement of ripening process (Cartwen 2000, Moneruzzaman *et al.* 2008). The percentage of TSS recorded in all treatments relatively higher compared to the commercial production. According to Jones (2008), higher TSS in tomato usually ranged from 4.5 to 6.0%. Despite, in our study the small diameter range of fruits like 1.6 to 3.0 cm were aslo contained higher percentage of TSS (Fig. 5)

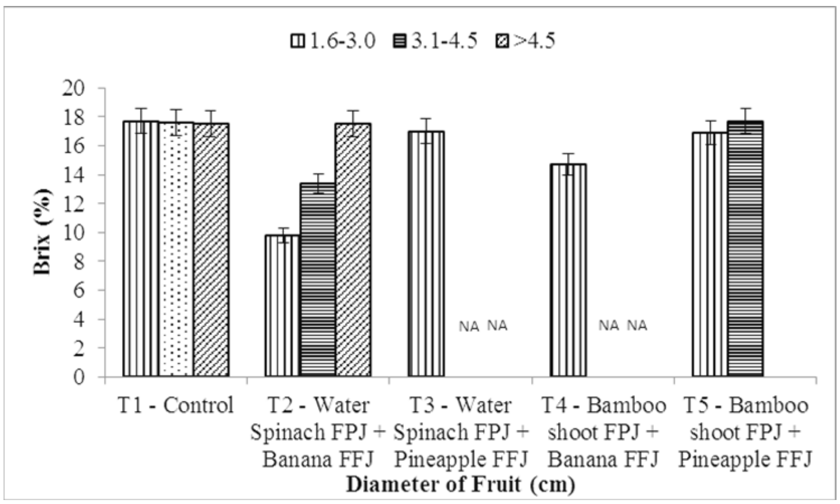

Fig. 5. Total soluble solid of tomato fruits is according on the diameter of fruits as influenced by FPJ and FFJ treatments after 10 WAT.

Present findings suggested that FPJ water spinach gave better result in enhancing the vegetative growth of tomato plants than FPJ bamboo shoots. While, FFJ pineapple supported the reproductive phase of tomato plants rather than FFJ banana. In conclusion, the findings of this research work have a number of important applications for future practice especially providing information in producing organic fertilizer from agriculture waste in order to move forwards in achieving sustainable agriculture.

Acknowledgements

The authors sincerely acknowledge Universiti Putra Malaysia for financial support of this study and Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia for providing all types of analytical and technical supports of this study. They also would like to thank Mr. Salehuddin Yahya and Mrs Noorazimah Taharim for providing them the commercial FPJ and FFJ to be used for this study.

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(Manuscript received on 8 December, 2016; revised on 25 January, 2017)